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# Soil Chemical Property Variation under Different Conservation Agriculture Practices, in Bako Tibe District, West Shoa, Ethiopia

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

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## ABSTRACT

Conservation agriculture is claimed to be one of the solutions 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 objective of assessing the impact of conservation agriculture practices on soil chemical properties. Five main treatments were selected for the study: 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 a grazing land as a control. A Randomized complete block design with four replications was used. A total of 40 composite soil samples (4 replication * 5 treatments * 2 soil depth) were collected and analysed for selected soil chemical properties. Results showed that soils in the study area were moderately acidic, and contained medium level of available phosphorus (AP) (7.33±0.58

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mg/kg), 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 following the four year of conservation agricultural practices. Thus, 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; monocropping.*

## 1. INTRODUCTION

Soil is a base of nourishing life on earth and sustains the maintenance of all terrestrial ecosystems [1]. In tropical African countries reducing poverty, reducing soil resource degradation, increasing agricultural productivity, and achieving food security are some of the major challenges influence the livelihoods of the populations. Ethiopia is one of the highly vulnerable countries in Africa due to soil degradation, deforestation, and other natural resource problems. Some of 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 [2,3]. 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 [4].

Continuous utilisation of inadequate methods of soil management, with 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. Among different tillage based agriculture practices, conservation agriculture (CA) has the potential to decrease soil loss, enhance the level of soil organic matter, increase soil moisture, improve soil fertility, and save costs due to fewer or no tillage operations [5]. Recently the uses of different conventional agricultural practices are the major threat to land productivity and soil fertility decline, but few studies clearly identify the problem and 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 monocropping with residue removal through burning and use for other purposes [6]. Bako agricultural research center has been undertaking a controlled study in comparing different conservation agricultural practices on farmers land. Taking this opportunity, the objective of the research was to assess the impact of different conservation agricultural practices on selected 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°08' N latitude and 37°03' E longitude; about 251 km from Addis Ababa. The altitude where the soil samples were collected was between 1670 and 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 [7]. 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°C and 29°C, respectively and the mean annual temperature is 20°C. Soils at the study site are dominantly Nitosols with reddish brown colour. They are generally clay dominated with a pH between 5- 6 in surface soils [7].

### 2.2 Experimental Treatments and Design

**Treatments**: Two factors were considered for this study: agricultural practices and soil depths.

Factor A: Five treatments

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

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 check point to assess extent of changes through time in soil properties.

**Design:** A 2x5 factorial arrangement of treatments in randomized complete block design (RCBD) replicated four times, was used. Based on the design 40 samples were collected from all the treatments.

## 2.3 Soil Sample Collection

Each treatment was replicated 6 times among those replication we select 4 plots randomly from each treatment for sampling. 10 m x 10 m plot size was arranged in all treatments using randomized complete block design (RCBD). To minimise the border effect soil samples were collected from 8 m x 8 m plot size since the main plots size was 10 m x 10 m and having a minimum distance of 1 m between each main plot. In each plot the soil samples were collected from two soil depths (0-10 cm and 10-30 cm) 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.

