**Original Research Article**

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

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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 different conservation agriculture practices on soil chemical properties. Five treatments were selected for the 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 a 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 contained 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; monocropping

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## 1. INTRODUCTION

Soil is a base of nourishing life on earth and sustains the maintenance of all terrestrial ecosystems [1]. 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 [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 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 [5]. 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 monocropping with residue removal through burning and use for other purposes [6]. Bako agricultural center has been undertaking a controlled study on different conservation agricultural practices on farmers land. Taking this opportunity, the objective research was to assess the impact of different conservation agricultural practices namely: Monocropping with Residues (MCR), Crop rotation with residues (CRR.), and Intercropping with Residues (ICR) on different 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 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 $^{o}C$ and 29 $^{o}C$, respectively and the mean annual temperature is 20 $^{o}C$. 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].

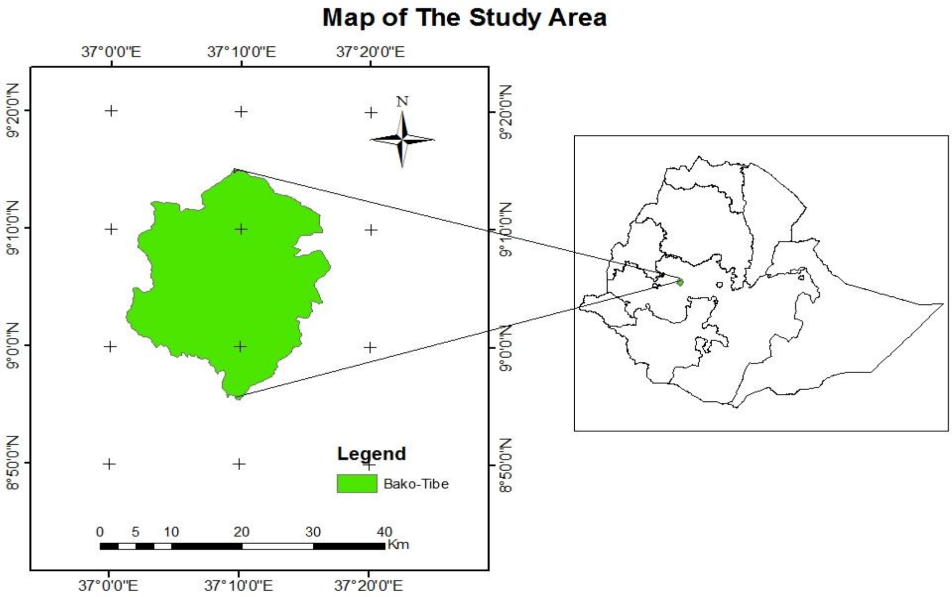


Figure 1: Map of the Study area – Bako district.

## 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.

**Comment [u1]:** Following the first comment need to explain which treatments is under conservation or conventional agriculture practices that is why I mentioned if not necessary it's possible to erase.

**Design**: A 2x5 factorial arrangement of treatments in randomized complete block design (RCBD) replicated four times, was used. Based on the 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. 10m x 10m plot size was arranged in all treatments using randomized complete block design (RCBD). To minimize the border effect soil samples were collected from 8m x 8m plot size since the main plots size was 10m x 10m and having a minimum distance of 1m between each main plot. In each plot the soil samples were collected from two soil depths (0-10cm 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. Samples were then analyzed 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 analyzed using the Kjeldahl digestion, distillation and titration method as described by Black [10] by oxidizing 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].

**2.4. 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 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 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 (p=0.958, p=0.998, p=0.219, p=0.140 and 0.568 respectively). Although SOC, TN and AP under selective agriculture practices was not statistically significant (p=0.936, p=0.330, and p=0.827 respectively). Regarding to soil depth, 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 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, slight increase was observed on the mean value of soil pH as indicated in Table 2 under all agricultural practices with soil depth. The soil pH values observed in the study area were within the range of moderate acidic soil as indicated by Foth and Ellis [12]. Numerous scholars [13, 14, 15, 16] reported that 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 [17] soil pH was significantly higher under conservation agriculture than conventional agriculture practices after 11 years of practices. Based on this finding, the absence of differences in pH under all the 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 [18, 19]. In contrast 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 reduced inputs of organic matter obtained from crop residues and frequent tillage which encouraged oxidation of organic matter. So, according to Nyamadzawo et al [20] and Gwenzi et al [21] 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 [22] 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 [23]. In agreement with the present study Saito et al [24] reported that there was no significant difference in total N under conservation agriculture practices after practicing for four years in Benin. Whereas, Ben-Moussa et al [19] and Enfors et al [25] 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 different 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. 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 [22] 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 [19] 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 for 11 years showed that available P increased when compared to conventional tillage practice [17]. 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 |
|---|---|---|---|---|---|---|
| | 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)$^{a}$ |
| MC(-R) | 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)$^{A}$ |
| | 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)$^{a}$ |
| MCR | 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)$^{A}$ |
| | 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)$^{a}$ |
| CRR | 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 mear | 0.18±(0.02)$^{A}$ | 2.41±(0.23)$^{A}$ | 13.95±(0.59)$^{A}$ | 7.50±(0.63)$^{A}$ | 5.65±(0.16)$^{A}$ |
| | 0-10cm | 0.18±(0.02)$^{a}$ | 2.53±(0.22)$^{a}$ | 14.50±(0.78)$^{a}$ | 7.30±(0.80)$^{a}$ | 5.60±(0.20)$^{a}$ |
| ICR | 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)$^{A}$ |
| | 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)$^{a}$ |
| GL | 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

The results of this study showed that the conservation agricultural practices did not influence the soil chemical properties like; soil pH, SOC, TN, C/N, and AP within consecutive four years of practice. Hence, conservation agriculture becomes more pertinent, because of the need to maintain and restore soil productivity through retained crop residues. Despite that it is also necessary to understand the dynamics of soil properties and associated with conservation agriculture practices. Therefore, this finding suggests that conservation agricultural practices namely: 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.

