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Conservation Agriculture: Maize-legume Intensification for Yield, Profitability and Soil Fertility Improvement in Maize Belt Areas of Western Ethiopia

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Conservation agriculture (CA) relies on soil management systems that include three basic principles aiming to produce high crop yields while reducing production costs, saving labor cost, avoiding crop risk failure, maintaining soil fertility and conserving moisture. On-farm experiments were conducted in two district of Western Ethiopia between 2010-2012. There were six treatments on eight farmers' field corresponding to different maize-bean cropping systems under CA including conventional practice (CP) for maize as control Rainfall variability and cropping systems with CA significantly affected yield of bean and maize. Significantly higher yield of early maturing haricot bean either planted as sole or intercrops were recorded in 2012 cropping season as compared to late maturing soybean. In high moisture stress season, a significant reduction of both bean and maize yields were recorded. In the rotation system, soybean used as precursor instead of haricot bean significantly improved yield performance of maize. Maize-bean intercropping considerably gave the highest production, increased water use efficiency and maximum net income as compared to crop rotation or continuous production in CA or farmers practices. However, maize-common bean intercrop is better in terms of yield and water use efficiency though soybean-maize intercrops is better in good rainy season. In intercropping systems, delaying bean planting after 25 days of maize planting significantly

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reduced yield as compared to that obtained after simultaneous planting. CA practices reduced by more than 31-42% total labor time required for ploughing as compared to that under CP. Up to half of labor time for weeding could be reduced due to CA practices. In particular, intercropping had the highest contribution for weed control. Though CA-based maize-bean intercropping followed by sole maize production had the highest net benefit, sole bean production after rotation gave the highest net return per unit cost that could be strategies for sustainable crop production and improvement. Continuous production of legume crops and maize mono cropping reduced soil pH though not significant. However, crop rotation and intercropping in combination with CA improved cation exchange capacity, soil pH, organic carbon and even total nitrogen though not significantly changed. Therefore, intercropping and crop rotation practices could be the best promising technologies that would improve for sustainable production and soil improvement.

Keywords: Conservation agriculture; cropping system; maize; legumes.

1. INTRODUCTION

Conservation agriculture (CA) is a widely-used terminology which refer to soil management systems that result in at least 30% of the soil surface being covered with crop residues after seeding of the subsequent crop [1]. CA practices are aiming to produce high crop yields while reducing production costs, maintaining the soil fertility and conserving water [2]. It is not a single component technology but a system that includes the cumulative effect of three basic components, minimum soil disturbance, permanent soil cover and crop rotation tillage, in order to preserve soil health and productivity [3]. CA is receiving an increasing attention in sub-Saharan Africa as a sustainable alternative to contribute to food security and minimize environmental degradation [4], especially aiming to maintain and improve yield [5]. All CA practices are not easy to apply, but farmers can increase their productivity benefits through labor cost saving, reduction of production cost, and improvement of soil fertility. The increased ability to hold water generally leads to crop yield increase [6,7]. CA improves extractable phosphorus, total nitrogen content, organic carbon content [8,9]. Since one of the contributions of CA is labor saving, farmers can use the time they have saved to expand the area they cultivate, or even to start other enterprises that earn more money. CA increases soil moisture, and restores soil fertility, so stabilizing yields and improving production over the long term [10].

One of the main challenges in Western Ethiopia, 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 [11]. The soil is intensively cultivated and overgrazed. Maize is mainly cultivated by small scale farmers depending on animal traction power under rain fed condition The conventional tillage (CP) for maize production in Western Ethiopia involved three to four times plowing until fine seedbed is obtained and stayed for 2-3 months prior to planting [12]. This practice coincides with high and intense rainfall leading to high soil erosion, resulting in low soil fertility and productivity. Therefore, soil and water erosion is the main problem today in Western parts of the country. In this study, different maize-legume cropping systems were evaluated under CA practices to determine the effects on yield and soil fertility in western Ethiopia.

2. MATERIALS AND METHODS

2.1 Study Area

The study areas are located in Gobu sayo and Bako Tibe districts (09.023700N to 09.120340N and 0.37.22313 to 0.37.017930 E) which correspond to the sub-humid maize belt area in western Ethiopia between altitudes from 1662 to 1807m a.s.l.

2.2 Experimental Design of on-farm Trials

During each of three consecutive years: 2010-2011 (the first season), 2011–2012 (the second season) and 2012-2013 (third season), a number of farms were selected to host permanent trials that composed different maize-legume cropping system in combination with CA practices and CP. Four farmers were selected in each district. Each on-farm trial was divided into six treatments, corresponding to different maize-bean cropping systems, including both CA and CP. The treatments were described in the (Table 1) below.

Table 1. Lists of treatment descriptions conducted at farmers' field, 2010-12

Treatment	2010	2011	2012	Description
HB-Mz-rot-CA[a]	-	✓	✓	Haricot bean-maize-rotation-CA
SB-Mz-rot-CA[a]	-	✓	✓	Soybean bean-maize-rotation-CA
Mz-per-CA[a]	-	✓	✓	Sole maize permanent-CA
Mz+SB-inter-CA[ac]	✓	✓	✓	Maize-soybean intercropping-CA
Mz+HB-inter_CA[ab]	✓	✓	✓	Maize-soybean intercropping-CA
Mz-per-CP[a]	✓	✓	✓	Sole maize permanent-CP
Mz-HB-rot-CA[b]	-	✓	✓	Maize-haricot bean–rotation-CA
Mz-SB-rot-CA[c]	-	✓	✓	Maize-soybean–rotation-CA
Sole-HB-CA[b]	-	✓	✓	Sole haricot bean-CA
Sole-SB-CA[c]	-	✓	✓	Sole soybean-CA

Note: CA=conservation Agriculture; CP=Conventional Practices; a=Maize component; b=Haricot bean; c=soybean, □=treatment considered for this report

Even though six treatments were planted in 2010, only bean-maize intercropping and sole maize permanent under CP were included here due to severe damage in other plots attacked by wild animals. However, all treatments were considered for 2011 and 2012. Starting from the second year, plots of beans in 2011 were used for maize under CA in 2012 and plots of maize under CA in 2011 were used for beans in next season.

