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3 **Soil property variation under different conservation**
4 **agriculture practices, in Bako Tibe District, West Shoa,**
5 **Ethiopia**

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8 **Abstract**

9 *Conservation agriculture is claimed to be one of the solution for the problems of poor*
10 *agricultural productivity in sub-saharan countries. The impact of conservation agriculture*
11 *depends on environmental factors such as slope, vegetation, soil type, rain fall pattern and*
12 *intended crops. This study was conducted from 2013 to 2014 with the objectives of assessing the*
13 *impact of different conservation agriculture practices on soil properties in Bako District, West*
14 *Shoa, Ethiopia, using five treatments were selected for the study namely: Monocropping (maize)*
15 *without crop residue, Monocropping (maize) with crop residue, Crop rotation (maize and haricot*
16 *bean) with crop residue, Inter cropping (Haricot bean with maize) with crop residue and*
17 *including a near by grazing land (Original land use). A completely randomized design with four*
18 *replications was used. A total of 40 composite soil samples (4 replication * 5 treatments * 2 soil*
19 *depth: 0–10 cm and 10–30 cm) were collected and analyzed for selected soil properties. The soils*
20 *in the study area were moderately acidic, and contain medium level of AP, but low*
21 *concentration of total N. Soil pH, SOC, TN, C:N, and AP did not significantly different among*
22 *the treatments after four years of conservation agricultural practices. Therefore, conservation*
23 *agriculture has little effect on soil properties in short term, but it may take longer time to*
24 *influence on different soil properties in the study area.*

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26 **Keywords:** Crop residue; intercropping; soil property; mono cropping; conservation agriculture.

27 **1. Introduction**

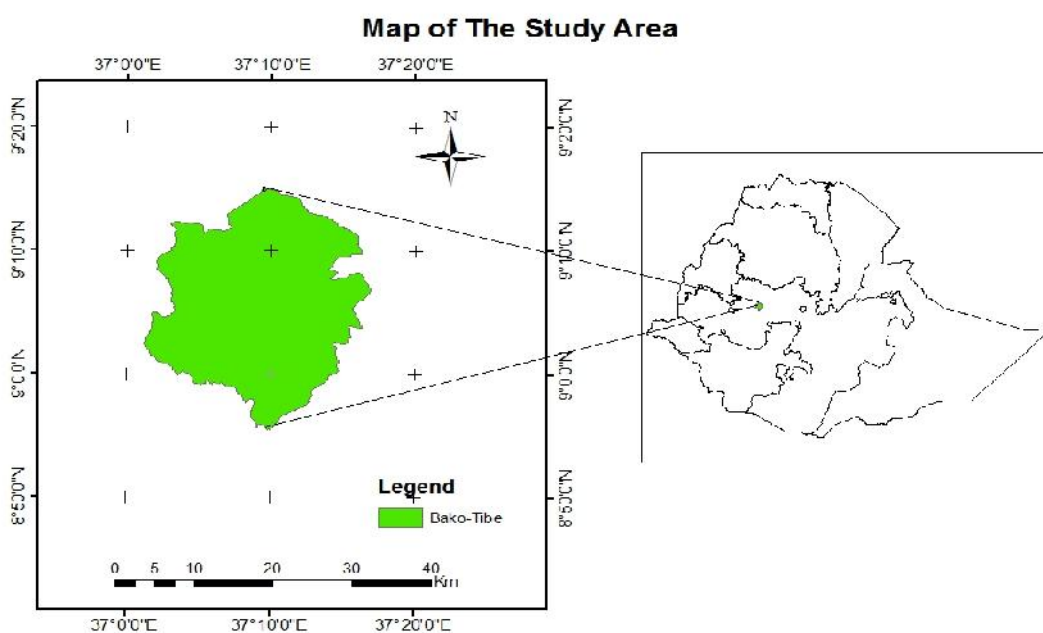
28 Conservation agriculture (CA) is a widely-used terminology which refer to soil management
29 systems that result in at least 30% of the soil surface being covered with crop residues after
30 seeding of the subsequent crop (Jarecki MK and Lal R, 2003). CA practices are aiming to
31 produce high crop yields while reducing production costs, maintaining the soil fertility and
32 conserving water [Hobbs PR *et al.*, 2008]. It is not a single component technology but a
33 system that includes the cumulative effect of three basic components, minimum soil
34 disturbance, permanent soil cover and crop rotation tillage, in order to preserve soil health
35 and productivity (West TO, Post WM, 2002). CA is receiving an increasing attention in sub-
36 Saharan Africa as a sustainable alternative to contribute to food security and minimize
37 environmental degradation (FAO, 2006) especially aiming to maintain and improve yield. All
38 CA practices are not easy to apply, but farmers can increase their productivity benefits
39 through labour cost saving, reduction of production cost, and improvement of soil fertility.
40 Since one of the contributions of CA is labour saving, farmers can use the time they have
41 saved to expand the area they cultivate, or even to start other enterprises that earn more
42 money. CA increases soil moisture, and restores soil fertility, so stabilizing yields and
43 improving production over the long term.

