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Effects of Maize / Legume Intercropping On Grain Yield of Component Crops, Land Productivity and Profitability under Conservation Agriculture

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***Abstract*— Sustainable crop production is adversely affected by the degradation of the natural resources. Conservation agriculture based maize legume intercropping was evaluated with objectives of exploring productivity and profitability of the systems in Boricha and Loka Abaya districts of Southern Ethiopia during 2014 to 2016 cropping seasons.The experiment had six crop management practiceslaid in randomized complete block design replicated three times (farmers field as replication).Results showed that mean yield of intercropped maize under conservation agriculture was higher by 11% than that of the sole maize, and lower by 9% than the conventional farmers practice. Similarly, maize /legume intercropping under conservation agriculture resulted by 27and 38 % higher common bean and cow pea yield than that of the conventional farmers practice, respectively. In both cow pea and common bean intercropping with maize under conservation agriculture, 71 and 54% more efficient use of land productivity was observed over sole cropping. The highest MRR (3353%) was measured from maize/common bean intercropping under Conservation agriculture during 2016. The result also indicated that farmers who are engaged in mixed crop livestock production can benefit from production of maize/ cow pea under Conservation agriculturewhere as those farmers who wants to maximize their income can be engaged duly in maize/common bean production under Conservation agriculture. Thus, highest yield, diet diversity and economic benefit of the conservation agriculture over the conventionally tilled plots is an alternative option for resource poor and female headed small holder farmers who does not have oxen to till their land.**

***Index Terms*— conventional, dominance, marginal return, net benefit, productivity, tillage, variable cost.**

I. INTRODUCTION

Population pressure has led to exploitative agriculture and declining soil quality including fertility, organic matter, physical properties, and rain water infiltration. Reduced crop biomass, ground cover and root development contribute to greater soil erosion. The net result is increased run-off and erosion, reduced water productivity, soil and water quality, and land productivity. Fundamental shift had taken place in agricultural research and world food production. In the past, the principal driving force was to increase the yield potential of food crops and to maximize productivity. Today, the drive for productivity is increasingly combined with a desire for sustainability. Inclusion of legumes in cropping system can play an increasingly important role to maintain soil fertility and sustain crop productivity. Though Ethiopia's cropping systems are diverse, the proportion of legume coverage on average is far exceeded by that of cereals. Crop rotation, fallowing, and use of green manure are largely difficult to implement in densely-populated areas with small farm sizes, and even more so where food supply is insecure. Intercropping does not face these same challenges. The benefits of legume- cereal intercropping have to be identified by research. The main reason for using a multiple cropping system is the fact that it involves integrating crops using space and labor more efficiently (Baldy and Stigter, 1997). In the absence of nitrogen fertilizer, intercropped legumes fix nitrogen from the atmosphere and not compete with maize for nitrogen resources (Adu- Gyamfi et al. 2007).

Soil tillage is probably as old as settled agriculture. It has been therefore an integral part of traditional and/or conventional agriculture. Specific reasons for tilling a soil include weed control, incorporation of soil amendments, crop residues and pesticides, and modification of soil physical properties, thereby improving soil conditions for crop establishment, growth and yield (Cassel, 1983). The impacts of tillage on soil degradation and hence agricultural sustainability are more important now than ever before. Among the food crops, maize is the main staple (Bänziger and Diallo, 2004), and legumes are an important dietary protein source for the rural poor (Onwueme and Sinha, 1991).

There is a diverse range of options available from direct drilling into a cover crop to deep cultivations, which have the same versatility as ploughing. Erosion by wind is also increased by tillage because the topsoil is left bare and loose. Reducing soil organic matter through oxidation and deleterious effects on soil micro flora and fauna, reduced soil structural stability and increased surface runoff and water or wind erosion. Moreover, erosion can be stopped on 15 percent slopes if the surface is covered by about 4t ha^{-1} straw along the contours and the soil moderately permeable to water (Carter, 2005). Thus, the present study was envisaged to test the effectiveness of maize/legume intercropping under conservation agriculture.