For CA treatments, round up was used to control the weed before seed emergence. Each plot had an area of 10mx10m. Minimum disturbance was done on maize and beans rows before planting time using local marasha, hence planted in shallow basin. A furrow was opened for row planting for both beans and maize. BH 543, a medium maturing maize variety, was used for both CA and CP. Ethio-ugozilavia of soybean variety (145-154 days to maturity) and Anger variety (85-96 days to maturity) of haricot bean were used in the trials. In 2010 cropping season, both haricot bean and soybean were planted 25 days after maize. However, both beans and maize were simultaneously planted in first to mid-june in 2011 and ending June in 2012. Sole beans were planted in mid-june. All maize and legume residues for CA treatments were retained on the plots for the next cropping season. For instance, maize plot under CA was rotated with either soybean or haricot bean and the residues were retained for the next season while bean plots were rotated with maize planting on the same plot.

Maize was planted by 75cmx30cm plant spacing whereas both sole soybean and haricot beans were planted 40cm x 10cm spacing. For intercropping of CA practices, both soybean and haricot beans were planted between maize rows, 53% of total sole plant population. Recommended inorganic fertilizer (110/46 N/P_2O_5 $kgha^{-1}$) rates were applied for all treatments except sole soybean and haricot bean, 46$kgha^{-1}$ P_2O_5 was applied. Split application for Urea and one time application of DAP were done as per site recommendation. Three to four times weeding at different time intervals for CA and CP plots were done. Finally, crop residues for CP plots removed at time of harvesting since no residue retentions were practiced under conventional systems.

2.3 Measurements

2.3.1 Yield and socio-economic data

Yield data were collected for both crops. Harvesting was done 7-10 days after physiological maturity. For each treatment, central rows of the crops were harvested and field moisture content was immediately determined using gravimetric hand moisture tester. Finally, the moisture content for maize grain was adjusted to 12.5% and for bean to 10%. Rain water use efficiency was also calculated as the ratio of yield obtained to total rainfall received from date of emergence to physiological maturity.

In addition, total time required for land preparation, planting, weeding, harvesting and threshing were assessed from each selected farmer in 2011. All variable input costs; seeds, fertilizer, and herbicide and operational costs were also assessed. Relative net return (NR) was computed to assess the profitability of cropping system under CA versus CP as followed by manual procedures [13]. Benefit to cost ratio (B:C) was calculated as the ratio of benefit to cost that vary. Both labor and economic analysis were considered for 2011 cropping season since all socio-economic data were assessed. The return analysis was calculated based on the yield of both crops.

2.3.2 Soil data

In the beginning of the season, a composite soil sample was collected from one representative farm of each district to characterize the soil. The sample was collected from 8 to 10 samples in each experimental plot and composite was prepared. After harvesting, in each cropping season, the soil was sampled from each trial at 0–10cm, 10-20cm, 20-40cm and 40-60cm of soil depth. Both physical (for initial soil composite) and chemical parameters were analyzed. Soil pH was measured in suspension of a 1:2.5 soil to distilled water mixture by using pH meter. The Walkley-Black method was followed for the determination of soil organic carbon (OC%). Cation exchange capacity (CEC, in cmol/100g soil) was analyzed using ammonium acetate method, which is suitable for slightly acid to neutral soils. Electrical conductivity (EC, ms/cm) followed by 1:2 soil/water suspension method, total nitrogen (TN, in %) using Kjeldahl method, total available phosphorus (mg/kg soil) using Bray-II method and available potassium (K, cmol/kg soil) were also determined.

2.3.3 Statistical analysis

Analysis of Variance (ANOVA) was used to assess the source of variability of maize and beans trials for 2011 and 2012 cropping season. However, simple statistical analysis was done for data collected in 2010 since total number of observation (n=10) were low. Similarly, statistical analysis for pH, K, EC, CEC, TN, and extractable P were also analyzed using SAS soft ware version-9. Treatment means were separated using least significant methods (LSD) at P=0.05 for each cropping season. Sigma plot version-10 was used for graphical representation.

3. RESULTS

3.1 Characterization of Seasonal Variability

The study area is part of a sub-humid agro-ecological zone characterized by a mean annual rain fall of 1255mm over the last 13 years. Meanwhile, rain fall variability is very high from one season to the next (between 882 and 1528mm) with more than 4/5 of annual rain fall occurring during the main rainy season between May to September. The long term average of, mean minimum, maximum and optimum temperature values were 13.5, 29.7 and 20.7°C, respectively. During the years 2010 and 2011 seasons, the average annual rain fall was 1338 and 1419mm. However, the annual rain fall amount was fall to 882 in 2012 season Fig. 1.

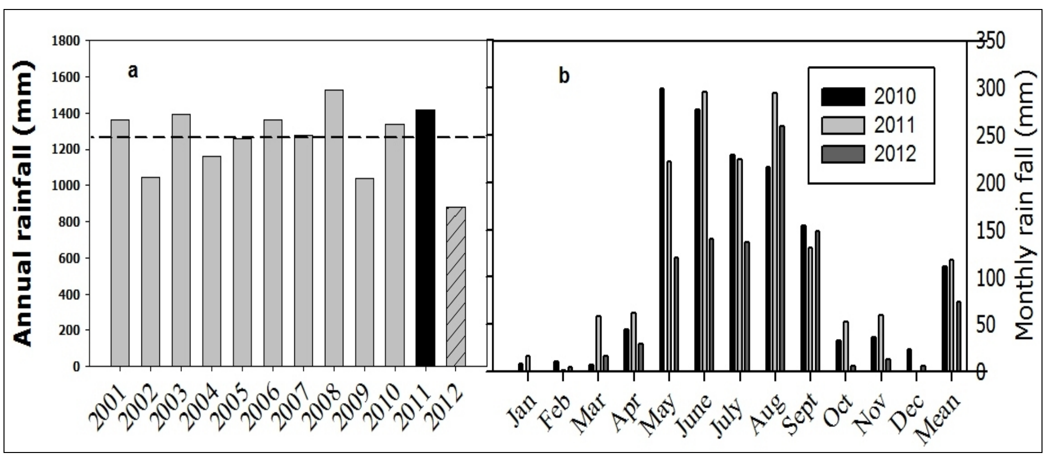

Fig. 1. Twelve years mean annual rainfall (mm) and amount of monthly rainfall for 2010-2012 cropping season (BARC meteorology, 2013)

