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Research Article

Conservation Agriculture Effects on Crop and Moisture in Central Rift Valley of Ethiopia

Yaya Tesfa[1,*], Jemal Abdulahi[2]

[1]Melkassa Agricultural Research Center, Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia
[2]School of Plant Sciences, Haramaya University, Dire Dawa, Ethiopia

Abstract

Cropping systems of maize-legume crops which mostly practiced under conventional practice has resulted in soil degradation and loss of crop yield in Ethiopia. This practice may be inversed by Conservation Agriculture. Optical sensor techniques particularly normalized difference vegetative index is immediate, non-devastative and quantitative assessment method; which opposes conventional plant tissue sampling analysis which is devastating and needs more time. CA practice may enhance soil water and crop yield. CA can improve soil health and crop productivity. It was suggested that CA should be studied by considering both crop and soil parameters in Ethiopia. By considering this field experiment was done at Melkassa agricultural research center during the rainy season of 2018 and 2019 to study the impacts of conventional practice and conservational practice under different cropping systems. Split plot treatment design with 3 replication was used. Two tillage levels were assigned to the main plots and four maize-legume systems were assigned to the sub plots. Results implied that conservation agriculture plot was early in maize emergence and late in maize tasseling, silking and physiological maturity than conventional practice. Maize bean intercropping under conservational was better in maize yield, biomass and harvest index than maize bean intercropping under conventional practice. High normalized difference vegetative index value was recorded under conventional practice for the earlier periods and low value was recorded under conservational practice during earlier periods of maize growing periods. However, Normal difference vegetative index was become higher for conservational practice during grain filling maize grain filling stage. Better soil moisture content at various soil depth was obtained from maize rotation system under conservational practice than cropping system under conventional practice.

Keywords

Soil Moisture, Conservation Practice, Tillage, Maize-legume Cropping System

1. Introduction

Maize and common bean are important crops in Ethiopia and are mostly grown by resource-poor farmers in risky farming systems. Maize is the second most important main staple and common bean is an important dietary protein source for the rural poor smallholder farmers in Ethiopia. The two crops are mutual to each other when used in rotation and intercropping systems under conventional crop production which causes degradation of soil and yield losses, especially in the semiarid regions. The Conventional crop production practice which involved intensive tillage plus re-

[*]Corresponding author: yaya.tesfa@gmail.com (Yaya Tesfa)

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peated cereal sole cropping with residue removal which causes poor soil structure and low yield.

Improved maize and common bean-based cropping systems practices are important to minimize adverse impacts of poor soil structure and climate on crop production in sem arid areas of Ethiopia.

Agricultural production systems which improve soil fertility and yield through conserving soil, water, nutrient and environment, socially and economically visible was suggested for regions with poor soil and erratic rainfall [9]. Conservation Agriculture practice is a collection of cropping elements setting for continuous increased crop yields with low negative outcome on environment-reduces crop production processes that contribute to emission of greenhouse gases, soil degradation and water pollution [7].

According to [11] CA has many advantages over CP which included soil moisture retention which allows earlier planting for longer maturity varieties, soil moisture conservation, reduced soil erosion, reduced runoff, and low labour demand as well as improved crop yields. With conservational agricultural practice various soil properties such as soil organic C, low soil compaction, improved water infiltration, low penetration resistance and reduced bulk density could be improved [27]. Effectiveness of a chosen agricultural management manner can be evaluated by the integration of crop growth, development and crop yields. Latest progresses in digital agricultural advancement have result in evolution of crop canopy optical sensor which is used to compute normalized difference vegetative index values.

Our farmers follow traditional fertilization practices or those which are based upon wide regional recommendations which fail to account for the intra-field variability and temporal variability of the crop nutrient requirement. This problem can be addressed with the help of NDVI which is a precision agriculture tool. Yield production model systems depend on early growth stage parameters are one desired goal to enable precision farming approaches to improve crop production.