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II. MATERIALS AND METHODS

Study area

The experment was conducted in Boricha (located at an altitude of 1849 masl, 7° 00' 167" latitude and 38°15"225" longitude having initial soil pH value of 6.32, 2.44 OC, 0.17 total N and 25.93 CEC), and Loka abaya geographically located at an altitude of 1781masl, 06° 44' 495" latitude and 038° 16' 291" longitude and 1720masl with 06° 641' 939" latitude and 038° 14' 334" longitude of farmers field of Almaz and yonas Latamo, respectively with 6.15 pH, 2.75 OC, 0.20 total N, and 24.88 CEC in Southern region of Ethiopia during 2014 to 2016 cropping seasons. Both locations receive bimodal rain fall with short rain during April and may and the long rain extends from July to November with irregular distribution.

Treatments and experimental design

Six cropping systems including the farmers practices (Farmers practice (check): One, traditional land preparation and maize and common bean intercropping as management but with the varieties and fertilizer application as the other treatments, residues may be grazed, removed, burned or incorporated, farmer decides on intercrop; Second, Maize-legume intercrop, Common bean sown between maize rows at maize planting and relay cropped at maize hard dough stage under conservation tillage; Third, maize–legume intercropping, cowpea sown between maize rows at maize planting and relay cropped at maize maturity under conservation tillage., fourth, Sole maize under conservation tillage., Fifth, sole Bean twice per season under conservation tillage and sixth , maize /common bean rotation under conservation tillage were laid in randomized complete block design in a 10 by 10 plot size replicated three times considering farmers field as replication. Maize variety BH 540 and common bean variety Hawassa Dume were investigated. It was additive type of crop geometry where 100 % of maize population density as base crop and 50% of that of the legume population in the system investigated due to the fact that the system is highly efficient regarding total system productivity and utilization of available farm resources (Javanat et al., 2018).

Note: Conservation Agriculture= (minimum soil tillage, residue retention, herbicide application)

Data analysis

The grain yield data were subjected to ANOVA using SAS computer software (SAS Institute, 2000). Treatments means were compared using the least significant difference (LSD) at 5% level of significance. The advantage and disadvantages of intercropping were determined using the land equivalent ratio (LER) which was used as the criterion for mixed stand advantage as both maize and common bean were common crop species (Willey and Osiru, 1972). Land use efficiency was determined by calculating Land equivalent ratio (LER). Land equivalent ratio of maize was calculated as intercrop yield of maize over pure stand yield of maize and that of common bean was calculated as intercrop yield of common bean over pure stand yield of common bean. The overall LER is simply the sum of LER of maize and LER of common bean (Mead and Willey 1980). MAI value indicates the profit of the cropping system and computed as follows:MAI = (value of combined intercrops) (LER-1)/LER. The market price for maize, common bean and cowpea at the time of crop harvest around the study areas was estimated at Eth. Birr 6.80 kg^{-1}, Birr 13.40 and Birr 9 kg^{-1}, respectively. The total gross monetary value (GMVt) was then estimated by addition of the GMV of maize and GMV of legume.

III. RESULTS AND DISCUSSIONS

Weather effects on crop yield

Results of 2016 generally showed similarity with 2014 despite the variation in rainfall pattern especially in Loka abaya. In 2014, the season was favorable for both crops (maize and common bean) as the rainfall was sufficient. However in 2016, there were irregularities in rainfall pattern in such a way that there was surplus rainfall during planting, rainfall was deficient during urea application (Fig 1); on the other hand, there was sufficient rain fall during grain filling. The surplus rain has resulted in floods and water erosion in Loka Abaya clay soils during 2016 (Fig. 2).

