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Assessing Soil Bund and Haricot Bean-Maize Intercropping Effects on Productivity of Maize at Arjo, Eastern Wollege Zone, Oromia, Ethiopia

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Abstract
Soil fertility depletion is a major challenge to agricultural productivity and natural resources integrity in the highlands of Ethiopia. Improving crop management practices are believed to mitigate the effect and increase crop productivity. An on-farm study was conducted during the cropping season of 2017 in Arjo District, Eastern Wollega of Oromia Regional State with the objective of evaluating soil bund and maize (Zea Mays L.)-Haricot bean (Phaseolus Vulgaris) intercropping effects on maize productivity and soil moisture availability. The study involved a split plot design where soil bund (with and without) and intercropping (sole-maize and maize- haricot bean intercropping) were the main and sub plot factors, respectively replicated on 15 farmers' fields. Soil moisture content during the growing season and agronomic parameters (Days to maturity, hundred seeds weight, biomass, and grain yield of maize) were determined. Analysis of Variance (ANOVA) was carried out to test the main and interaction effect of the treatments. Results showed that soil bund increased soil moisture availability during the entire growing period, which may be related to the likely reduction in surface runoff and increase infiltration. Consequently, the maize yield and most of the yield components were significantly increased due to soil bund. On average, soil bund increased maize grain yield from 5998 $kgha^{-1}$ to 6668 $kgha^{-1}$with a corresponding increase in biomass from 13973 $kgha^{-1}$ to18056 $kgha^{-1}$. Also, significantly higher maize grain (6783 $kgha^{-1}$) and biomass (18256 $kgha^{-1}$) yield were obtained due to intercropping of maize with haricot bean than sole maize, which resulted in 14831 $kgha^{-1}$ biomass and 5882 $kgha^{-1}$ grain yield. Because of the higher soil moisture during the grain filling period with soil bund, which extended days to maturity has led to the increased hundred seeds weight, biomass, and grain yield. Therefore, the use of soil bund and intercropping of maize with haricot bean have a potential for increasing crop productivity. However, as this is based on a single year data, further investigation is needed to establish undisputed evidence base to recommend the practices as a strategy to reverse land degradation, increase productivity and build resilience and increase adaptation to shocks such as climate change.
Keywords: Haricot-Bean, Intercropping, Maize, Maize Productivity, soil moisture content

1. INTRODUCTION

Land degradation is a serious global problem. Loss and degradation of this natural resource is widespread, particularly in developing countries like Ethiopia. Of the world's 8.7 billion ha of agricultural land, pasture, forest and wood land, nearly 2 billion ha (22.5%) have been degraded since 1950, and 5-10 million ha (0.36–0.71 %) of global arable land) are lost every year due to severe degradation (20). If such trend continues; 2.8 percent of the total agricultural, pasture and forest land will be lost by the year 2020 (10). The immediate consequence of land degradation is reducing crop yields, which leads to economic decline and increasing social stress (33; 19).

Soil erosion affects an estimated 1,100 million hectares of land worldwide and transport of soil to the oceans each year. Similarly, soil erosion is one of the principal environmental problems in Ethiopia resulting in reduction of productivity of arable lands. About 1.5 billion tons of soil is lost from Ethiopia and Eritrea alone per year (19) and 2 million hectares of land in Ethiopia has been severely degraded. An annual yield reduction of 1-2 percent is estimated due to soil erosion in Ethiopia (19). Erosion removes the most productive portion of the soil, that is, the chemically active part such as organic matter and clay fractions. It also causes a deterioration of soil structure, moisture holding capacity through lowering soil depth, increasing bulk density, soil crusting, and reducing water infiltration.

Soil fertility decline due to soil erosion and crop uptake is among the manifestation of land degradation prevalent in Sub- Saharan Africa (SSA). Soil erosion, which affects about 30 % of the cropland, leads to a grain loss of about 7,000 tons per year in Ethiopia (5). Soil erosion is a serious problem in Western Ethiopia, due to intense rain storms, steep slopes, and low infiltration capacity of the soil and high volumes of runoff. It has also been indicated that nowhere is the severe effect of poverty and environmental degradation more evident than in Ethiopia (12). Consequently, maintenance of soil fertility and organic matter content has become a major issue for agricultural research and development in Sub-Saharan Africa (7).

To reverse the current trend of soil fertility decline, there is an urgent need for adopting economically viable soil conservation measures. Crop water productivity modeling approach, that maize grain yield can increase from 2.5 Mg ha^{-1} to 6.4 and 9.2 $Mgha^{-1}$ under poor, near optimal and non-limiting soil fertility conditions, respectively (9). The crop yield from rain fed agriculture in sub-Saharan Africa remains low, although the potential is high especially in areas receiving ample rainfall (9).

Soil bund is among the commonly used measures to overcome soil erosion and nutrient depletion (19). Soil bunds are ridges and ditches made of soil, dug across the slope along the contour and they are used to prevent run-off, conserve soil and water, applied to maximize infiltration, drain excess water from rainstorms and to retain moisture in the soil, allowing chemical fertilizers to be used effectively (34).

Maize is the main staple food in world diet (3). Between 15 and 18 million persons may depend on the production of corn for their livelihood. World production of corn averages 450 million metric tons a quarter of global grain production (13). The use of maize in Ethiopia has doubled between 2003 and 2012 and the yield was 3.23 tons per hectare and is produced two million hectares of land which is the largest of crop harvest in Ethiopia (Ethiopian Herald, November 27, 2014).

Farmers in Africa traditionally practice intercropping to achieve greater land productivity and as insurance in case one fail (35). Intercropping is a type of mixed cropping and defined as the agricultural practice of cultivating two or more crops in the same space at the same time. In Ethiopia, farmers intercrop maize and sorghum with sesame, haricot-bean, sweet potato, mustards and other cereals depending mainly on the region (16).