Knowing the relationship among moisture, soil nutrient, crop reflectance and farm variably would be useful for further evaluation of optical sensor as a tool for moisture and nutrient monitoring.

However, there are very limited studies help to examine the role of NDVI index to examine effect of crop management on crop growth and development in Ethiopia.

Therefore, objectives this study were:

1) To evaluate performances of different cropping systems under conventional and conservation agriculture.
2) To assess in-season maize and common bean growth under contrasting crop management practices using handheld optical sensor.

2. Materials and Methods

2.1. Description of the Study Site

The study was conducted at Melkassa agricultural research center which is located at about 117 Km in east of capital city of a country Addis Ababa. Melkassa is located at $8^0$24'N and $39^0$21'E with 1550 m elevation. It is categorized under arid to sem-arid agro ecological zone.

Its soil type is Andosols with PH 7 to 8.2. Its minimum and maximum temperature is 14℃ and 28.4℃ (http://www.eiar.gov.et/marc).

2.2. Description of the Experimental Materials

The on-going long-term CA experiment which was established in 2010 was used for this study. The two locally widely used open pollinated Melkassa II maize variety and Nassir common bean variety were planted (Table 1). A Green seeker hand held optical sensor unit was a tool used for collection of normalized difference vegetative index values during different development stages of maize. Moisture meter was used to measure soil moisture with a meter long access tube tool.

2.3. Treatments and Experimental Design

Combination of two types of tillage and four cropping systems were used to develop treatments. The randomized complete block design with split plot design was used. CA and CP were the tillage types and they were randomly assigned to the main plots. Conservational Agriculture had full residue retention from previous harvest and no till, while conventional crop production practice was three times tillage pass with animal drawn local *maresha* with complete residue removal. Cropping systems were maize-common bean intercropping, maize-common bean rotation, maize-monoculture, and common bean monoculture. The treatments were replicated three times.

Table 1. *Combination of treatments for maize-common bean cropping systems at MARC.*

Treatment Number	Main Plot	Sub Plot
1	CA	Sole maize
2	CA	Sole bean
3	CA	Rotation
4	CA	Intercropping
5	CP	Sole maize
6	CP	Sole bean
7	CP	Rotation
8	CP	Intercropping

2.4. Field Management

The CP tillage was using the oxen drawn plow and tilling three times. Though depends on local climate conditions, the first and second tillage were in June and final tillage was during planting of maize crop. Maize was planted on late June, and common bean was planted at mid-July.

The cultivar Melkassa-II for maize and cultivar Nassir for common bean was used.

For maize 0.75 × 0.25 and for common bean 0.40 × 0.10 m, plant spacing was used.

Common bean was planted between each maize rows by maintaining full population of maize and 53% of common bean sole crop plant population, for the intercrop treatments. Pre planting herbicide was used once at two weeks before planting of CA treatments to control weeds and hand weeding is practiced when weed control is needed. For CP plots was controlled using hand hoe.

2.5. Data collected

2.5.1. Plant Data

Days to 50% emergence: Days from planting to when above 50% of the plants in a plot emerged for both maize and common bean crops was recorded.

Days to 50% flowering: Days from planting to when above 50% the plants in a plot produce flower was recorded for common bean.

Days to 50% silking: Days from planting to when above 50% of the plants in a plot produce silk for maize was recorded for maize.

Days to 90% physiological maturity: The number of days from planting to when the 90% of the plants in a plot show maturity for both crops were recorded.

Grain yield: After harvesting seeds from plot area was cleaned, weighed and converted to yield in Kg for both maize and common bean.

Above ground biomass: The above ground biomass was measured after sun drying. This is done for ten plants after randomly selected for both maize and common bean.

Normalized difference vegetative index: This optical sensor readings was taken weekly at three growth stages of plant growth. These stages are vegetative, tasseling and silking for maize. Three rows from each plot were taken by green seeker hand held at a height of approximately 70 cm above the crop canopy.