## 5. REFERENCES

1. Belay S. 2003. Integrated watershed management approach to sustainable land management (Experience of SARDP in East Gojjam and South Wollo). PP.127-136.
2. Hurni H. 1988. Degradation and conservation of the resources in the Ethiopian highlands. *Mountain Research and Development*. 8: 123-130.
3. Jones J. 2003. Agronomic handbook: management of crops, soils, and their fertility. CRC press LLC, N.W. Corporate Blvd., Boca Ratio, Florida.
4. Celik I. Barut Z. Ortas I. Gok M. Demirbas A. Tulun, Y. Akpinar C. 2011. Impacts of different tillage practices on some soil microbiological properties and crop yield under semi-arid Mediterranean conditions. *International Journal of Plant Production* 5:237-254.
5. Teklu E. 2011. Tillage effects on physical qualities of vertisol in the central highlands of Ethiopia. *African Journal of Environmental Science and Technology* 5:008-1016.
6. Wakene N. 2001. Assessment of important physicochemical properties of Nitisols under different management systems in Bako Area, western Ethiopia. A Thesis submitted to School of Graduate Studies, Alemaya University, Ethiopia. 93p.
7. Legesse D. Gemechu G. Tesfaye K. and Getahun D. 1987. Bako mixed farming zone, Wellega and Shewa Regions. Diagnostic survey report No. 1. Institute of Agricultural Research, Department of Agricultural Economics and Farming Systems Research, Addis Ababa, Ethiopia.
8. Van Reeuwijk L.1992. Procedures for soil analysis, 3rd Ed. International Soil Reference and Information Center (ISRIC), Wageningen, the Netherlands. 34p.

9. Walkle A. and I.A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci*. 37: 29-38.

10. Black C.1965. Methods of soil analysis. Part I, American Society of Agronomy. Madison, Wisconsin, USA. 1572p.

11. Bray K. and L.T Kurtz. 1965. Determination of total organic and available forms of phosphorus in soils. *Soil Sci.* 59: 39-45.

12. Foth HD. and B.G Ellis. 1997. Soil fertility, 2nd Ed. Lewis CRC Press LLC., USA.

13. Abebe Y. 1998. Evaluation of the Contribution of Scattered *Cordia africana* Trees to Soil Properties in Cropland and Rangeland Ecosystems in Western Oromia, Ethiopia. M.Sc. Thesis, Swedish University of Agricultural Sciences, Sweden.112p.

14. Islam K. & Weil R. 2000. Soil quality indicator properties in mid-Atlantic soils as influenced by conservation management. *Journal of Soil and Water Conservation* 55:69–78.

15. Wakene N. and Heluf G. 2003. Influence of land management on morphological, physical-chemical properties of some soils of Bako, Western Ethiopia. *Agropedology* 13:1-9.

16. Gebeyaw T. 2007. Soil fertility status as influenced by different land uses in maybar areas of south Wello zone, north Ethiopia, M.Sc. Thesis Submitted to School of Graduate Studies, Alemaya University, Ethiopia. 86p

17. Du Preez C. Steyn J. and Kotze E. 2001. Long-term effects of wheat residue management on some fertility indicators of a semi-arid plinth sol. *Soil and Tillage Research,* 63: 25-33.

18. Bielders C. Michels K. and Bationo A. 2002. On-farm evaluation of ridging and residue management options in a sahelian millet-cowpea intercrop. Soil quality changes. *Soil use and Management,* 18: 216-222.

19. Ben-Moussa M. Ben-Hammouda M. and Nouira S. 2010. Comparative effects of conventional and no-tillage management on some soil properties under Mediterranean semi-arid conditions in north-western Tunisia. *Soil and Tillage Research.*106:247-253.

20. Nyamadzawo G. Chikowo R. Nyamugafata P. Nyamangara J.and Giller K. 2008. Soil organic carbon dynamics of improved fallow-maize rotation systems under conventional and no-tillage in central Zimbabwe. *Nutrient Cycling in Agroecosystems,* 81:85-93.

21. Gwenzi W. Gotosa J. Chakanetsa S. and Mutema Z. 2009. Effects of tillage systems on soil organic carbon dynamics, structural stability and crop yields in irrigated wheat (triticum aestivum L.)-cotton (gossypium hirsutum L.) rotation in semi-arid Zimbabwe. *Nutrient Cycling in Agroecosystems,* 83:211-221.

22. Landon J. 1991. Booker tropical soil manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York.

23. Malo D. Schumacher T. and Doolittle J. 2005. Long-term cultivation impacts on selected soil properties in the northern Great Plains. *Soil and Tillage Research.*81: 277-291.

24. Saito K. Azoma K. and Oikeh S. 2010. Combined effects of stylosanthes guianensis fallow and tillage management on upland rice yield, weeds and soils in southern Benin. *Soil and Tillage Research,* 107: 57-63.

25. Enfors E. Barron J. Makurira H. Rockström J. and Tumbo S. 2010. Yield and soil system changes from conservation tillage in dry land farming: A case study from north eastern Tanzania. Agricultural Water Management 22: 156-165.