44 Compared to tillage based agriculture, conservation agriculture (CA) has the potential to
45 decrease soil loss, enhance levels of soil organic matter, increase plant available soil water,
46 and save costs due to fewer or no tillage operations (Teklu, 2011). Current uses of different
47 conventional agricultural practices are the major threat to land productivity and soil fertility
48 decline in sub-Saharan Africa, but few studies were carried out to identify the limitation of
49 conventional agricultural practices. One of the main challenges in Western Oromia generally
50 and particularly to Bako district, where maize is the main stable and major producing crop, is
51 continuous mono cropping with residue removal through burning and/or used for other
52 purposes (Wakene N, *et al.*, 2011). Bako agricultural research centre has been undertaking a
53 controlled study on different conservation agricultural practices on farmers land. Taking this
54 opportunity, this research initiated to assess the impact of conservation agricultural practices
55 namely: Mono-cropping with Residues (MCR), Crop rotation with residues (CRR.), and
56 Intercropping with Residues (ICR) on different soil properties.

57 2. Materials and Methods

58 2.1 Description of the study area

59 The study was conducted Bako district, western Oromia. Bako is located at $9^{\circ} 08' N$ latitude and
 60 $37^{\circ} 03' E$ longitude; about 251 km from Addis Ababa. The altitude where the soil samples
 61 collected was located ranged from 1670 to 1690 m.a.s.l. The long term weather information
 62 revealed that the area has unimodal rainfall pattern extending from March to October, but the
 63 effective rain is from May to September (Legesse *et al.*, 1987). The mean annual rainfall is about
 64 1237 mm, with a peak in July. It has a warm humid climate with annual mean minimum and
 65 maximum temperature of $14^{\circ} C$ and $29^{\circ} C$, respectively and the mean annual temperature is 20
 66 $^{\circ} C$. Soils at the study site are dominantly Nitisols with reddish brown colour. They are generally
 67 clay dominated with a pH in between 5- 6¹ in surface soils (Legesse *et al.*, 1987).



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

70 2.2 Soil Sampling and Laboratory analysis

71 Four plots (10m x 10m) were randomly selected in each of the five treatments arranged in a
 72 RCBD. To minimize border effect soil samples were collected from 8m * 8m plot since the
 73 main plots have a minimum distance of 1m between the plots. In each plot (8m*8m), the soil

74 samples were collected from two soil depths (0-10 and 10-30cm) at the corners and centre of
75 the plots. Then the samples from each plot were bulked to form a composite sample at 0-10
76 and 10-30 cm layers, and a total of 40 composite soil samples (5 treatments* 2 soil depths *
77 4 plots) were collected for the study. The five treatments in this study are Monocropping
78 without crop residue (maize), Monocropping with crop residue (maize), Crop rotation with
79 crop residue (maize and haricot bean), Inter cropping with crop residue (haricot bean with
80 maize) and a nearby grazing land (Original land use). The samples were first air-dried at
81 room temperature and sieve (mesh size 2mm) in order to remove roots, litter and stones from
82 the soil samples. Then soil samples were analyzed at Bako Agriculture Research Center
83 (BARC) soil laboratory using all laboratory procedures.

84 **2.3. Statistical analysis**

85 Laboratory results were analyzed using General Linear Model (GLM) procedure of SAS
86 statistical software version 9.0.2004. Analysis of variance (ANOVA) was employed to test the
87 variations. For significant differences, mean separation using LSD was conducted at 5 % level of
88 significance.

89 **3. Results and Discussion**

90 **3.1 Soil Chemical Properties**

91 **3.1.1 SOC, Soil pH, TN and C:N Ratio**

92 The interaction among the agricultural practices including the grazing land with soil depth was
93 not significant for soil pH, SOC, TN, and C:N ratio ($p=0.958$, $p=0.998$, $p=0.219$, and $p=0.140$),
94 respectively. Soil pH, SOC, TN, and C:N ratio were not significant ($p=0.866$, $p=0.936$, $p=0.330$
95 and $p=0.196$), among the agricultural practices and the grazing land. Depth wise SOC and TN
96 were statistically significant ($p=0.0035$, and $p=0.0004$), while, soil pH and C:N ratio were not
97 significantly ($p=0.589$ and $p=0.460$), respectively different at a given soil depths (Table 1).