In addition to fixing atmospheric nitrogen, leguminous plants play a significant role in conserving NO_3 (8; 36). It is well recognized that legume can add organic N and their residues contribute to the improvement of soil structure and microbial activity. Food production practices through an integrated approach of cultivating intercropping practices for sweet corn, maize with legumes (haricot bean) and organic farming to minimize the dependence on mineral fertilizers (14).

Inclusion of grain legumes or green manure legume crops in rotation with corn can protect degradation of soil fertility, improve soil structure, water holding capacity and result in greater productivity and higher income, while minimizing production risk and ensuring long-term sustainability, as well as ensure a greener environment(26). Indeed, legumes have been proven to be commendable in terms of their positive effects to improve soil health for productivity of crops (14).

The availability of water is one of the most important factors determining productivity in cereal legume intercropping systems in Arjo areas. The amount of rainfall received in a particular area is only an indication of the potential of such an area to support crop production (9). The effects of landscape position, crop type and variety, and agronomic management practices, such as method of planting, tillage frequency and use of compost, on land and water productivity of the crop-livestock system in the Blue Nile basin are important factors determining crop productivity.

Soil erosion in Arjo District is a serious problem due to intense rain storm, continues cultivation of crops, over grazing, steep slopes, poor soil infiltration capacity and high volumes of runoff. High volumes of runoff, washes the upper top soil as a result of which fertility of top soil is declining (personal communication with District DA). This leads to low crop productivity and food insecurity in the area. Although there is an ongoing attempt by the agricultural extension system to introduce soil and water conservation measures, soil bund being the dominant practice implemented and there is dearth of information on the effects of soil bund and inter cropping on crop productivity in the area.

Therefore, the goal of this study is to investigate the effects of soil bund and legume (haricot bean) intercropping and their interaction effects on productivity of maize and soil moisture availability at Didessa Kebele, in the lowland areas of Arjo District in Western Ethiopia.

2. MATERIALS AND METHODS

2.1. Description of the study site

The study was conducted in Didessa Kebele, close to Didessa River and around Arjo Didessa Sugar Factory in South-western part of the Abbay River. Geographically located between $09^0$10'N and $09^0$0'N latitude and $36^0$10'E and $36^0$30'E, longitude, about 370 km from Addis Ababa and 48km from Nekemte town to the West in the Arjo Districts of Eastern Wollega Zone of Oromia Regional States. The area shares boundaries with Bunno Bedele Zone in the West, Getema District in the East, Chewaka District in the North and Leka Dulecha in the South (23).

Didessa Kebele is one of the 18 Kebeles in Arjo District. The study areas was selected by researchers purposively based on the vulnerabilities of the land degradation due to soil erosion, gradient of farming types and varying socioeconomic conditions (10). The dominant soil color of the area is red in the middle altitude, and black in the low land and generally classified as Acrisols and Alisols, with some occurrence of Vertisols and Nitosols (10).

The area receives bimodal rainfall pattern with short rainy season from March to April and main rainy season from June to September. The mean annual rainfall ranges between 1376 and 2007mm (DOA, 2010, unpublished report). The study area has an average rain fall and temperature of 1900mm and 31^0c respectively. The study area covering a total of 139,389 ha has variable agro ecology. The major crop is maize followed by sorghum, sesame and finger millet in mid and low altitude agro-ecologies while teff, finger millet, and niger seed are major crops in representative highland agro-ecology (WOA, 2016, unpublished report).

2.2. Socio-economic features and farming system

Farmers, commonly practice crop rotation cultivation in the area. Mango trees (*Mangiferaindica L*) and Eucalyptus (*Eucalyptuscamaldulensis*) is common especially at lower land agro-ecology as cash crop. Honey bee production for food and market is common in the forest found at eastern part of the watershed. Timber production for home construction and market are common (23).

High population pressure exists in the mid altitude where human beings were settled first and in low land areas, the distribution of population was low and scattered. According to Agriculture Bureau, Arjo District has a total population of about 33,695over 90 % of which are dependent on agriculture for livelihood (6; 23).

Cultivation in steep slopes which aggravates soil erosion and plant nutrient depletion decreased soil fertility caused by soil erosion and crop uptake are major limiting factors for crop production and crop productivity in the area (38). In response to productivity decline, farmers open a new agricultural land which increases deforestation. Maize, sesame and finger millet are the dominant crops (23). Crop production and animal husbandry are the two agricultural practices in the Districts (Arjo Didessa Agricultural Office, 2016). The main crops grown in the study area are; Teff (*Eragrostistef*) Finger millet, Noug(*Guizotiaabyssinica*), Faba bean (*Viciafaba*) and Barely(*Hordeumvulgare*) in the middle altitude and Maize, Sorghum, Seasam (*Sesamumindicum L*) and Haricot bean are grown in the low land areas (38).

2.3. Treatments and Experimental Design

From the total of 18 Kebeles of the District, Didessa Kebele was selected for the study. For experimental work 30 farmers' plots a quarter of a hectare each, were randomly selected and the experimental protocol was as follows:

I. Fifteen farm plots were with soil bund, and each plot was sub divided into two equal parts, one for sole maize and another one for maize inter cropped with haricot bean.
II. Fifteen farm plots were without soil bund and each plot was sub divided into two equal parts: one for sole maize and another one for maize inter cropped with haricot bean

Four treatments including:

(1) pure stand maize on a plot without soil bund (T1)
(2) pure stand maize on a plot with soil bund (T2)
(3) maize intercropped with haricot bean on a plot with soil bund (T3)
(4) Maize intercropped with haricot bean on a plot without soil bund (T4)

The treatments were arranged in a split plot design where soil conservation practice (soil bund) was the main plot and cropping system (intercropping) was the sub-plot factor with 15 replications (Figure 1).