3.2 Soil Characteristics

The Nitosol, characterized by sandy loam to loam (Table 3), is dominant in the area and the soil texture was mainly sand in both districts. The total nitrogen (TN) was between 0.05 and 0.08% in Gobu Sayo and between 0.8 and 0.12% in Bako Tibe at depths varying from 0-10 to 40-60cm, which corresponds to the low range (Table 2). Organic carbon was also found in the low range, but there was a higher carbon to nitrogen ratio (C:N) in Gobu Sayo district. The relatively poor soil organic carbon and N fertility of the fields could be attributed to the continuous mono cropping and intensive cultivation through heavy applications of NP fertilizers. Soil pH in this district was categorized under slightly moderate to moderately acidic (5.2-5.9) while in Bako Tibe; it was moderately acidic (5.8-6.1). Maize is the major cereal crop grown in the study area, but sorghum, finger millet, haricot bean and soybeans are also widely cultivated. Conventional practices are the main dominant for maize production but also for other crops.

Table 2. Initial some chemical properties of the experimental site

Depth (cm)	Soil pH		OC (%)		TN (%)	
	G/sayo	Bako	G/sayo	Bako	G/sayo	Bako
0-10	5.2	6.1	2.51	2.65	0.05	0.12
10-20	5.8	6.1	1.71	1.81	0.09	0.08
20-40	6.1	6.4	1.52	1.51	0.08	0.12
Mean	5.93	6.20	1.91	1.99	0.07	0.11

Table 3. Initial soil texture at Bako Tibe and Gobu Sayo district (2010)

District	Depth(cm)	Sand (%)	Silt (%)	Clay (%)	Category
Bako Tibe	0-10	31.5	43	25.5	Loam
	10-20	27.5	59	13.5	Silty loam
	20-40	23.5	61	15.5	Silty loam
Gobu Sayo	0-10	51.5	27	21.5	Sandy clay Loam
	10-20	37.5	49	13.5	Loam
	20-40	33.5	57	9.5	Silty loam

3.3 Crop Productivity

Cropping season and location significantly affected both maize and bean yields. In both consecutive cropping seasons, maize and bean yield were significantly affected by different cropping system (Table 4).

Table 4. Analysis of variances for bean and maize yield as influenced by maize-legume intensification with tillage practices across district and cropping season

Source of variation	Significance level						
	¤	Maize			Beans		
Cropping system(CS)	DF 5	2011 **	2012 *	Mean NS	2011 **	2012 **	Mean NS
District(D)	1	NS	NS	4732.0	**	*	NS
Season(S)	1	-	-	**	-	-	*
CS*S	5			NS			NS

**=significant at P=0.05, **=highly significant at P=0.01; NS=non significant*

Significantly higher maize and beans were obtained in 2011 cropping season as compared to the last season (2012) in regardless of location and treatment variation Fig. 2.

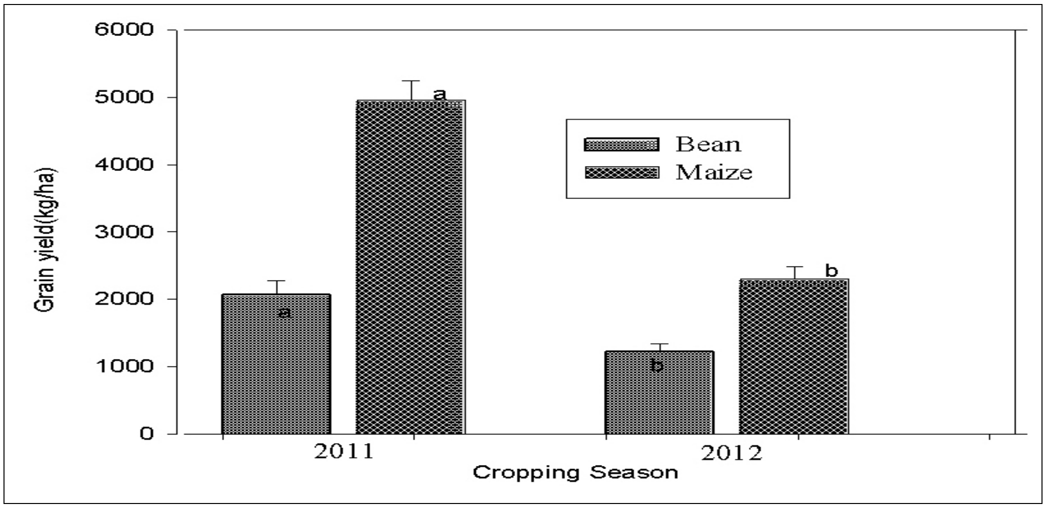

Fig. 2. Bean and Maize yield as affected by cropping season (2011-2012)

Vertical bars=standard errors of means, letters represent means are significantly different in each season

Moreover, reduced rainfall and distribution during tasseling to silking stage of the main crop and even for soybean might be the main reason for yield reduction Fig. 3.