2.5.2. Soil Data

Soil water: soil moisture meter was used to record moisture conserved in each plot. Soil moisture was taken periodically in each growth stage of the main crop at 0 to 10, 10 to 20, 20 to 30, 30 to 40, and 40 to 50, 50 to 60 and 60 to 100 cm depths from auto moisture reader sensor.

2.5.3. Data Analysis

Data collected from this experiment were analyzed using statistic 10.0 computer software and mean separation was done using Fisher LSD at $p<0.05$ for significant treatment effects. Data was tested for normality using normal probability plot and ANOVA was computed following the general linear model procedure to test for statistical differences among treatments. F test for main plot effects was done using Error a, and for sub plot and its interaction done with Error B.

3. Results and Discussion

3.1. Maize Component

3.1.1. Maize Phenology

Days to 50% maize emergence was significantly affected by tillage types only as shown in table 4. Days to 50% maize silking and physiological maturity were significantly affected by tillage types and combination of tillage types and cropping systems (Table 4).

Table 2. *Soil properties of study sites at Melkassa Agricultural Research Center, Ethiopia.*

Soil properties	Soil depth				
	0-15	15-30	30-45	45-60	60-90
Bulk density (g cm^{-3})	1.19	1.23	1.24	1.25	1.24
Organic C (g kg)	10.6	10.4	10.4	10.4	10.2
Total N (g kg^{-1})	1.2	1.3	1.6	2.0	2.1
pH	7.3	7.5	7.6	7.8	7.9
Olsen P (mg kg^{-1})	17	12	10	7	6
Ca (mg kg^{-1})	3400	3600	3800	4000	4200

Soil properties	Soil depth				
	0-15	15-30	30-45	45-60	60-90
Mg (mg kg^{-1})	436	436	484	557	520
Sand (g kg^{-1})	360	350	330	310	300
Silt (g kg-1)	450	470	490	510	510
Clay (g kg-1)	200	190	190	180	180
Soil texture	Loam	Loam	Sandy Loam	Sandy Loam	Sandy Loam

Table 3. *Weather data of Melkasa during the experimental period.*

Month Rain fall (mm) mean Air T° (℃) Relative humidity (%) Wind speed (m/s) Sun shine Min Max						
July	95.9	13.6	23.3	72	2.18	5.3
August	191.4	14.8	22.9	70	1.74	5.3
September	174.5	13.1	22.6	66	1.47	5.5
October	111.6	11.9	22.9	59	1.00	4.9
November	0.0	4.5	22.9	41	1.20	9.4
Mean (Total)	573.4	11.6	22.9	62	1.52	6.1

Source: Melkasa Weather Station

About 95% of maize plant was emerged successfully in case of selected tillage classification as well as cropping system. Days to 50% emergence was comparatively earlier for CA plots than CP plots. Seedlings of CA plots reached 50% emergence at less than 7 days, but seedlings of CP plots had taken greater than 7 days to be reached 50% of emergence (Table 4). This might be due to pre-emergence favorable germination conditions especially soil moisture. It is in line with the findings of Quinones [21] that up on germination process is started, emergence might occur a day less than a week, if moisture is available.

Table 4. *Effects of tillage, and tillage * cropping system interaction effects on maize phenological parameters.*

Tillage	DE	DS	DPM
CP	8.22a	71.00b	90.56b
CA	6.55b	72.89a	112.33a
SEM (±)	0.14	0.0786	0.0786
CV (%)	8.53	10.33	7.2
T x C	DE	DS	DPM

Tillage	DE	DS	DPM
CA_MBI	6.67	73.00 b	116.00b
CA_MBR	6.33	74.00a	120.00a
CA_MMC	6.67	71.67c	101.00c
CP_MBI	8.00	71.00d	90.00e
CP_MBR	8.67	71.00d	91.67d
CP_MMC	8.00	71.00d	90.00e
SEM (±)	0.3043	0.0962	0.1361
CV (%)	7.13	6.13	6.23

The soil of Melkasa is characterized by weak aggregate stability so that inclined to soil crusting and poor in water infiltration which might be solved with moisture management practices such as tie-ridging to reduce run off and soil erosion.