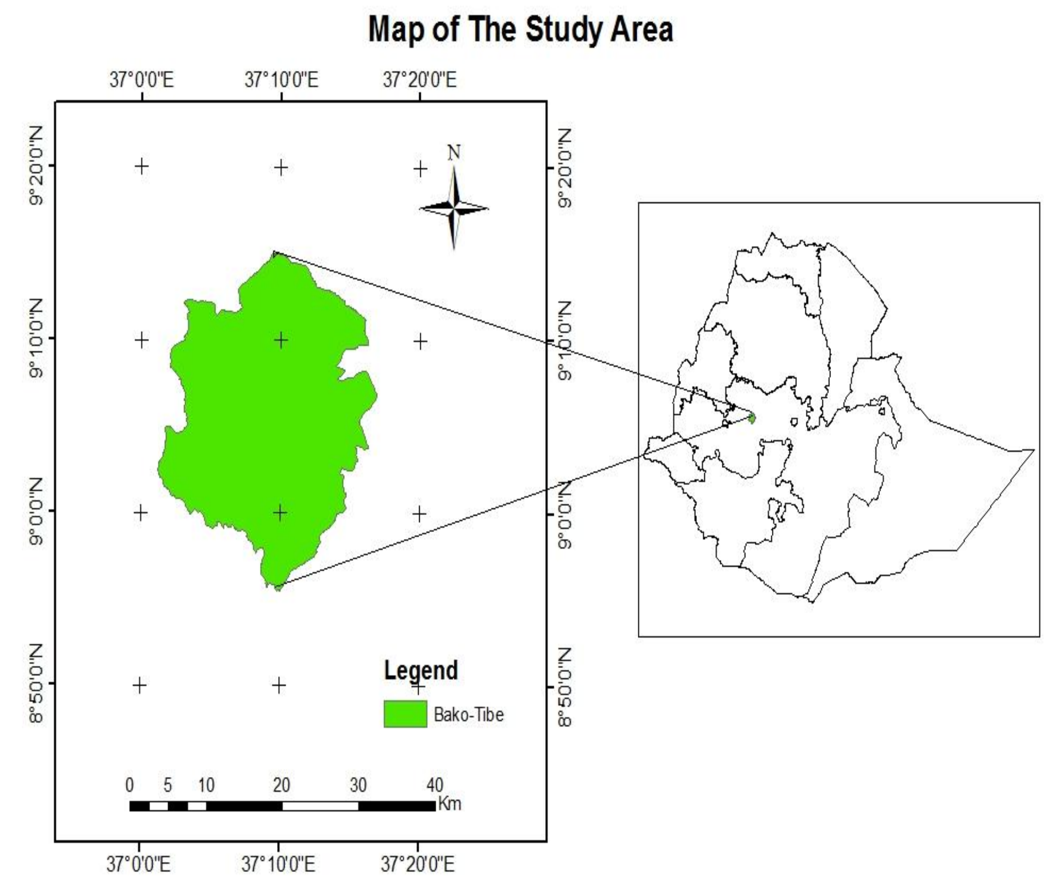


**Fig. 1. Map of the study area – Bako district**

## 2.4 Soil Analysis

The soil samples were first air-dried at room temperature crushed and mixed with mortar and sieved using 2 mm mesh size. Samples were then analysed for soil chemical properties at Bako Agriculture Research Center 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 [8]. According to Walkley and Black [9] wet digestion method was used to determine soil carbon content. Total N was analysed using the Kjeldahl digestion, distillation and titration method as described by Black [10] by oxidising the OM in concentrated sulfuric acid solution (0.1N $H_2SO_4$). Available phosphorous (AP) was determined according to the standard procedure of Bray II method [11].

## 2.5 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 Analysis of variance (ANOVA) was employed to test the variations among the treatments. The least significance difference (LSD) was used to find difference $P < 0.05$ among treatment means.

# 3. RESULTS AND DISCUSSION

## 3.1 Soil Chemical Properties

### 3.1.1 SOC, SOIL PH, TN and C/N RATIO

The soil depth and agriculture practices interaction including the control grazing land was not statistically significant for soil pH, SOC, TN, and C/N ratio (p=0.958, p=0.998, p=0.219, and p=0.140 respectively). Although SOC and TN under selective agriculture practices was not statistically significant (p=0.936, and p=0.330, respectively). Regarding to soil depth, soil pH and C/N ratio were not statistically significantly (p=0.589 and p=0.460 respectively) different at a given soil depths (Table 1).

As displayed in Table 1 the soil pH under different agricultural practices was not statistically different which meant agricultural practices had no effect on soil pH within short period of time. On the other hand, a slight increase was observed on the mean value of soil pH as indicated in Table 2 under all agricultural practices with soil depth. As indicated by Foth and Ellis [12], the current soil pH values observed in the study area were within the range of moderate acidic soil. Numerous scholars [13, 14,15,16] reported that soil pH was lower in agricultural than grazing land; this might be due to the depletion of organic matter because of intensive agriculture practices and also due to the highest microbial oxidation that produces organic acids, which provide H ions to the soil solution. Related to these studies, the mean value of soil pH was relatively lower under agricultural practices than grazing land but not statistically difference was observed under all agricultural practices, and grazing land. According to Du Preez, et al. [17] soil pH was significantly higher under conservation agriculture than conventional agriculture practices after 11 years of practices this might be due to the period of practices. On this finding, the absence of differences in soil pH under all the agricultural practices could be attributed to the age of conservation agriculture practices which were only four years old practices.

The concentration of Soil Organic Carbon (SOC) was not significantly different between the agricultural practices and the grazing land, whereas, the overall mean of SOC 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 [18,19]. On the other hand, Nyamadzawo et al. [20] and Gwenzi et al. [21] 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 reduce inputs of organic matter obtained from crop residues and frequent tillage which encouraged oxidation of organic matter. Therefore, according to Nyamadzawo et al. [20] and Gwenzi et al. [21] the SOC might change after practicing conservation agricultural for greater than four years.