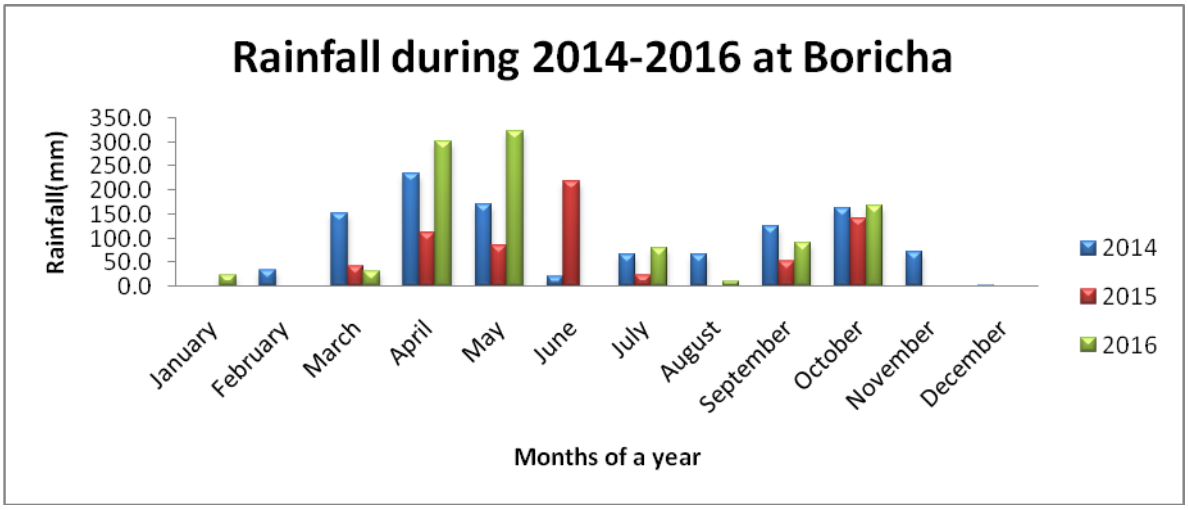


Fig 1.Rainfall during 2014-2016 at Boricha

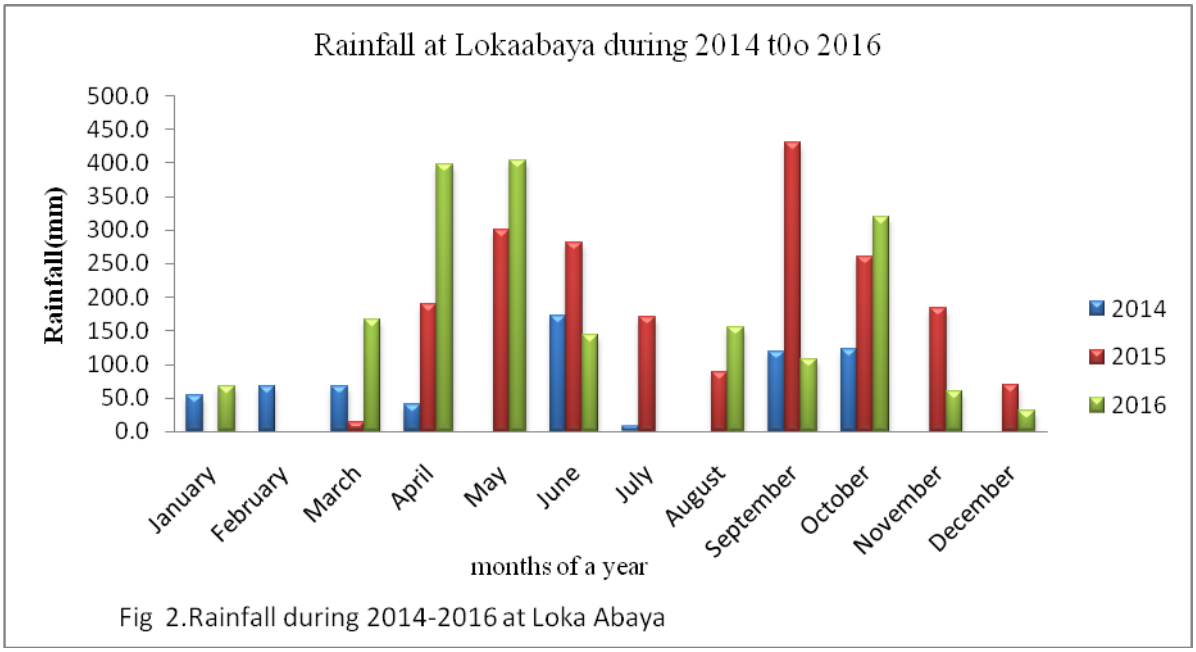


Fig 2.Rainfall during 2014-2016 at Loka Abaya

Effects of Location on maize yield

Maize yield was not significantly different during 2014 and 2015 cropping season across locations. However, it was significant ($P<0.05$) during 2016 (Table 1). This was due to rainfall irregularities i.e excess during planting and seed filling, and then shortage of rainfall during vegetative growth stages affecting maize crop grown in clay soils of Loka Abaya (Fig 1 and 2).