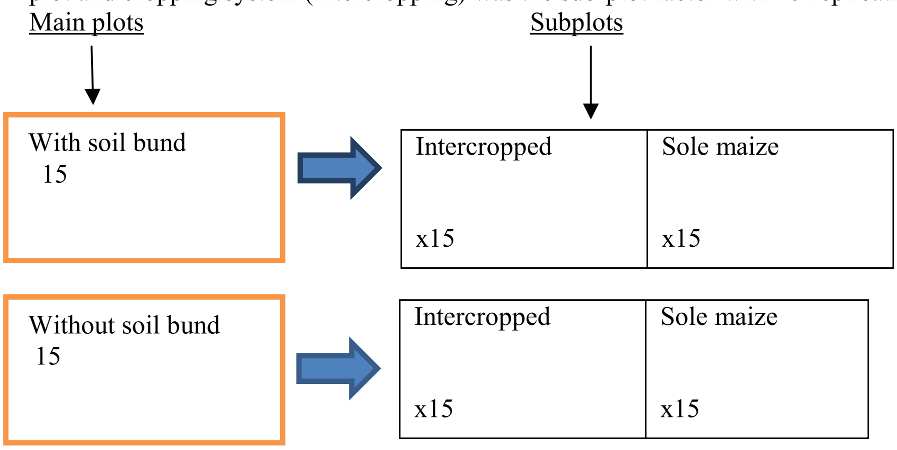

Figure 1: Experimental design

2.4. Land preparation and agronomic practices

The experimental plots were prepared by farmers following their traditional practices such as two to three times tillage. Those having soil bund already constructed on their land did maintenance and repair supported by the Technical Staff from the District Office of Agriculture, while those who were selected for the treatments involving soil bund, but did not have soil bunds on their land constructed new ones following the guidelines provided by the Office of Agriculture. Maize Hybrid (*BH543*), which is adapted to the agro-ecology of the area (22), was planted at 75 cm x 60 cm spacing while Haricot bean (*Nasir*) was planted at 37.5 cm x 30 cm spacing. Intercropped maize was 75 cm from maize to maize and 37.5 cm from maize to haricot bean rows in arrangement. Two seeds planted per hill for both maize and haricot bean, but haricot bean was planted at 36-40 day's interval after maize planting.

Nitrogen-phosphorous-sulfur (NPS) fertilizer was applied (100 $kgha^{-1}$) at planting and Nitrogen in the form of UREA was top-dressed (100 $kgha^{-1}$) at about 36-40 days after planting. Weeding was done by hand three times for all plots and harvesting was done after crop maturity and leaf senescence.

2.5. Monitoring soil moisture

Soil sample was taken from all plots at 0-60cm depth every fifteen days throughout the study periods for gravimetric soil moisture content determination. The soil moisture content was determined by drying the soil to constant weight and measuring the soil sample mass after and before drying. The water mass was calculated as the difference between the wet and oven dry samples.

This was done as follows: initially weighing the field samples (10 g) using sensitive balance and drying the field samples at 105^0c for 48hours in the oven and weighing them again. The percentage of water held in the soil was calculated as the weight difference of the field and oven-dried soil divided by weight of soil sample before oven dry, multiplied by 100 (Equ. 1)

$$\% MC = \frac{Weight\ of\ sample\ before\ oven\ dry - Oven\ dried}{Weight\ of\ sample\ before\ oven\ dry} \times 100\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Equ. 1$$

And the soil moisture content changed into (mm/depth), according to the following equation form (http://www.bulk density calculator.com):

$$Soilmoisurecontent\,(mm) = MC \times BD \times Depth,$$

Where, MC= Fraction of soil moisture content, BD=Bulk density (g/cm^3) and mm= millimeter

2.6. Agronomic Data Collection

Agronomic data recorded included planting date, date of weeding, days to 50% flowering, days to maturity, number of cob and number of fertile cobs per plant and number of seeds per cob were recorded taking five plants randomly.

Days to maturity (DM): It was recorded as the number of days after sowing to the formation of a black layer at the point of attachment of the kernel with the cob.

Yield and yield components

Biomass: It was calculated at harvesting stage by measuring the biomass using spring balance from three randomly selected samples using a 2mx2m quadrant at each plot. Then about 5kg from each plot was taken to laboratory after making the average to calculate dry biomass.

Moisture content of the straw: was calculated by taking about 20 g weight and oven drying at 65^oc for 48 hours and oven-dried biomass were recorded again to get %moisture straw.

$$\% SM = \frac{FB - OD}{FB} \times 100\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Equ. 2$$

Where, SM= Straw Moisture, FB =fresh biomass, OD=oven dried biomass

Hundred seeds weight: This was determined by counting seeds randomly from each yield sample used for grain yield. A total of 300 oven dried seeds were counted by hand, weighed using sensitive balance and then divided by three.

Grain yield: Grain yield from 2 m x 2 m per plot was measured using electronic balance and then adjusted to 12.5% moisture and converted to hectare basis after oven drying the samples.

Harvest index: This was calculated from ten-plant sampled at each plot and calculated as (seed weight/total sample weight) x100.

2.7. Data analysis

The data was subjected to analysis of variance (ANOVA) using SAS software (SAS, 2004, version 9.1). Least Significance Difference LSD (5%) was used to separate the means when the analysis of variance indicated the presence of significant difference (Gomez & Gomez, 1984).

3. RESULTS AND DISCUSSION

3.1. Effects of Soil bund and intercropping on yield and yield components of maize

3.1.1. Effects on days to flowering and days to maturity

Soil bund and intercropping have no significant effect on date of flowering (Table 1). This means that using either soil bund or intercropping did not bring difference on flowering variation on maize crop. Unlike days to flowering, early cob and early formation of kernel are indicators for good performance.

Soil bund had highly significant effect ($p<0.001$) on days to physiological maturity (DPM) and harvesting maturity (DHM) (Table 1). Intercropping which was the second treatment factor for this experiment also has significant effect on the date of maturity and it extends the date of crop maturity (Table 1).