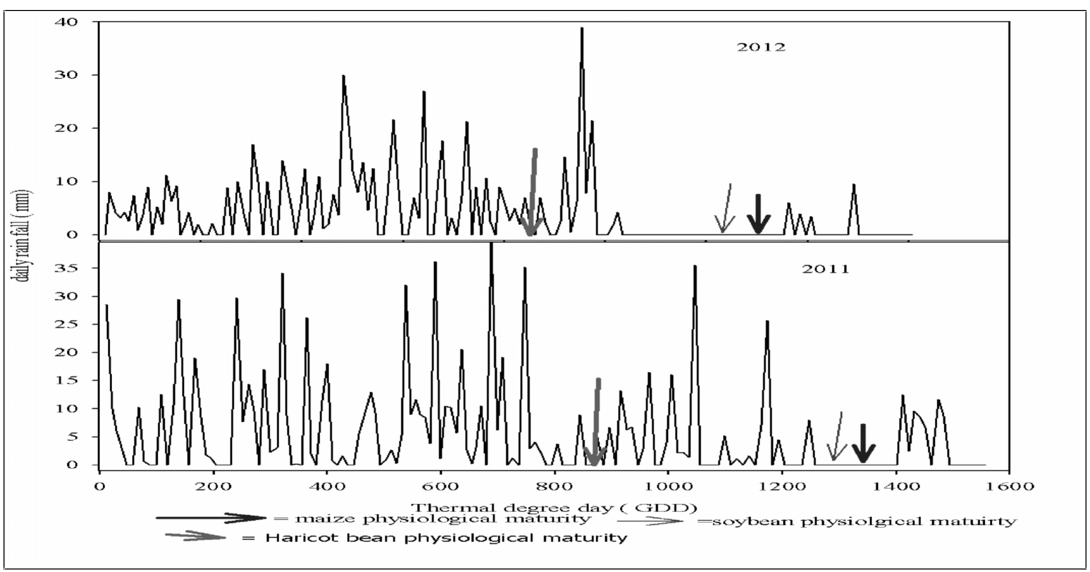

Fig. 3. Daily rainfall and thermal degree days during the bean-maize intercropping system

Arrowed points correspond to certain phonological stages that affected the yield of the crop components

3.4 Maize Yield

Cropping system with tillage practices significantly affected maize yield both in above-average rainfall seasons (2010 and 2011) and below-average rainfall season Fig. 2. When maize was planted on previous soybean plot with minimum tilling in 2011, it gave the highest significant yield (4515kg/ha) as compared to previous haricot bean plot Fig. 4. Yield trend for intercropping indicated that a significantly better yield advantage was obtained in 2011 though rainfall amount and even distribution was similar with 2010 season. Significantly better maize yield was obtained when intercropped with soybean than haricot bean across the season except in 2010. Similar crop performance was observed in 2011 when sole maize was planted either in CP or CA practice.

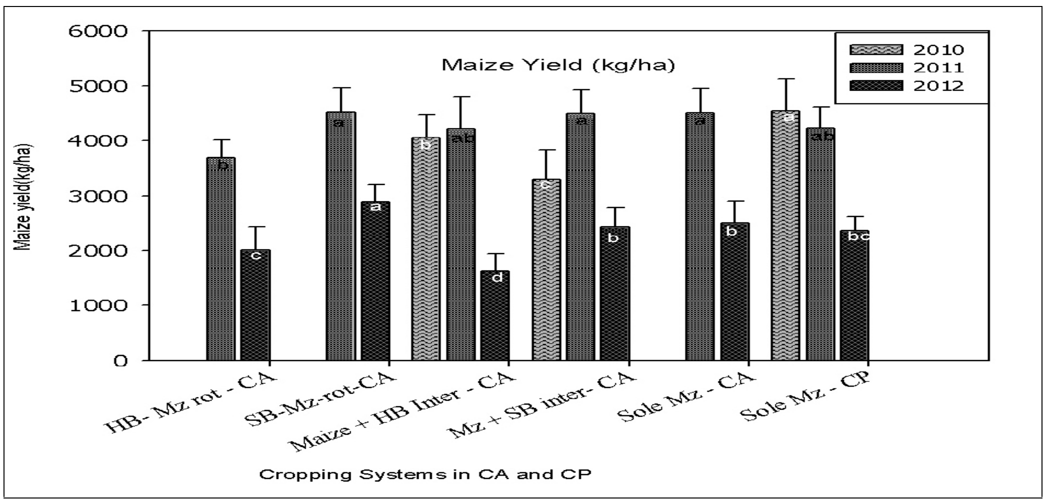

Fig. 4. The effect of cropping system and CA practices on maize yield at Maize belt area of Western Ethiopia (2010-2012)

The vertical bars represent standard errors of different treatment means; different letter represents means are significant

However, significantly higher maize yield was recorded in 2010 under CP as compared to the following years Fig. 4. In bad season (2012), CA practice gave better yield advantage of sole maize as compared to CP practice.

3.5 Bean Yield

The yield of beans was significantly affected by cropping systems with various tillage practices Fig. 5. The seasonal variation had a major effect on the performance beans. More than 42% yield reduction was recorded between 2011 and 2012 Fig. 2. In 2011, soybean planted after maize and on permanent plot under CA gave the highest significant yield as compared to haricot bean Fig. 5. More than 20% and 39% of soybean yield advantage over haricot bean was obtained when grown under rotation with maize plots and sole plots under CA, respectively Fig. 5. Crop rotation significantly improved soybean performance as compared with continuous production of the crop. However in 2012, haricot bean yield as considerably better than that of soybean either planted in crop rotation or permanent plot with CA. In each cropping season, the lowest yield of both beans was obtained in intercropping systems as compared to that of sole cropping since the total population in intercropping was 53% of sole beans.