Table 1. Maize grain yield (kg ha^{-1}) across locations from 2014 to 2016 cropping season

Locations	2014	2015	2016
Boricha	11321	9172	10190
Lokaabaya1	11055	8443	6670
Lokaabaya2	11149	9597	9460
Cv%	13.35	10.56	12.38
LSD	NS	NS	4028

Effects of intercropping on maize yield (kd ha^{-1})

Maize yield was not statistically significant among cropping systems during 2014 and 2016. However, it was significant during 2015. Highest maize grain was obtained during 2015 when maize /bean rotation under consrvation tillage., however,it was statistically higher only from maize cow pea intercropping (Table 2).

Table 2. Effects of intercropping on maize yield (kd ha^{-1})

Cropping system	2014	2015	2016	Mean
MaizeCN	11665	9703a	8817	10062
Maize+cb CA	10867	9906a	9933	10235
Maize+cp CA	11453	7008b	8033	8831
Sole Maize	10650	8633ab	8117	9133
Maize cb rot.	11240	10103a	8967	10103
Cv%	13.35	10.56	12.38	
LSD	NS	1803	NS	

CN – conventional tillage, CA – conservation agriculture, CV- coefficient of variation, LSD – least significance difference, CP – cow pea, CB – common bean

The overall mean yield of maize over years is considered, it was the intercropped one under conservation tillage which is by 11% higher than that of the sole and by 9% lower than the conventional farmers practice (repeatedly tilled). This result is in agreement with different scholars who stated as the limiting resources like water, light, and nutrients are efficiently utilized in intercropping systems as against their respective sole cropping, it leads to higher yield (Li et al. 2006; Lithourgidis et al. 2011; Bedoussac et al. 2015).

Effects of Location on legume yield

There was no significant legume (common bean and cow pea)yield difference observed across years(Table 3)

Table 3. Effects of Location on legume yield

Location	2014	2015	2016
Boricha	1414	2452	1320
Lokaabaya1	1597	2950	1404
Lokaabaya2	1453	2695	990
Cv%	14.55	13.21	23.97
LSD	NS	NS	NS

Effects of intercropping on legumes yield

As presented in table 4, the effect of intercropping to legume yield was significant. Mean yield of legume over years under conservation tillage resulted by 27% and 38 % higher common bean and cow pea yield than that of the conventional farmers practice, respectively.

Table 4. Effects of Intercropping on legume yield (kg ha^{-1})

Cropping system	2014	2015	2016	Mean
Maize +cb CN	845c	1504b	489c	946
Maize+cb CA	1222bc	2153b	542c	1306
Maize+cp CA	1505b	1694b	1390b	1530
Sole cb	2378a	5444a	2531a	3451
Cv%	14.55	13.21	23.97	
LSD	433	712		

As cereal and legumes widely differ for their rooting patterns, intercropping of them increases the water uptake as well as transpiration and reduces the water loss from soil either through evaporation or deep percolation (Carlson 2008).When treatments were compared, the highest LER (1.71and 1.54) were measured due to maize/cowpea intercropping under conservation agriculture plots during 2014 and 2016, respectively regardless of the districts. On the other hand, the LER of maize common bean intercropping under conservation agriculture gave the highest LER(1.54) during 2015. The diverse rooting pattern, growth pattern, differences in nutrient requirement, crop duration, etc. tend to impart them a certain degree of ability to come up well even under stressed conditions (Jayanta *et al*, 2018). In both cow pea and common bean intercropping with maize under conservation agriculture, 71 and 54% more efficient use of land productivity was observed over sole cropping (Table, 5). Thus, it depicts that farmers would maximize their land use if they employ maize and legume (common bean and cowpea) intercropping with conservation tillage practices. Moreover, conservation agriculture rewarded farmers with highest yield mainly because rainfall irregularities were addressed by conservation technique compared to conventionally tilled plots.