Also, there was significant effect on date of maturity and delayed maturity of crops observed as soil bund and maize intercropped with haricot bean interacted (Table 2). The maximum day to reach maturity was 167 days from intercropped plots with soil bunds, while the minimum 160 days was recorded from the sole maize without soil bund. It was due to early senescence physiological activities of plants that grew without soil bund and low moisture contents. Plants in the control treatment matured at the earliest, while plants in the soil bund showed delayed maturity. The same was observed by (3) who reported that maturity day of crop was based on soil moisture availability. These results are corroborated with the observation of (2) who reported that, the maturity days of crops and physiological maturity increase with increases in soil moisture content. As a result, the yield of plots with intercropped and soil bund was higher than the plots with sole maize and without soil bund.

As soil bund conserves water for plant growth, more average number of seeds per cob, which gave high crop yield per hectare and seed quality as indicated in Table 3. This moisture conserving benefits of soil bund was not only increasing the yield by extending maturity, but it also increased soil moisture contents by reducing soil erosion and avoid sediment loss by reducing water runoff. This finding goes well with the studies of (21), who reported that conservation agriculture can reduce runoff and nutrient loss. Thus soil bund and intercropping maximize infiltration, to drain excess water from rainstorms and to retain moisture in the soil as reported by (2).

Table1: Effects of soil bund on days to flowering and maturity on maize crop at Didessa Kebele.

Treatment	Days to flowering	Days to maturity
Conservation measures		
With soil bund	65	167^{a}
Without soil bund	66	160^{b}
LSD (5%)	NS	2.89
CV (%)	4.06	3.42
Cropping system		
Intercropped	65	164
Sole maize	65	162
LSD (5%)	NS	NS
CV (%)	4.06	3.42

Means within the same column or row followed by the same letter are not significantly different.
NS= Not significance difference

3.1.2. Interaction effects of soil bund and intercropping on days to maturity

Interaction effects of soil bund and intercropping effects, on days to maturity of maize crop at Didessa Kebele is presented in Table 2. Soil bund and intercropping have significant effects on crop maturity and seed quality. Increased soil moisture, can increase maize biomass production significantly (23). The results further showed that, the maturity day of maize was delayed under intercropping system when compared to sole cropping system. It is thus concluded that, days to maturity was significantly different with interaction of soil bund with intercropping (Table 2), but there was no significant found on days to flowering. Intercropping reduces raindrops and increases infiltration capacities and moisture contents of soil for crops to mature late and grow longer. Further, intercropping reduces diseases, weeds and crop failure and increases crop productivity. More similar observation has been made by (32), who reported that, intercropping suppressed the growth of weeds and increased production thereby increased income than the sole crop.

Table 2: Interaction effects of soil bund and intercropping effects, on date of flowering and maturity maize crop at Didessa kebele.

	Days to flowering			Days to maturity		
Conservation measures	Intercropped	Sole maize	Mean	Intercropped	Sole maize	Mean
With soil bund	64	65	65	168	165	167[a]
Without soil bund	66	65	66	160	159	160[b]
LSD, (5 %)			NS			2.89
CV (%)			4.06			3.42

Means within the same column or row followed by the same letter are not significantly different at 95% confidence limit.
NS= not significantly.

3.2. Effects of soil bund on agronomic parameters

One of productivity indicators for maize is number of fertile cob per plant, which gives end output yield. Higher average number of fertile cob per plant gives higher yield per plant and per hectare. While this finding confirms that soil bund gives more number of fertile cobs (1.53 cobs/plant) than control plots (1.17 cobs/plant) (Table 3), the same trend was observed for intercropping also. This finding is also in line with the trend observed by (20) who reported that “the grain yield is the magnitude of hundred grain weight, number of grains per cob and biological yield and the potential of a crop yield depends upon its yield contributing factors, such as hundred grain weight of the crop”.

Unlike average number of fertile cob per plants, average number of seeds per cob was not significant for soil bund but it was highly significant for intercropping which was 642 and 586 for intercropping and control plots respectively at 95% confidence interval (Table 3).

The average number of cob per plant was analyzed and the results indicated that, no significant difference was found for both treatments. Average number of cobs per plant was, 2.67 for soil bund and 2.4 for control plots, whereas, 2.6 for intercropping and 2.47 for control plot at LSD (5%), (Table 3).

Table 3: Mean effects of soil bund and intercropping on average number of cob, fertile cob and average number of seed per cob of maize crop collected at Didessa Kebele /2017/2018

Treatment	Number of cobs per plant	Number of fertile cobs per plant	Number of seeds per cob
Conservation measures			
With soil bund	2.67	1.53[a]	613
Without soil bund	2.4	1.17[b]	616
LSD (5%)	NS	0.155	NS
CV (%)	19.96	22.18	10.94
Cropping systems			
Intercropped	2.6	1.53[a]	642[a]
Sole maize	2.47	1.17[b]	586[b]
LSD (5%)	NS	0.155	34.8
CV (%)	19.96	22.18	10.94

Means within the same column or row followed by the same letter are not significantly different at 95% confidence limit. NS= not significantly.

3.3. Interaction effects of soil bund and intercropping on some agronomic parameters

The interaction between soil bund and intercropping is highly significant only for the number of fertile cob per plant. There was no significant interaction on number of cob and average number of seeds per plants between soil bund and intercropping (Table 4).Number of seeds per cob and average number of cob were the only parameter which was not affected by the interaction treatments. The interaction between soil bund and intercropping was highly significant for the number of fertile cob per plant, since grain yield is the magnitude of hundred grain weights, number of grains per cob and biological yield, and the potential of a crop yield depends upon its yield contributing factors, such as hundred grain weight of the crop.

Table 4: Mean interaction effects of soil bund with intercropping on average number of cob, fertile cob and average number of seed per cob of maize crop.

	Number of cobs per plant			Number of fertile cobs per plant			Number of seeds per cob		
Treatment	*Cropping systems*								
Conservation measures	Intercropped	Sole maize	*Mean*	Intercropped	Sole maize	Mean	Intercropped	Sole maze	*Mean*
With soil bund	2.67	2.67	2.67	1.8	1.27	*1.53*[a]	641	584	613
Without soil bund	2.53	2.27	2.4	1.27	1.07	*1.17*[b]	643	589	616
LSD, (5%)			NS			0.16			NS
CV (%)			19.96			22.18			10.9

Means within the same column or row followed by the same letter are not significantly different at 95% confidence limit.
NS= not significantly different.