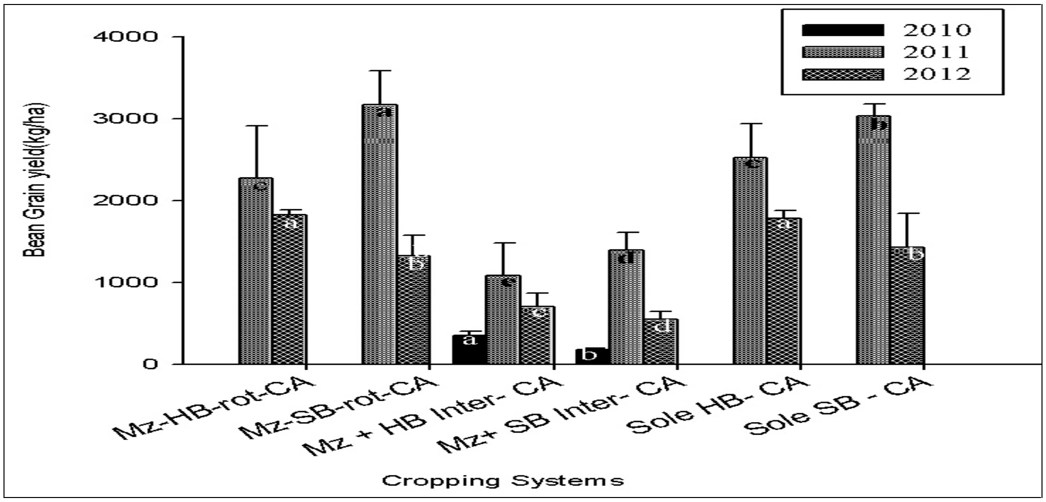

Fig. 5. The effect of cropping systems and CA practices on bean yield at Maize in Western Ethiopia (2010-12)

Different letter represent means are significantly different; and the vertical bars indicate standard errors of difference of treatment means

Even though the amount of annual rainfall and the distribution was similar in 2010 and 2011 seasons, a significant yield reduction in both intercropped soybean and haricot bean was recorded in 2010. In intercropping, considerably better yield was obtained from soybean in good season where as haricot bean had superior yield in bad season (2012). More than 700kg/ha and 547kg/ha during bad season to 1080kg/ha and 1397kg/ha during good growing season of additional haricot bean and soybean yield were, respectively, obtained without significant reduction of maize yield in an intercrops.

3.6 Rain Water use Efficiency

Intercropping systems considerably increased water use efficiency as compared to crop rotation or continuous production in CA or farmers practices. In good season, soybean-maize intercropping efficiently utilized more rain water Fig. 6. However, in bad season, haricot bean-maize intercropping is more efficient and hence accumulated more yields. Continuous production of maze in CA considerably showed more water efficiency as compared to farmers' practices.

3.7 Labor Requirement

Conventional practice need more labor requirements for ploughing as compared to CA practice since CP practice needed three to four time ploughing. However, CA practice reduced 32-41% total labor required for ploughing as compared to CP Fig. 7. During planting, intercropping required more labors since both crops were planted at different time. Weeding operation is the main operational components that required more labors, particularly in CA practices. Convectional practice for maize production required more labor for weeding as compared to CA as no herbicide application in CP was done in 2011 Fig. 7.

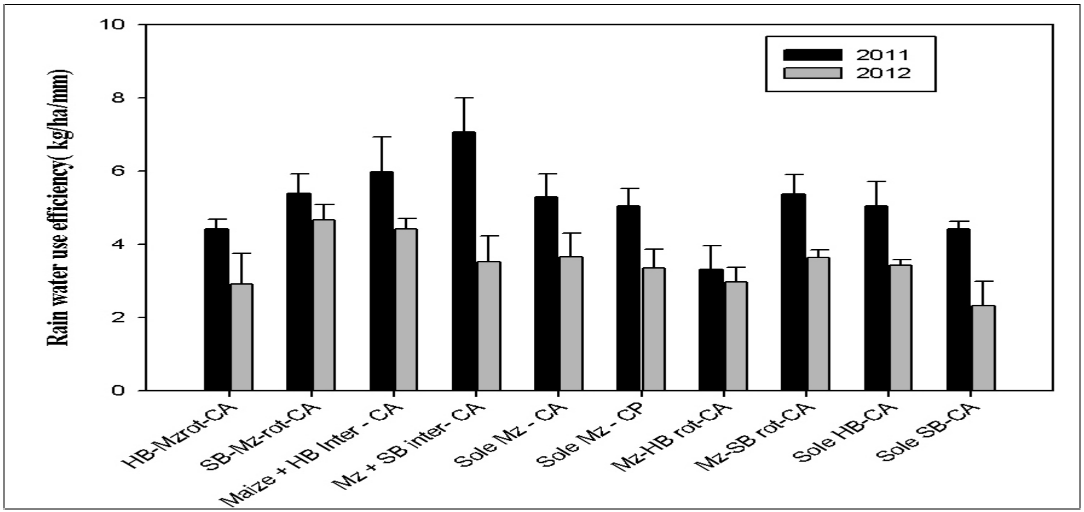

Fig. 6. The effect of cropping systems and CA practices on rain water use efficiency (2010-2012)