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107 Table 1: Summary of ANOVA for pH, SOC (%), N (%), AP (mg/kg), and C:N ratio under
 108 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	

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110 Soil pH increased with soil depth. Different agricultural practices systems for four years had no
 111 effect on soil pH (Table 2). Hence, the soil pH values observed in the study area are within the
 112 range of moderately acidic soil as indicated by Foth and Ellis (1997). Several authors Abebe
 113 (1998), Islam and Weil (2000), Wakene and Heluf (2003) and Gebeyaw (2007) reported that the
 114 soil pH was lower in cultivated land than grazing land, and this was attributed to the depletion of
 115 organic matter because of intensive cultivation.

116 In contrast to these studies, in the present study the mean value of soil pH was relatively lower
 117 under agricultural practices than grazing land but no statistical difference was observed among
 118 all agricultural practices, and grazing land. According to Du Preez, *et al.*, 2001, experimental
 119 research revealed that soil pH was significantly higher under conservation agriculture than
 120 conventional agriculture practices after 11 years of practices. Based on this finding, the absence
 121 of difference under all agricultural practices and grazing land could attribute to the age of
 122 conservation agriculture practices which were only four years old.

123 Soil Organic Carbon (SOC) concentration was not significantly different among the agricultural
 124 practices and the grazing land, while the overall mean of SOC concentration was in the range
 125 between 2.23 to 2.46%. Consistent with the present study, SOC was not affected by conservation
 126 agriculture within four years of practice when compared to conventional agriculture Biolders, *et*
 127 *al.*, (2002), Ben-Moussa, *et al.*, (2010). In contrast, Nyamadzawo, *et al.*, (2008) and Gwenzi, *et*
 128 *al.*, (2009), reported that SOC was higher under conservation agriculture after five and ten years
 129 of practice, respectively. They attributed the low SOC content in continuous cultivated soils of
 130 conventional agriculture to reduced inputs of organic matter obtained from crop residues and
 131 frequent tillage which encouraged oxidation of organic matter. So, according to Nyamadzawo, *et*

132 *al.*, (2008) and Gwenzi, *et al.*, (2009), the SOC might change after practicing conservation
133 agricultural for greater than four years.

134 The mean of total N content varied from 0.15 to 0.20% under agricultural practices and the
135 grazing land. After practicing conservation agriculture for four consecutive years, total N did not
136 differ significantly when compared to conventional agriculture (Table 2). Following the rating of
137 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%
138 as very low N status as indicated by Landon (1991), all the agricultural practices and the grazing
139 land have low content of total N. The low level of nitrogen in the practices may imply that
140 fertilizer additions have not replaced the total N lost due to harvest removal, and /or leaching
141 Malo *et al.*, (2005). In agreement with the present study, Saito, *et al.*, (2010) reported that there
142 was no significance difference in total N under conservation agriculture practices after practicing
143 for four years in Benin. Whereas, Ben-Moussa., *et al.*, (2010), and Enfors, *et al.*, (2010) reported
144 that total N was significantly higher under four years' conservation agriculture practices than
145 conventional due to the addition of manure on the experimental fields. Crop residue
146 management, intercropping, and crop rotation in the present study can potentially increase total N
147 in the soils, but the level of influence may depend on the age of the practice.

148 The mean C:N ratio was not significantly different among the agricultural practices and the
149 grazing land, and the C:N ratio had a very narrow range between 12.2 and 15.4 (Table 2). A SOC
150 with high C:N ratio is low in quality as compared to SOC with low C:N ratio due to the increased
151 immobilization of N by micro-organisms Handayanto *et al.*, (1997). As a general guideline,
152 when the C:N ratio is greater than 30:1, N is immobilized by soil microbes while if C:N ratio is
153 less than 20:1, there is a release of mineral N in to the soil environment. The N released in to the
154 soil under the latter condition (C:N < 20:1) is available for plant uptake (Jones, 2003). In the
155 present study, the C:N ratio was below 16.6 for all the soils in the study area which indicates that
156 there could be release of available form of N to the soil system through the mineralization
157 process of soil OM. The observed values of C:N ratios may suggest that there was no problem of
158 N immobilization which could significantly affect the availability of N for crop uptake.

159 **3.1.2 Available Phosphorus**

160 Agriculture practices and or its interaction with soil depth was not significantly different
161 ($p=0.568$) for available P (Table 1). According to Landon (1991) available soil P level of 5-15
162 mg/kg is rated as medium, and accordingly the available P of the study area was found in the
163 medium range. Ben-Moussa., *et al.*, (2010) reported that available P was similar in the soils of
164 conservation agriculture when compared to conventional agriculture practices within four years

165 of practices in Tunisia. In contrast, conservation agriculture practice the 11 years showed that
 166 available P increased when compared to conventional tillage practice Du Preez, *et al.*, (2001).
 167 Based on these findings, the present study may suggest that the available P could change after
 168 exercising conservation agriculture for greater than four years of time.