Interaction of tillage types and cropping system had significantly affected 50% silking and 90% of physiological maturity of maize.

Days to silking and maturity were significantly (P<0.05) affected by interaction of cropping system and tillage types. For CA, prolonged moisture due to residual moisture and the potentially transpirable water was still available in the soil after crops matured. As a result, days to silking and maturity were longer. But for CP, occurrences of terminal drought forced to enhance silking and maturity of maize.

Mean separation showed that CP with MBI, CP with MBR and CP with MMC required relatively shorter number of days to reach at silking stage while CA with MBI, CA with MBR and CA with MMC required longer number of days (Table 4). Generally, it required 71 days to 74 days to reach 50% of silking among treatment combination, while the number of days required to reach 90% of maize crop physiological maturity was ranged between 90 and 120 days (Table 4).

Those plots that showed early silking were also found to be early in maturity while those showed late silking were also late in maturity. In general, CP_MMC and CP_MBI was the earliest while CA_MBR and CA_MBI were the latest in terms of days to 50% silking and days to 50% physiological maturity. This might be because of terminal moisture availability in CA plots. The present results on phenology are in agreement with previous reports on the crop [4].

Amare [4] and Nigussie [19] also reported that differences in climatic conditions of a given location influences plant phenology especially days to 50% tasseling and days to 90% physiological maturity for maize-common bean intercropping system.

3.1.2. Maize Grain Yield

Maize grain yield was significantly affected (P<0.05) by tillage types effect and interaction of cropping systems. CA_MBI had significantly higher grain yield of 6070 Kg/ha than maize yields under the other treatments. This might be due to good moisture content in CA and improved soil fertility of bean intercropping. [4] stated that efficient use of natural resources such as light, moisture and nutrients is a cause of increased productivity by the intercropping system.

Current experiment also examined that maize bean rotation under CA plot had also relatively higher grain yield than maize bean rotation under CP plot. This might be due to nutrient availably from previous year of common bean. [31] stated that higher maize yield was obtained from maize soybean rotation than maize monoculture because of availability to maize of N fixed previously by soybean.

3.1.3. Above Ground Biomass Yield

Above ground biomass was significantly affected (P<0.05) by main effect of tillage types and, interaction effects of tillage types with cropping system. Higher above ground biomass was obtained from maize bean intercropping under CA and maize bean rotation under CA than other treatment combination. This might be due to improved soil properties of CA by crop residue retention and zero tillage practices.

It is stated that CA has great role in producing higher yield than CP because its improved soil organic C by crop residue retention, reduced soil compaction and low soil bulk density in the CA [12].

***Table 5**. The main effects of tillage and interaction of tillage and cropping system on maize yield and related parameters.*

TX C	BM (kg/ha)	GY (kg/ha)	HI (%)
CA_MBI	14207a	6070.0a	0.4267a
CA_MBR	13902ab	5271.3b	0.3800b
CA_MMC	13287c	4383.3cd	0.3300c
CP_MBI	11773d	3831.7d	0.3233c
CP_MBR	13460bc	4474.3c	0.3300c
CP_MMC	12093d	3897.7cd	0.3233c
SEM (±)	172.24	179.98	0.0100
CV (%)	2.27	6.70	4.940

Tillage	BM (kg/ha)	GY (kg/ha)	HI (%)
CP	12442b	4067.9b	0.3256b
CA	13798a	5241.6a	0.3789a
SEM+	98.099	63.961	0.13
CV%	2.24	4.12	3.07

3.2. Common Bean Component

Common bean phenology

Days to 50% flowering and days to 50% maturity were not significantly affected by tillage, cropping system and interaction. However, flowering date and physiological maturity date were slightly earlier for sole bean under both tillage types than intercropped bean under CA and CP.