The vertical bars indicate standard errors of different means

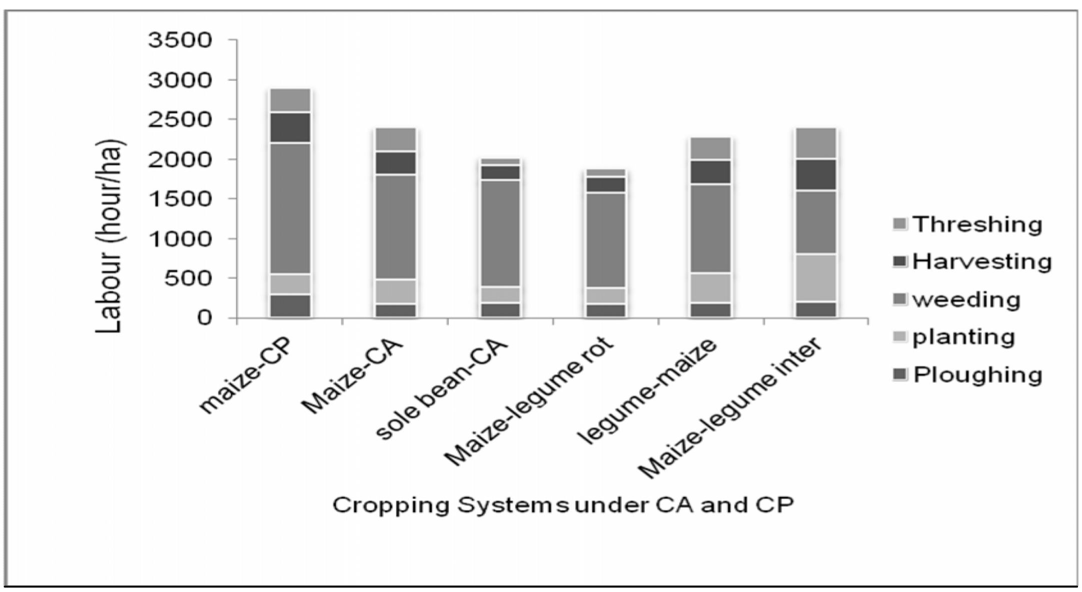

Fig. 7. Labor requirements for different operation in maize-legume intesification with CA and CP practices, 2011

Crop rotations had reduced by 15-27% labors as compared to continuous maize or legume production under CA practices. However, intercropping practices with CA by far reduced from 29% to 52% Fig. 7. In addition to herbicide application before time of planting, different maize-legume intensification under CA save labor required for weeding. However, more labors were required at time of harvesting as the maturity period of the component crops were totally different and hence need different time.

3.8 Profitability

The highest growth return was obtained from maize-soybean intercropping under CA where as sole maize production with CP practice recorded the highest total variable cost Fig. 8b. The maximum net benefit, 15545 ETH birr/ha and 12693 were obtained when soybean and haricot bean were intercropped in maize, respectively though their variable production costs were also higher. However, for low income households who cannot afford inputs for maize production, both soybean and haricot bean production were also much profitable since their input and operational cost, particularly fertilizer, were much lower. For sole bean production, 34-36% reduction of total variable cost was denoted as compared to maize production.

The highest B:C ratio(3.2) was obtained when soybean were grown as sole in crop rotation or continuous with CA practices while the minimum B:C ratio (1.7) was recorded from CP maize production Fig. 8a. However, there was a decrease in 20-46% of return per unit cost obtained from haricot bean as opposed to soybean since yield performance for the earlier was much higher Fig.8a. Maize production with CA practice provided better net return than farmers' practices since cost incurred for animal traction was much reduced by more than 25% Fig. 8b.

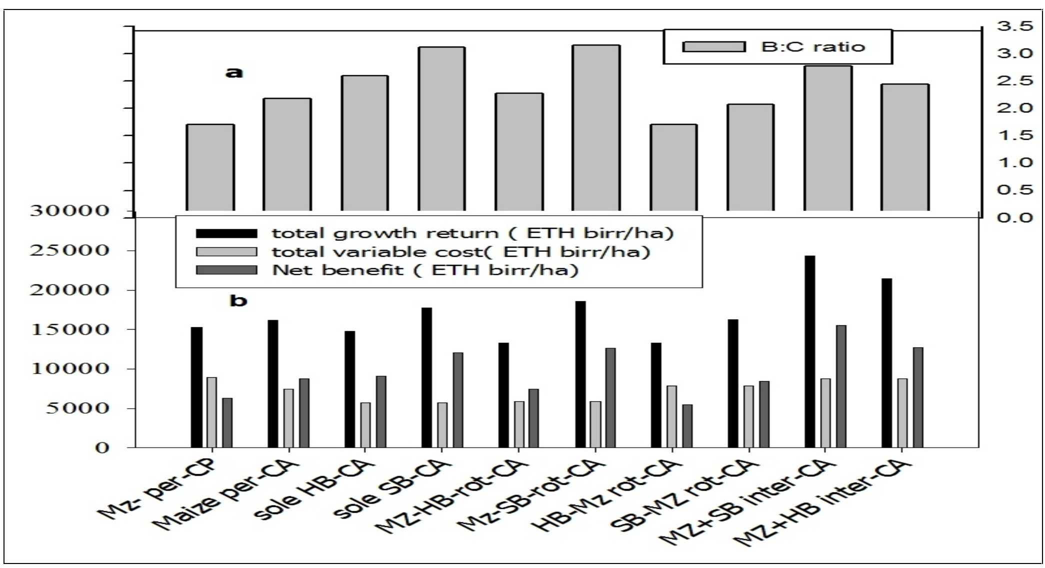

Fig. 8. Total variable cost, growth return, net benefit (b) and benefit: cost ratio (a) as affected by different cropping systems in CA practices

3.9 The Effect of Maize-legume Intensification on Some Soil Chemicals

The results of the analysis of variance revealed that all chemical properties except electrical conductivity (EC) were significantly affected by location. However, variation in cropping seasons did not significantly affect except the cation exchange capacity (CEC). Cropping systems in combination with CA practices showed a significant difference on pH, total extractable phosphorus and total nitrogen (Table 2). Moreover, available K, total phosphorus, OC as well as total nitrogen was significantly varied as the function of varying soil depth.