3.4. Effects of soil bund and intercropping on biomass and grain yield of maize

Both biological and physical land management practices are the two important parameters, one supports the other, and one without the other is not as much effective in improving cropland productivity. However, application of a set practice of biological and physical land management practices on the farmland simultaneously would have improved cropland productivity (Table 5). This is the reason why we constructed soil bund and applied intercropping together to improve maize crop productivity through land intensification.

The soil bund plots gave high biomass (18056kg ha^{-1}) and highly significant ($p<0.0001$) as compared with that of the control plots (13973kgha^{-1}). Also, biomass obtained from intercropping was 17642kg ha^{-1} which is significantly different as compared to plots without intercropping (14745kg ha^{-1}). A similar observation was made by (29) that, the cultivation of nitrogen fixing and non-nitrogen fixing crops would increase productivity than sole cropping system either nitrogen fixing or non-nitrogen fixing crops.

The interaction between soil bund and intercropping was significant for the biomass production (Table 6). This indicates that the magnitude of the difference between soil bund treatments and intercropping depend on intercropping system, and vice-versa. The percentage increase of biomass between treatment and control maize cropping plots was 29.2% and 20 %respectively both for soil bund and intercropping plots (Table 5), and 36.8 % for interaction treatments over control plots (Table 6).The same was true for grain yield which were, 11.2 % and 15.3 % grain yield increased due to soil bund and intercropping treatment over control plots respectively as indicated in Table 5. Also the same was reported that, biomass yield of wheat, maize and teff increased with increased level of treatments (9). The same observation was also reported (18) that, the level of soil bund without any agronomic or biological techniques showed decreased production.

Table 5: Effects of soil bund and intercropping on biomass and grain yield

Treatment	Biomass (kgha^{-1})	Grain yield (kgha^{-1})	Percent's increased due to treatment	
Conservation measures			Biomass	Maize grain yield
With soil bund	18056[a]	6668		
Without soil bund	13973[b]	5998		
LSD (5%)	1682	NS		
CV (%)	20	23	29.2	11.2
Cropping system				
intercropped	17642[a]	6783[a]		
Sole maize	14745[b]	5883[b]		
LSD (5%)	1682	806		
CV (%)	20	23	20	15.3

Means within the same column or row followed by the same letter are not significantly different at 95% confidence limit.
NS= not significantly different.

The highest maize yield (6783 kgha^{-1}) was obtained from intercropping treatments (Table 5). Intercropping maize with haricot bean increased the yield and that was the main reason why maize intercropped with haricot bean to increase the maize yield. The grain yield of maize consistently increased as the total biomass increased. According to (29), intercropping increases yield and crop productivity as well as avoid crop failure, which confirmed the present finding. Also (29) reported that, the mixing up of nitrogen fixing crop and non-fixing crop give great productivity than sole maize cropping. Maize yield obtained from intercropping was higher as compared to sole cropping systems, which were 6783kgha^{-1} and 5883kgha^{-1} respectively. Also (18) reported that, the level soil bund without any agronomic or biological techniques showed decreased production. At the end, for interaction effects of soil bund with intercropping, no significant effect was found on yield. Also, even if it was not significant, the treatments increased the yield by 6.2 percent, as compared to sole maize cropping systems (Table 6).

Table6: Interaction effects of soil bund and intercropping on biomass and grain yield of maize

Main plot* sub plot	Biomass (kgha^{-1})			Grain yield (kgha^{-1})		
Treatment Conservation measures	Intercropped	Sole maize	Mean	Intercropped	Sole maize	Mean
With soil bund	19256	17510	19114^{a}	7178	6157	6668
Without soil bund	15794	12152	13973^{b}	6387	5609	5998
LSD (MP), (5%)			1681			NS
LSD (SP), (5%)			1682			NS
CV (%)			20			20

Means within the same column or row followed by the same letter are not significantly different at 95% confidence limit.

NS= not significantly different, *= interaction treatment

In terms of sustainability, these treatments would have long-term positive and significant impacts on agricultural productivity as compared to the sole application of crop managements without intercropping and without soil bund.

Results showed that, yield components of maize were significantly affected by the application of different integrated soil fertility management practices. Maize grain yield and total biomass were significantly responded to the application of different soil and crop productivity improvement and methods of crop management methods as indicated in Table 5 and 6. This suggests that to intensify land and to increase crop productivity, an interaction treatment of soil bund with intercropping was mandatory for small land holder of households' like Arjo Districts and it can hold true for similar ecological conditions like the study site.

Figure 2: Maize grain harvested from a trial plot

3.5. Effects of soil bund and (haricot bean-maize) intercropping on harvest index and kernel weight of maize

Harvest index

The harvest index which was used to assess crop efficiency and forecast grain yields was recorded as 32.78% for soil bund, and 32.36% for plots without soil bund, whereas, 33.03 % and 32.11 % were recorded for intercropped and sole maize cropping systems(Table 7). For interaction treatments, 32.78 % was obtained for treatments and 32.36 % was for control plots (Table 8). The harvest index was insignificantly different for all the treatments; both soil bund and intercropping. It was also true on interaction effects of soil bund and intercropping systems. The harvest index for both treatments and control plots was between 30% and 50% (Table 7 and 8). With similar fashion (27) indicated that, the average harvest index was ranging between 30 and 50%.

Kernel weight

Soil bund and intercropping had significant effects on kernel weight of maize, as indicated in Table 7. It was significantly different for soil bund effects on hundred seed weight which were 36 g and 33 g, respectively for soil bund and plots without soil bund (Table7). While considering subplot treatments, it was highly significant ($p<0.0002$), for intercropping effects on hundred seed weight which were, 36 g and 32 g, respectively for intercropping and sole cropping systems (Table 7).