3.3. Normalized Differentiated Vegetative Index (NDVI)

Optical sensor has been proven to be an effective tool for monitoring cropping practices.

normalized differentiated vegetative index of maize at vegetative stage was significantly affected by tillage types and tillage x cropping system interaction (Table 6). Thus, normalized difference vegetative index was significantly affected by maize-bean intercropping and maize rotation under conventional practice. Normalized difference vegetative index of maize at tasseling stage was also significantly affected by tillage types, by tillage x cropping system interaction. normalized difference vegetative index was significantly affected by maize-bean rotation and maize bean intercropping under conventional practice. normalized difference vegetative index of maize at grain filling stage was significantly affected by tillage types but not significantly affected by cropping system and interaction.

The maize crop growth performance measured over three growing period is presented in Table 6 in terms of Normalized difference vegetative index. NDVI was affected by main effects of tillage, and the interaction of tillage * cropping system. The NDVI was greater with CP for the earlier periods and less with CP at all measurement periods and lower with CA at earlier periods and become greater with CA during grain filling stage relatively. NDVI was high with the rotation under CA and intercrop under CP but low with maize monoculture under CP during the vegetative stage.

In general cases NDVI has an increasing trend with crop growing period but finally declined because of pollen dropped at maize silking stage. By considering terminal soil moisture and other crop production limiting factor it is estimated that treatment with high NDVI has better in yield and yield components. In case of this study CA has better to overcome terminal drought with highest NDVI values at grain filling stages. Continued crop residue retention in the field may eventually may improve CA crop performance by controlling runoff, stimulating microfauna activity.

Table 6. *The effects of tillage, cropping system, and interaction of tillage and cropping system on NDVI at different maize growth stages.*

Tillage	Vegetative	Tasselling	Grain filling
CP	64.667a	82.000a	70.667b
CA	60.333b	80.889b	75.222a
SEM+	0.27	0.0786	2.0382
CV%	27.31	8.38	13.29

T X CS	Vegetative	Tasselling	Grain Filling
CA_MBI	70.333ab	81.667b	78.000
CA_MBR	61.000b	77.667d	74.333
CA_MMC	59.667c	83.333ab	73.333
CP_MBI	73.333a	80.000c	67.000
CP_MBR	49.333d	81.333b	73.000
CP_MMC	61.333b	84.667a	72.000
SEM	7.6703	1.5870	4.2936
CV	21.2	3.37	10.20

As NDVI is one of the apparatuses involved in measurement of crop growth and performance by indicating crops photosynthetic performance. Focuses should be line up with Crop management which improve photosynthetic capacity of crop, as [3] indicated that research efforts aimed at improving crop production through improved photosynthetic performance should have a major focus on the efficiency of operation under non saturating light conditions.

The greater NDVI with maize–bean intercrop under CP during maize vegetative stage could be because of faster growth of maize due to less immobilization by the previous season soybean compared with maize residue and due to residue removal with CP. Decomposition of high C/N ratio crop residue has the potential to immobilize N with a delayed net N release [11]. More over the leaf canopy of intercropped soybean undoubtedly contributed to NDVI during this early growth period.

The increased NDVI with maize dry bean intercropping and maize dry bean rotation under CP during maize flowering to grain fill stage in 2015 at Melkassa reflects faster early growth of maize foliar biomass under CP. This may have been associated with less N immobilization with dry bean compared with maize residue and with residue removal under CP [14].

However, the greater NDVI with maize dry bean intercropping and maize dry bean rotation under CA during the maize grain fill to dough stage were related to the measured soil water.

Verhulst, N. et al., reported similar results and suggested differences in inorganic N availability as a reason [27]. This may imply that relatively more N should be applied early for CA compared with CP as excess early N availability with CP increases potential for N leaching loss. Improved stored water availability with CA compared with CP could also account for the greater late NDVI in CA.