Table 5. Analysis of variances for some chemical properties of the soil as influenced by cropping systems with tillage practice, location, and cropping season, 2010-2011

		Mean squares						
Source	**DF**	**pH**	**EC**	**CEC**	**K**	**P**	**OC (%)**	**TN (%)**
Year	1	0.01042	0.00013	45.38*	0.001	0.017	0.001	0.00167
Cs	5	0.32768*	0.00176	11.14	0.43	1.85**	0.320	0.00773*
Location	1	2.9330**	0.00030	175**	3.32**	3.07**	1.05*	0.02734**
Depth	3	0.00024	0.00165	16.59	0.61*	14.66**	5.997**	0.06385*

CS= cropping systems; Df=degree of freedom; EC=electrical conductivity; CEC=cation exchange capacity= extractable phosphorus; OC=organic carbon; TN=total nitrogen;=significant at P=0.05;**=highly significant at P=0.01*

Soil pH in Gobu Sayo district was categorized under moderately acidic (5.78pH) and significantly lower as compared to Bako Tibe (6.1pH),which is moderately to slightly acidic Fig.9. Similarly, concentration of P and CEC were significantly higher in Bako Tibe (FAO, 2008). Even though percentage of OC in each location was found in medium range (1-3%) as indicated on FAO (2008) soil laboratory manual, notably higher percentage was found on farmer's field of Gobu Sayo. Similar results were also found for total nitrogen and available K Fig.9.

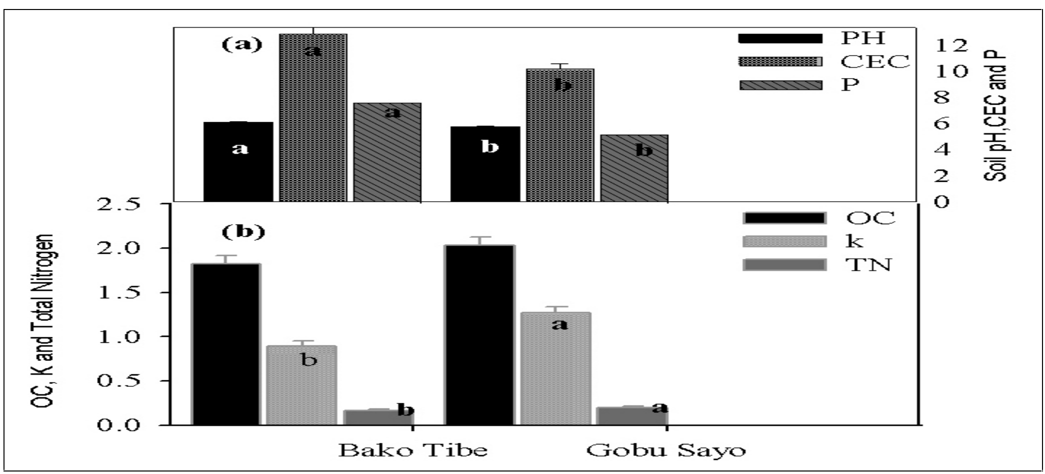

Fig. 9. Variation in experimental location on some chemical properties of the soil (2010-2011)

Maize and haricot bean in permanent plots showed significantly lower pH value as compared to bean-maize rotation and maize-bean intercropping and even to the initial soil pH value. However, the lowest pH value was recorded when maize was continuously produced under CP practice Fig.10. Total phosphorus was much more in bean plots either planted continuously or in crop rotation.

However, the lowest concentration was recorded from mono cropping practices for maize Fig. 10. Numerically higher percentage of organic carbon was found in maize-bean intercropping, sole haricot bean and haricot bean-maize rotations. However, farmers' practices considerably reduced the OC content. Plots of sole maize with CP and CA practices significantly reduced N content where as better improvement was observed in crop rotation and intercropping systems.

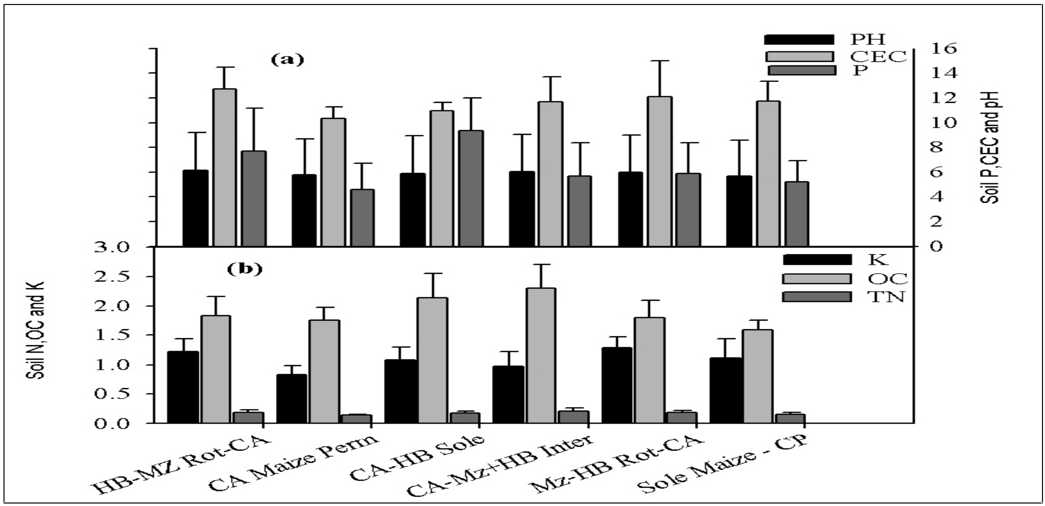

Fig. 10. some chemical properties of soil as influenced by different cropping systems with tillage practices (means across the year and location)

The vertical *bars represent the standard errors of different means*

4. DISCUSSION

4.1 Rainfall Variability Influence Yield Component

The result clearly revealed that 53% and 41% maize and beans yields reduction were observed in short rainfall season as contrasted to good season. This result might significantly be correlated by 94.3% (data not indicated) between maize yield and growing rainfall, from tasseling to physiological maturity, and even with uneven monthly distribution during growing period for each crop. Even though positive correlation for both beans was recorded, yield of soybean was highly correlated (by P=0.78*) with the total growing rainfall (from podding to physiological maturity stages) as compared to haricot bean (P=0.36). Similar results were suggested that the amount of yield of maize is significantly and positively correlated with the total amount of rain in each cropping season [14]. Treatment effects also depended on seasonal distribution of rainfall. For example, the work of authors [15] revealed that maize grain yields with N fertilizer application were 7.7 and 4.7 t ha^{-1} with favourable and unfavourable rainfall distributions, respectively.