As presented in Table 6, highest MRR obtained when maize cowpea intercropped under conservation tillage; farmers can

expect 1980 ETB when investing one ETB during 2014. In 2015, highest MRR (1994 ETB) was expected by investing one ETB when maize and common bean intercropped under conservation tillage followed by sole common bean production under CA; in 2015. In general, the highest MRR (3353ETB) was measured from maize/common bean cropping system under CA during 2016. The result also indicated that farmers who are engaged in mixed crop livestock production can benefit from production of maize/ cow pea under CA where as those farmers who wants to maximize their income can be engaged duly in maize/common bean production under CA.

Table 5. LER and net benefit of cropping systems considered in Conservation agriculture exploratory trials.

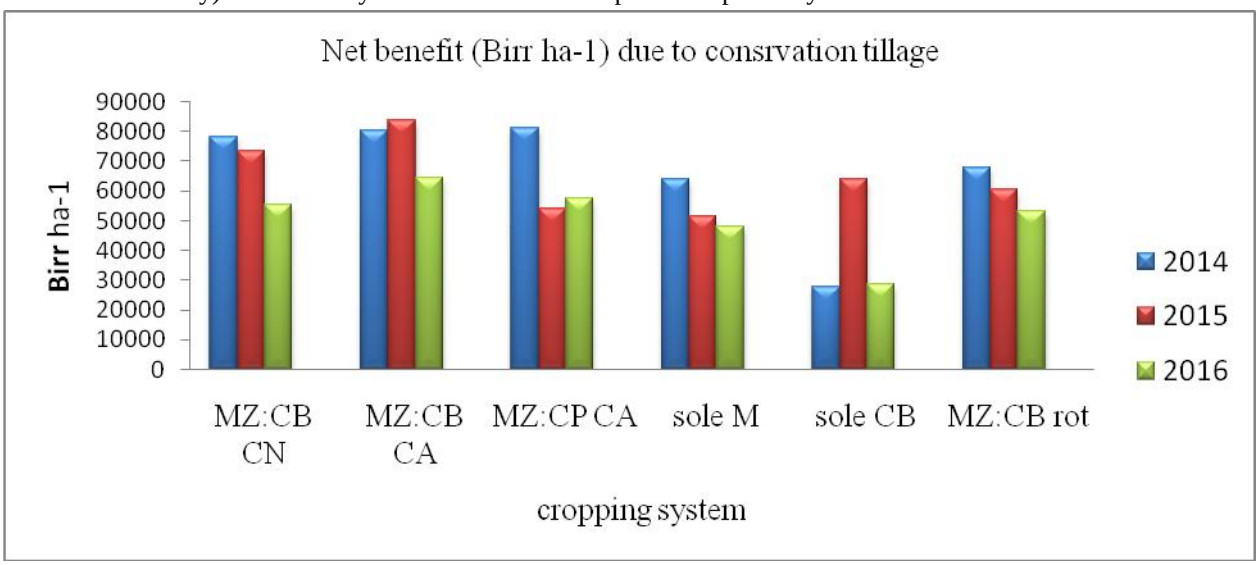
Year	Treatment	Mzyld (kg/ha)	Adj mzyld	Cbyld (kg/ha)	Adj legyld	LER Mz	LER Cb	Total LER	Gross benefit (etb)	Cost that vary (etb)	Net benefit (etb)
2014	Mz:cbcn	11665	10498.5	845	760.5	1.10	0.36	1.45	81581	3400	78181
	Mz:cb ca	10867	9780.3	1222	1099.8	1.02	0.51	1.53	81243	900	80343
	Mz:cp ca	11453	10307.7	1505	1354.5	1.08	0.63	1.71	82283	950	81333
	Sole m	10650	9585	0	0	1	0	1.00	65178	1050	64128
	Sole cb	0	0	2378	2140.2	0	1	1.00	28679	975	27704
	Mz:cb rot	11240	10116	0	0	1.06	0	1.06	68789	1000	67789
2015	Mz:cbcn	9703	8732.7	1504	1353.6	1.12	0.28	1.40	77521	4000	73521
	Mz:cb ca	9906	8915.4	2153	1937.7	1.15	0.40	1.54	86590	2800	83790
	Mz:cp ca	7008	6307.2	1694	1524.6	0.81	0.31	1.12	56610	2700	53910
	Sole mz	8633	7769.7	0	0	1	0	1.00	52834	1500	51334
	Sole cb	0	0	5444	4899.6		1	1.00	65655	1800	63855
	Mz:cb rot	10103	9092.7	0	0	0	1.06	1.06	61830	1500	60330
2016	Mz:cbcn	8817	7935.3	489	440.1	1.09	0.19	1.28	59857	4500	55357
	Mz:cb ca	9933	8939.7	542	487.8	1.22	0.21	1.44	67326	3000	64326
	Mz:cp ca	8033	7229.7	1390	1251	0.99	0.55	1.54	60421	2800	57621
	Sole mz	8117	7305.3	0	0	1.00	0.00	1.00	49676	1800	47876
	Sole cb	0	0	2531	2277.9	0.00	1.00	1.00	30524	2000	28524
	Maize cbrot	8967	8070.3	0	0	1.10	0.00	1.10	54878	1800	53078