The interaction effects of the two factors did influence kernel weight of maize. When the soil bund interacted with intercropped, the hundred seed weight was affected as compared with control plots which were 36 g and 33g respectively, which indicated that hundred seed weight, was significantly different as indicated in Table10. Also (23), repeated an increased kernel weight with increasing moisture level and formation of more leaf area which might have intercepted more light and produced more carbohydrates in the source which was probably 35 % trans-located into the sink (the grain) and resulted in more increased kernel weight than the control.

Also soil bund contributed enhanced growth period that increased seed quality and a legume and also contributed in its nitrogen content and covers the grounds to reduce runoff, which hinders rain drop impacts. Thus increased kernel weights imply the contribution of many implications in this component, which means that, it was the output of interaction effects of soil bund and legume (haricot bean). Thus, soil bund contributed soil moisture content whereas haricot bean contributed to reduce runoff and reduced weed competition and crop failure. “The grain yield is the magnitude of hundred grain weight, number of grains per cob and biological yield and the potential of a crop yield depends upon its yield contributing factors, such as hundred grain weight of the crop” (20).

Table7: Mean Effects of soil bund and intercrop on hundred Seed weight and harvest index

Treatment	Hundred seed weight (g)	Harvest index (%)
Conservation measures		
With soil bund	36^{a}	33
Without soil bund	33^{b}	32
LSD (5%)	2.13	NS
CV (%)	12	14
Cropping system		
Intercropped	36^{a}	33
Sole maize	32^{b}	32
LSD (5%)	2.13	NS
CV (%)	12	14

Means within the same column or row followed with the same letter are not significantly different.
NS= not significantly

Table8: Mean of interaction effects of soil bund and intercropping on average hundred seed weights and harvest index

Main plot*Sub plot	Hundred seed weight (g)			Harvest index (%)		
Treatment						
Conservation measures	Intercropped	Sole maize	Mean	Intercropped	Sole maize	Mean
With soil bund	38	33	36^{a}	34	31	33
Without soil bund	35	31	33^{b}	32	33	32
LSD (MP), (5%)			2.13			NS
CV (%)			12			14

Means within the same column or row followed by the same letter are not significantly different at 95% confidence limit.
NS=not significantly different, *= interaction treatment

3.6. Time of intercropping effects on haricot bean yield

Haricot bean had showed good vegetative growth but mostly failed to bear seed due to shade effect of maize. This shows that, it was not suitable time for intercropping. As local people suggested, planting haricot bean simultaneously with maize gave better yield. And also, simultaneously planting maize and haricot bean doesn't influence maize grain yield. Late planting of haricot Bean negatively affects yield from haricot bean. Also ((24); (28)) reported that, simultaneous planting of maize and sweet potato have not influenced maize grain yield, whereas late planting of sweet potato negatively affects maize yield.

3.7. Effects of soil bund on soil moisture

The moisture content of the soil of the study area is presented in Figure 6-8. The results showed that the moisture content of the soil varied between the farmland with soil bund and without soil bund. The sum of soil moisture content for both treatments was 74 mm and 59 mm, respectively at 0-60 cm depth of soil sampled. At the end of the rainy season also, there was enough soil moisture for crop growth, which was 27 mm and 16 mm, respectively. The maximum soil moisture content recorded for soil bund were 43 mm and 31 mm for both the depths, while 41 mm and 24 mm were maximum soil moisture recorded for the control plots. Highest soil moisture was recorded during August and September months during the main rainy season. Also soil moisture content not only varied between treatments, but also based on the landscape as reported by (11), the location, the landscape positions, methods of planting, are among the factors that significantly affected the physical water productivity.

30-60 cm depth was considered necessary to take soil sample when rain fall had ended in the rainy season. Soil moisture content all in all was found above the water field capacity for the depth of 30-60 cm sampled from the soil bund plots, whereas, for the control plots even for 30-60 cm depth, soil moisture availability was mostly found below the field capacity (Figure 3 and 4).

The reason for higher moisture content of soil from soil bund farmland might be due to the fact that, the soil bund reduces the runoff water and allowing more time for water to infiltrate, and the bund minimizing the soil erosion and conserving the soil moisture on site. The higher moisture content under soil bund management was therefore, the result of reduced water velocity and enhanced infiltration rate during rains and enriches underground water potential.

In addition, intercropping reduces water runoff, and as crops covering land, it reduces rain drop impacts on soil nutrient depletion, and thereby increasing the crop productivity. The residues and the root system of legume interact with soil bund, thereby preventing soil erosion and increasing the infiltration capacity of the soil and maintaining the soil moisture content as reported by (29).

As rain fall is uncertain at all times, water conservation and cop managements practices are the best options to increase agricultural production and productivity, and this is in accordance with the reports of (31) who reported that as developing countries like Ethiopia depends on rain fed agriculture, there is an imperative need to increase soil moisture content which will increase crop production and productivity. Also (4) reported that, rain making is impossible, but ensuring water availability to crops is possible through water conservation practices.

Soil moisture content in soil has many advantages. Soil moisture increases maturity days of maize. Increased days of maturity can influence effective filling of grains per cob to have large sized seeds resulting in increased yield. As the same reported by (25) that, total dry matter yield increased significantly with increasing soil moisture availability.