4.2 Conservation Practice has Positive Indication for Sustainable Production

There was considerable yield improvement because of maize-legume intensification with minimum practices that interacted differently across variable cropping seasons. However, various agronomic management practices could response under favourable rainfall. In good season, better yield of maize could be obtained when soybean is used as precursor crop as compared to haricot bean. This might be its high capacity to fix atmospheric nitrogen or its high biomass accumulation that were decomposed and may be retained for next crops and enhance soil fertility [16]. Intercropping practices, particularly maize-haricot bean intercrops under CA also ensure to avoid risks in case of variable and short rainfall and similar results were also documented [3]. More than 38-41% in unfavourable season and 44-47% during favourable season of additional yield were obtained without significant reduction of the main crop. In bad season, higher additional yield of intercropped haricot bean could be obtained as compared to soybean. However, delayed planting of beans in maize significantly reduced the yield. Some reports [17] also confirmed that higher dominance on resource competition was enhanced for main crop when companion crops were planted lately, and hence its yield was highly reduced. The same author indicated that more than 47% yield reduction was recorded when haricot bean was inter planted after 30 days of maize planting. The work of many researchers [18] in line with this result confirmed that there was a positive indication of CA in conserving soil moisture, particularly in short rain season. However, it is obvious that CP practice enhances maize yield in the beginning as compared to minimum tillage. In short growing season, early types of legume crops could perform better than late types since the early types might coincide its short duration with limited growing period.

4.3 Conservation Agriculture Save Labor and Money

One of the main merits of CA practice for small hold famers is its ability to save time and Money. The result confirmed that CA reduced 32-41% total labor and for animal traction power as compared to CP. Similar result was also reported that minimum tilling with crop residue retention could reduce labour requirement up to 50-60% at a critical time of agricultural calendar [19,20]. The result also revealed that weeding operation is the main operational components that required more than 20-52% of the total labor required for CP practice than CA though it was supported by pre-emergence herbicides. Crop rotation and residue retention with CA practice reduced by 18% labor required as compared to continuous growing of the crop with minimum tilling. This technology might reduced germination of soil seed bank, and reduce the pressure of infestation [21]. This finding also indicated that intercropping practices with CA by far reduced from 29% to 52% of total time required for weeding since there might be highly smothering effect on weed that might largely reduced its competitions effects.

Maize-legume intercropping produced the highest net benefits though its variable production cost was also high. However, the highest B:C ratio was obtained when legume crops were grown under CA. For sole bean production in CA, up to 36% of input cost could be saved since the crops need much less inorganic fertilizer. Relatively higher net income was gained when minimum tilling would also be ensured for maize production as compared to intensive cultivation since considerable animal power for traction was saved. Similar result was also reported that energy cost of crop production with conventional tillage and direct seeding estimated that the total inputs are about 40-50% lower for conservation agriculture and the increase net income ranged from 50% to more than 60% [22].

4.4 CA-based Cropping Systems Improve Soil Fertility

Crop rotation and intercropping practices with CA improved and considerably enhanced soil fertility. However, continuous cultivation of legume crops on permanent plot reduced pH of the soil. This result in agreement with other findings indicated that legume crops reduce soil pH since the crops absorb high concentration of base cations and available nitrogen in the form of nitrate by releasing H^+ into rhizosphere, which leads to soil acidification [23]. Repeated application of acidic inorganic fertilizer could also enhance soil acidity, particularly in convectional system, the nitrification is more enhanced in much disturbed soil than minimum tilling so that nitrate leaching might be aggravated and leads to high concentration of H^+ in the soil solutions become increased. Similar to soil pH, CEC capacity of the soil was increased in crop rotation and intercropping systems in combination with minimum tilling due to addition of soil organic carbon [24]. Conventional practices also reduced total nitrogen content owing to CA- based intercropping or crop rotation. The reduced nutrient availability under tilled may be due to removal of crop residue, higher decomposition rate of organic matter, and rapid leaching of the nutrients [25].

5. CONCLUSION

Maize-haricot bean intercropping with minimum tilling is more stable in unfavourable season and hence preferable to get more productivity as compared to maize-soybean intercropping though its performance in good season is considerably better. Similarly, CA based early type of crop production yielded better yield and hence advisable in variable and short rain season. Maize performance regardless of tillage practices highly affected by rainfall even if there is minor yield increment in CA practices as compared to conventional one during bad season. Crop rotation, particularly use of soybean as precursors, is a paramount important practice since it considerably improved the performance as compared to continuous mono cropping. Simultaneous planting of maize-bean intercropping significantly provided better yield as compared late planting.

Convectional practice is more laborious for tilling as compared to CA practice. During planting, intercropping required more laborious than any other treatments since both crops were planted at different time. Convectional practice for maize production is more laborious for weeding. However, intercropping practices with CA by far reduced from 29% to 52% and hence one of its main benefits in addition to risk avoidance and high water use efficiency. The maximum net benefit could also be obtained from intercropping practices though total variable cost is high as compared to CA-based sole bean production, which have the highest net return per unit cost and is advisable for small holder farmers who could not afford all input required for maize production.

Crop rotation and intercropping practice in combination with CA could be more advisable to reduce soil acidity as compared to continuous production of maize and beans with frequent application of acidic fertilizer. Better improvements of CEC, OC and Nitrogen could also be recorded if crop rotation and intercropping practices could be promoted.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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