Note: market price of common bean, maize, and cow pea was 13.4, 6.80, and 9.00 ETB kg^{-1}.

Table 6. Marginal analysis for the effect of maize legume intercropping under conventional and conservation tillage in Boricha and Loka abaya district during 2014 to 2016

Year	Treatment	Cost that vary (etb)	Net benefit (etb)	Marginal cost	Marginal benefit	Mrr
2014	Mz:cb ca	900	80343			
	Mz:cp ca	950	81333	50	990	19.80
	Sole cb	975	27704	25	-53629	D
	Mz:cb rot	1000	67789	50	-13544	D
	Sole m	1050	64128	100	-17205	D
	Mz:cbcn	3400	78181			
2015	Mz:cb rot	1500	60330			
	Sole mz	1600	51234	100	-9096	D
	Sole cb	1800	63855	300	3525	11.75
	Mz:cp ca	2700	53910	900	-9945	D
	Mz:cb ca	2800	83790	1000	19935	19.94
	Mz:cbcn	4000	73521	1200	-10269	D
2016	Maize cbrot	1800	53078			
	Sole mz	1900	47776	100	-5302	D
	Sole cb	2000	28524	200	-24554	D
	Mz:cp ca	2800	57621	1000	4543	4.54
	Mz:cb ca	3000	64326	200	6705	33.53
	Mz:cbcn	4500	55357	1500	-8969	D

As presented in figure 3, highest net benefit obtained from maize /legume intercropping over the sole cropping. Among the intercrop, maize common bean under conservation tillage stands first with ETB 83790(eight three thousand seven hundred and ninty) followed by that of maize cow pea (81333(eight one thousand three hundred thirty three). Moreover, farmers practice (growing maize/bean intercropping under conventional tillage) resulted in higher (6%, 50%) net benefit over the sole maize and common bean, respectively.



MZ=maize, CB=common bean, CN=conventional tillage, CA=conservation agriculture, CP=cowpea

Fig. 3. Effect of maize /legume intercropping on net benefit under conservation tillage

CONCLUSION AND RECOMMENDATION

Results of present study indicated that the maize/ legume intercropped under conservation agriculture was higher by 11% than that of the sole maize, and lower by 9% than the conventional farmers practice. Similarly, the intercropped legumes under conservation tillage resulted by 27 and 38 % higher common bean and cow pea yield than that of the conventional farmers practice, respectively. In both cow pea and common bean intercropping with maize under conservation agriculture, 71 and 54% more efficient use of land productivity was observed over sole cropping. Moreover, highest MRR was obtained when maize cowpea and maize common bean intercropped under conservation agriculture. Thus, conservation agriculture rewarded farmers with highest yield, diet diversity (maize and legume) and economic benefit over the convention agriculture mainly because rainfall irregularities were addressed by conservation technique.

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