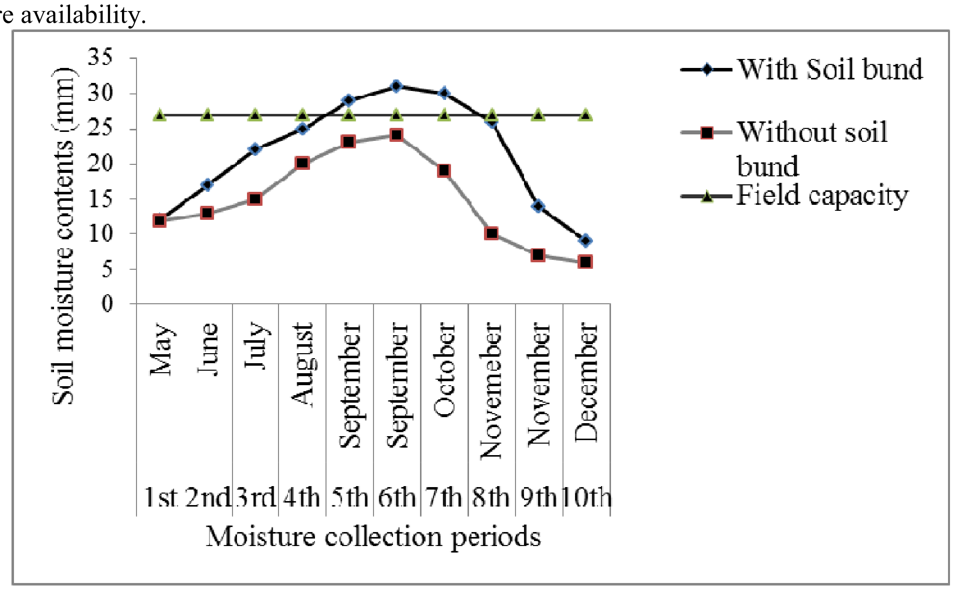

Figure 3: Soil moisture content at 0-30 cm as affected by the use of soil bund during the growing periods of maize.

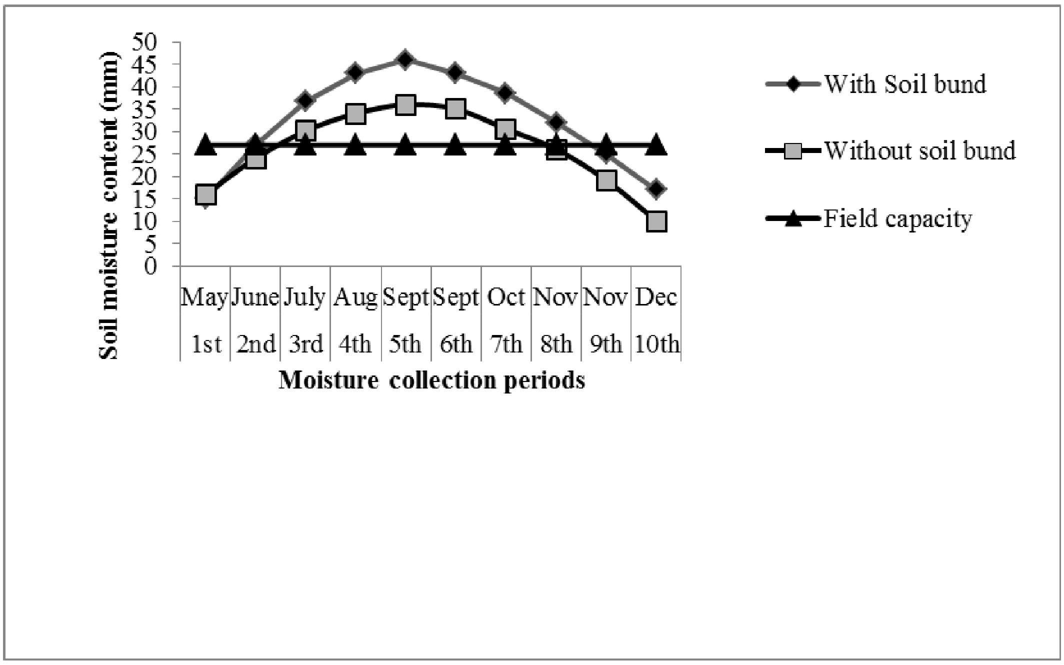

Figure4: Soil moisture content at 30-60 cm as affected by the use of soil bund during the growing periods of maize

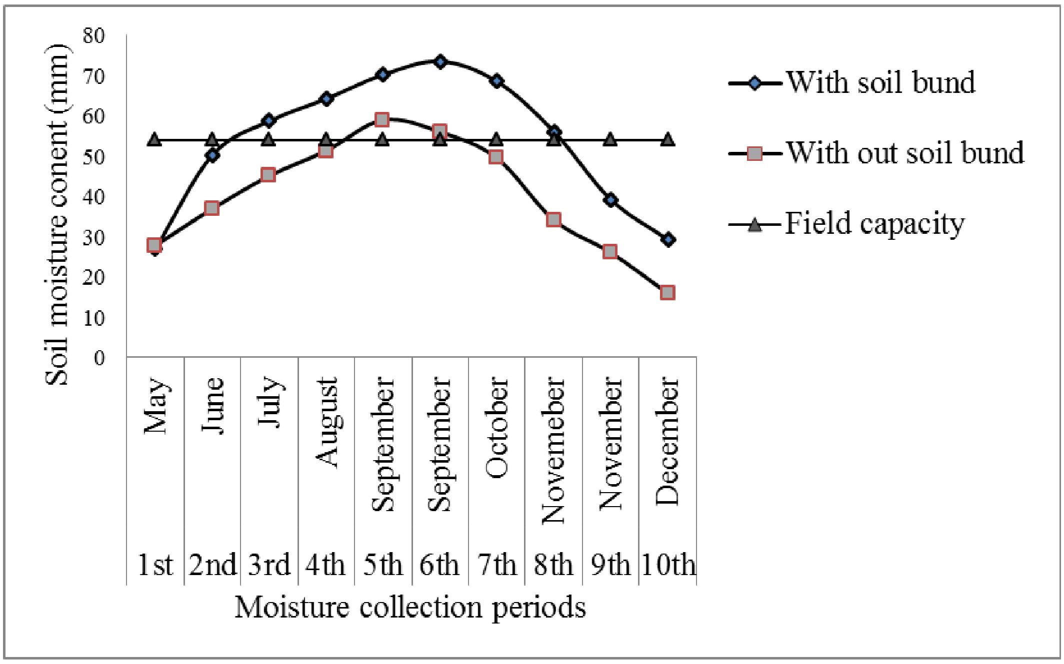

Figure 5: The sum of soil moisture content at 0-60 cm as affected by the use of soil bund during the growing periods of maize.