Under all agriculture practices and grazing land the mean value of total N content varied from 0.15 to 0.20%. However, following the four year practices of conservation agriculture, the result of total N did not differ significantly when compared to conventional agriculture (Table 2).

**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 | TN (%) | | SOC (%) | | C/N | | AP (mg/kg) | | pH | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MS | P | MS | P | MS | P | MS | P | MS | P |
| Soil Depth (D) | 1 | 0.031 | 0.0004 | 2.618 | 0.0035 | 3.310 | 0.460 | 9.180 | 0.087 | 0.041 | 0.589 |
| Practices (P) | 4 | 0.002 | 0.330 | 0.067 | 0.936 | 9.260 | 0.196 | 1.270 | 0.827 | 0.051 | 0.866 |
| P*D | 4 | 0.003 | 0.219 | 0.013 | 0.998 | 10.610 | 0.140 | 2.340 | 0.568 | 0.028 | 0.958 |
| Error | 30 | 0.002 | | 0.267 | | 5.940 | | 2.979 | | 0.138 | |

**Table 2. Total N (%), SOC (%), C/N, AP (mg/kg) and pH (*Mean ± SE*) in two soil depth with different agricultural practices including grazing land**

| Practices | Soil depth | TN (%) | SOC (%) | C/N | AP (mg/kg) | pH |
|---|---|---|---|---|---|---|
| | 0-10 cm | 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] |
| | 10-30 cm | 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] |
| MC(-R) | Average | 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] |
| | 0-10 cm | 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] |
| | 10-30 cm | 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] |
| MCR | Average | 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] |
| | 0-10 cm | 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] |
| | 10-30 cm | 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] |
| CRR | Average | 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] |
| | 0-10 cm | 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] |
| | 10-30 cm | 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] |
| ICR | Average | 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] |
| | 0-10 cm | 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] |
| | 10-30 cm | 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] |
| GL | Average | 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)*

According to 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 [22]. The result of total N in this study under all agricultural practices and grazing land show that low content of total N. The low level of nitrogen in the practices may imply that additions of fertiliser have not replaced the total N lost due to harvest, removal of residues, and /or leaching [23]. Similar to the present study Saito et al. [24] reported that there was no significant difference in total N under conservation agriculture practices after four years practice in Benin. While, Ben-Moussa et al [19] and Enfors et al. [25] reported that the result of total N was significantly higher under four years' conservation agriculture practices than conventional this might be due to the addition of manure on the experimental fields. Crop residues retention, intercropping, and crop rotation in the present study could be potentially increase the total N, but the level of influence might depend on the age of the practice [26]. On the other hand, the values of C/N ratio were not significantly different within agricultural practices and grazing land. Besides, the results of C/N ratio had a very narrow range between 12.2 and 15.4 as indicated in Table 2. Hence, C/N ratio was below 16.6 for all soils in the study area which indicates that there could be release of available form of N to the soil system through the mineralisation process of soil OM. Therefore, the values of C/N ratios may suggest that there were not shortages of N immobilisation which could significantly affect the availability of N for crop uptake.

#### 3.1.2 Available phosphorus

The result of available P in the present study under all agriculture practices with soil depth was not significantly different (p=0.568) as indicated in (Table 1). Landon [22] rated the level of available P in different categories, for example; the available of P level of 5-15 mg/kg is rated as medium and based on that category the available P of the study area was found in the medium range. Besides, Ben-Moussa et al [19] reported that available P was similar under conservation agriculture when compared to conventional agriculture practices within four years of practices in Tunisia. In the other way, after 11 years practicing of conservation agriculture the availability of P increased when compared to conventional tillage [17] from this result we understood the influence of conservation agriculture could be seen after a long period of time. 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 duration.

## 4. CONCLUSIONS AND RECOMMENDATIONS

Following the analysis the results of the present study showed that conservation agriculture practices did not influence the soil chemical properties like; soil pH, SOC, TN, C/N, and AP within four years practices. Thus, conservation agriculture becomes more pertinent, because of the need to maintain and restore soil productivity through retained crop residues and improve soil fertilities. Despite that it is also necessary to understand the dynamics of soil properties and associated with conservation agriculture practices. Therefore, this study suggests that conservation agricultural practices: crop residue retention, 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 conservation agriculture practices in chronosequence should be considered to identify the years needed for the practices to bring impact on soil chemical properties.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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