For many crops more than half of the economic yield derives from photosynthesis after flowering. Therefore, photosynthesis at the reproductive stage is more directly related to yield size. The positive correlation between leaf photosynthesis and yield is observed mostly at this stage. It is not expected to get the correlation at all stages of crop development. It is estimated that NDVI is linearly correlated with the canopy of the crop. Once the canopy began to close at vegetative stage leaves from larger plants covered leaves and whorl of smaller plants, extending further in to the linear row. As the leaves began to fill the row intersecting with and in some cases covering up leaves from small plants; soil coverage becomes decreased and the amount of green vegetation visible increased, increasing NDVI. Low NDVI values are the result of sensing bare soil associated with uneven plant stands and some missing plants, and these low populations were no longer obvious by vegetative stages. Early vegetative stage could be estimated as the best time to apply in season foliar N fertilizer. At this time spatial variability of NDVI values may become highest.

It is indicated that the spatial variability encountered at vegetative stage of maize growth could be correlated with final estimates of grain yield potential and a response to applied N could be achieved. [29] demonstrated that accurate mid-season of yield potential were indeed possible using NDVI readings collected at vegetative stages.

From the tasseling growth stages the variability in plant spacing or growth was masked due to overlapping leaves and canopy closure. After tasseling and with more rapid senescence sloughing off led again to recognize the same variability encountered early in the season. For many crops more than half of the economic yield derives from photosynthesis after flowering. So, photosynthesis at the reproductive stage is more directly related to yield. Thus, positive correlation between leaf photosynthesis and yield is mostly observed at this stage.

3.4. Soil Moisture Content

Soil moisture at depth of 100 mm was significantly (P< 0.05) affected by interaction of tillage types of tillage types and cropping systems, but not significantly affected by the main effects of tillage types.

Maize bean rotation and maize bean intercropping had significantly (P<0.05) higher moisture content of 12.55 and 10.24% respectively than maize monoculture for 0-100 mm.

The interaction of tillage x cropping system (P<0.05) had significantly affected soil moisture content at the depth of 100 mm. CA_MBR had significantly affected soil moisture at 100 mm soil depth. ANOVA also revealed that interaction of cropping system x tillage (P<0.05) had significant effect on soil moisture content at the depth of 200 mm. CP_MBR and CP_MMC had significantly affected soil moisture at this soil depth. The interaction of cropping system x tillage (P<0.05) had significantly affected soil moisture content at soil depth of 400 mm. CP_MBR and CP_MMC had significantly affected soil moisture of this depth. Cropping system had significant effect (P<0.05) on soil moisture at the depth of 400 mm. Maize bean rotation had significantly (P<0.05) higher moisture content of 10.25% than others. The interaction of cropping system x tillage (P<0.05) had significantly affected on soil moisture content at 400 soil depth. MMC had significantly affected soil moisture at this depth. ANOVA revealed that cropping system has significant effect (0.05) on soil moisture at depth of 600 mm. whereas tillage types and interaction of tillage types x cropping system has no significant effect on soil moisture at 1000 mm soil depth. Maize bean rotation had significantly (P<0.05) higher moisture content at 600-1000 mm than others.

In this study soil moisture was minimal during reproductive period due to critical soil moisture requirements and high uptake of soil water during this stage. At this stage soil moisture content during analysis was lower as compared to other stages. At vegetative stage possible to find in high quantity due to a significant role of soil physical property on soil moisture retention and minimal usage by crops during this stage.