169 Table 2: Mean \pm SE of total N (%), SOC (%), C:N ratio, AP (mg/kg) and pH of soil in relation
 170 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 \pm (0.03) ^a	2.44 \pm (0.17) ^a	16.62 \pm (2.90) ^a	7.50 \pm (1.19) ^a	5.50 \pm (0.14) ^a
	10-30cm	0.14 \pm (0.01) ^a	2.02 \pm (0.29) ^a	14.17 \pm (1.23) ^a	6.30 \pm (0.48) ^a	5.60 \pm (0.28) ^a
	Over all mean	0.15 \pm (0.02) ^A	2.23 \pm (0.19) ^A	15.39 \pm (1.53) ^A	6.88 \pm (0.64) ^A	5.55 \pm (0.11) ^A
MCR	0-10cm	0.20 \pm (0.02) ^a	2.57 \pm (0.24) ^a	12.67 \pm (0.60) ^a	7.80 \pm (0.95) ^a	5.50 \pm (0.30) ^a
	10-30cm	0.15 \pm (0.02) ^a	2.11 \pm (0.30) ^a	14.07 \pm (0.80) ^a	7.00 \pm (0.71) ^a	5.70 \pm (0.20) ^a
	Over all mean	0.18 \pm (0.02) ^A	2.34 \pm (0.19) ^A	13.37 \pm (0.53) ^A	7.40 \pm (0.64) ^A	5.60 \pm (0.17) ^A
CRR	0-10cm	0.20 \pm (0.01) ^a	2.61 \pm (0.26) ^a	13.30 \pm (0.80) ^a	7.00 \pm (0.91) ^a	5.60 \pm (0.27) ^a
	10-30cm	0.16 \pm (0.03) ^a	2.22 \pm (0.40) ^a	14.64 \pm (0.80) ^a	8.00 \pm (0.90) ^a	5.70 \pm (0.21) ^a
	Over all mea	0.18 \pm (0.02) ^A	2.41 \pm (0.23) ^A	13.95 \pm (0.59) ^A	7.50 \pm (0.63) ^A	5.65 \pm (0.16) ^A
ICR	0-10cm	0.18 \pm (0.02) ^a	2.53 \pm (0.22) ^a	14.50 \pm (0.78) ^a	7.30 \pm (0.80) ^a	5.60 \pm (0.20) ^a
	10-30cm	0.16 \pm (0.02) ^a	2.06 \pm (0.28) ^a	13.00 \pm (0.94) ^a	6.80 \pm (0.85) ^a	5.70 \pm (0.18) ^a
	Over all mean	0.17 \pm (0.01) ^A	2.29 \pm (0.19) ^A	13.75 \pm (0.63) ^A	7.00 \pm (0.53) ^A	5.65 \pm (0.11) ^A
GL	0-10cm	0.26 \pm (0.05) ^a	2.48 \pm (0.19) ^a	10.17 \pm (1.34) ^a	8.00 \pm (0.75) ^a	5.70 \pm (0.10) ^a
	10-30cm	0.14 \pm (0.01) ^a	2.01 \pm (0.25) ^a	14.17 \pm (0.66) ^a	7.50 \pm (0.65) ^a	5.80 \pm (0.14) ^a
	Over all mean	0.20 \pm (0.02) ^A	2.24 \pm (0.09) ^A	12.17 \pm (1.03) ^A	7.87 \pm (0.48) ^A	5.75 \pm (0.04) ^A

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

176 4. Conclusions and Recommendations

177 In the study area the local farmers widely practiced traditional farming systems. This farming
 178 system involves intensive and continuous cultivation which highly depleted the soil fertility,
 179 reduced the production of the land and exposed the soil for leaching and erosion. Conservation
 180 agriculture per se is considered as one of the most effective management practices to obtain

181 mutual benefits in terms of erosion control, carbon sequestration and reduced input of energy and
182 labour. Based on this the objective of the present study focused on the impact assessment of
183 different conservation agricultural practices on soil properties. Accordingly, the results of the
184 present study showed that the conservation agricultural practices did not influence the soil
185 properties like; soil pH, SOC, TN, C:N, and Av.P within four years of practice. Therefore; this
186 finding suggests that conservation agricultural practices namely: addition of crop residue, crop
187 rotation with crop residue, and intercropping with crop residue in Bako (study area) may require
188 longer years of practice before their influence on different soil properties are visible. Thus,
189 further study on CA practices in chronosequence should be considered to identify the years
190 needed for the practices to bring impact on soil properties.

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