Table 7. *The effect of tillage x cropping system interaction (T x C) on soil water at different soil depth (mm) at Physiological Maturity.*

T x C	0-100	100-200	200-400	400-600	600-1000
CA_MBI	4.10cd	8.00cd	10.5c	12.9d	16.5
CA_MBR	15.75a	17.50a	18.4a	18.0bc	19.5
CA_MMC	10.27b	15.23ab	18.4a	23.9a	15.2
CA SB	8.10bc	6.75d	6.9d	20.5b	11.4
CP_MBI	4.80cd	7.10cd	10.15c	12.17d	15.55
CP_MBR	9.65bc	11.90b	17.9b	14.8cd	17.8
CP_MMC	1.83d	9.80c	7.8cd	15.9c	19.0
CP_SB	5.90c	7.50	12.5	12.7	12.5
SEM (±)	5.978	1.969	3.94	3.43	3.15
CV (%)	52.9	27.2	45.8	45.2	42.9

Soil moisture content in the CP in the first 1000 mm was almost constantly below that of the CA. Maize bean rotation under CA and monoculture under CA had played a significant role on soil moisture content. The higher moisture content in soil measured from CA plot may have been attributed to the soil organic content in the soil, which was able to hold moisture as compared to CP. On average higher soil moisture content was recorded from CA treatments than CP plots. Higher available moisture especially at reproductive crop growth stage reduce the risk of crop failure and resulting higher crop yields. The higher soil moisture from CA plot also implied that soil conservation practice was also critical factor on soil moisture content. It is in line with the findings of [13] a significant interaction between tillage and cropping system on soil moisture content. [5] stated that soil rich in clay content caused an increase in water holding capacity and decrease in evaporation. Higher infiltration rates and soil moisture contents are due to the absence of tillage and surface retention [11].

Plot with soil water retention ability could be used as indicator of soil physical quality [2]. This reflects plots with poor soil structure will not be able to hold enough moisture to maintain good plant growth and this resulted with poor plant growth due to reduced absorption of plant nutrients.

For treatment of MMC under CP soil moisture content were lower than the other treatments towards the end of cropping season. The lower soil moisture content may be due to more surface soil disturbance because of more frequent and intensive hand weed weeding. It is justified that erosion and runoff on the CA plots were considerably lower than on conventionally ploughed plots.

Use of herbicides would help to overcome the problem of surface soil disturbance and reduce the amount of soil erosion [26]. [1] stated that soil moisture content in the soil was reduced dramatically in the sole crop of maize due to high evaporation potential.

4. Summary and Conclusion

Agricultural production systems which improve soil fertility and yield through conserving soil, water, nutrient and environment, socially and economically visible was suggested for regions with poor soil and erratic rainfall.

Farming system in the next generation will have to produce more food from less land by making more efficient use of natural resources and with less impact on the environment. Only by this tactic will food production keep pace with demand and the productivity of land be preserved for the future generations. This must be a tall order for agricultural scientists, extension personnel and farmers. Use of productive but more sustainable management practices described in this study can help resolve this challenge. Crop and soil management systems that help to improve soil health parameters and reduce costs are very crucial.

In this study, CA played a vital role in terms of maize growth and yield. Rotational and intercropping under CA were very advantageous as compared to monocropping under CP.

Maize-common bean rotation under CA improved soil moisture content and maize plant growth as compared to intercropping and monocropping systems. Common bean grain yield, biomass yield and harvest index were significantly affected by cropping system, in which grain and biomass yield was significantly affected by sole bean and harvest index was significantly affected by intercropping. Maize yield and yield components were higher under CA maize rotational system. Based on this, it is then recommended that maize-common bean rotation under CA is suitable for high maize production better crop growth and improved soil moisture.

NDVI which is used as measurement of crop growth and performance is significantly affected by tillage type, cropping system and interaction of tillage and cropping system. CP was significantly higher at vegetative and tasseling stage, whereas CA was highest significantly at grain filling stage.

Farmers should therefore, practice soil moisture conservation practices together with intercropping maize and haricot bean to sustainably increase productivity and optimize use of resources.

Abbreviations

CA	Conservation Agriculture
CP	Conventional Practice
NDVI	Normalized Difference Vegetative Index
MMC	Maize Monoculture
MBI	Maize Bean Intercropping
MBR	Maize Bean Rotation
SB	Sole Bean

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Conflicts of Interest

The authors declare no conflicts of interest.

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