3.8. Using some biological measures to increase effectiveness of soil bund

Marga Dashoo or Dasho Grass (*Pennisetum pedicellatum*) which was planted on the side of bund to reduce soil erosion and runoff, have reduced sediment loss by increasing infiltration and nutrient trapping. Dasho Grass, which was planted on this water conservation structures, had improved the soil physical structures. As reported by (15), who observed that introduction of soil and water conservation structures in the farm land can increase yield and improve soil fertility using improved grass with soil and water conservation structures. Some of the farmers are using Dasho Grass for animal fattening and they also sold it for income generation. It can grow throughout the year if farmers can adopt proper management strategies to protect the grass from cattle reach out. Also planting this improved grass around the lower parts of soil bund can increase the effectiveness of soil bund against soil erosion and makes soil bund to resist heavy rains, as reported by (1). Not only moisture conserving benefits, but also Dasho Grass can trap nutrients and reduce sediment loss and increases effectiveness of soil bund if used together with soil bund rather than using soil bund or Dasho Grass only (Takele Ulfina, DA of Districts).

Figure 7: Dasho Grass (*Pennisetumpedicellatum*) planted on soil bund and effectiveness of soil bund with perennial grasses.

4. CONCLUSIONS

Soil bund and haricot bean-maize intercropping significantly influenced productivity of maize. The increased yield of maize under soil bund was due to conservation of soil and water as it delayed the maturity, provided longer time for photosynthesis especially during grain filling stage.

Soil bund influences agronomic parameters like days to maturity, number of fertile cobs, biomass, and hundred seed weights positively. Intercropping increased the number of fertile cobs per plant, number of seeds per cob, biomass, yield and hundred seed weight.

The combined use of soil bund with haricot bean intercropping increased days to maturity, number of fertile cobs per plant, biomass and hundred seed weight, but no significant effect on date of flowering.

The higher moisture content under soil bund was the result of reduced runoff and enhanced infiltration rate during rains. In addition, intercropping reduces runoff, and as crops covering land, it reduces rain drop impacts on soil detachment, and thereby increased crop yield.

REFERENCES

(1) Abay Ayalew (2011).Construction of Soil Conservation Structures for improvement of crops and soil productivity in the Southern Ethiopia; *Journal of Environment and Earth Science*
(2) Akbar, H., Miftahullah, Jan. and Ihsanullah, M.T. (2002). Yield potential of sweet corn as influenced by different levels of nitrogen and plant population. *Asian Journal of Plant Science.* 6: 631-633.
(3) Amanullah, R., Khattak, A. and Khalil, S.K. (2009).Effects of Plant Density and N on Phenology and Yield of Maize. *Journal of Plant Nutrition*, 32: 246-260.
(4) Araya Alemie and Stroosnijder L. (2010). Effects of tied ridges and mulch on barley (HordeumVulgare) rain water use efficiency and production in Northern Ethiopia. *Agricultural Water Management,* 97: 841-847.
(5) Bojo, J. and Cassells, D. (1995). Land degradation and rehabilitation in Ethiopia: reassessment, Working Paper No. 17, World Bank, 1995: 36.
(6) Central Statistical Agency (2013). Agricultural Sample Survey: Area and Production of Major Crops, Meher Vol. I. Addis Ababa, Ethiopia.
(7) Corbeels, M., Shiferaw, A. and Haile, M. (2000). Farmers' knowledge of soil fertility and local management's strategies in Tigray, Managing Africa's Soils No. 10

(8) Dabney, S. M., Delgado, J. A. and Reeves, D. W. (2001). "Using winter cover crops to improve soil and water quality," Communications in Soil Science and Plant Analysis, vol. 32, no. 7-8: 1221–1250. View at Publisher · View at Google Scholar · View at Scopus
(9) Erkossa, Teklu and Seleshi, Bekele (2010). Soil Fertility Effect on Water Productivity of Maize and Potato In: P.M. Asha Karunaratne (ed.) Improving Management Strategies through AquaCrop: Worldwide collection of case studies, 8-9 October, Yogyakarta, Indonesia.
(10) Erkossa, Teklu., Amare, Haileslassie and Mac, Alistera (2014).Enhancing farming system and water productivity through alternative land use and water management in vertisol areas of Ethiopian Blue Nile Basin (Abay).*Agricultural Water Management,* 132 (2014): 120– 128,*journal* home page: www.elsevier.com/locate/agwat
(11) Erkossaa, Teklu., Amare, Haileslassie., Tilahun, Amede and Fitsum, Hagos (2015). Agricultural water productivity across landscape positions in the Ethiopian Highlands. International Water Management Institute, Addis Ababa, Ethiopia: 5-6
(12) FAO (1998).Crop Evapotranspiration. In: Allen, R., Pereira, L.A., Raes, D., Smith, M.(Eds.), FAO Irrigation and Drainage Paper No. 56. FAO, Rome.
(13) FAO (2003).Raising WaterProductivity.http://www.fao.org/ag/magazine/0303sp2.htm (Accessed 1May 2015).
(14) Faridah, A. (2001). "Sustainable agriculture system in Malaysia," in Proceedings of the Regional Workshop on Integrated Plant Nutrition System (IPNS '01), Development in Rural Poverty Alleviation, UN Conference Complex, Bangkok, Thailand, September 2001.
(15) Gerba, Leta., Alan Duncan and Asebe Abdena (2013). Led by IWMI (International Water Management Institute), Research Program on Water, Land and Ecosystem; The Nile Basin Development Challenge (NBDC) the CGIAR Challenge Program on Water and Food (CPWF) in Ethiopian Highlands. http://www.nilebdc.org
(16) Getu, Nigatu (2002). Ecological analysis of stem borers and their natural enemies under maize and sorghum bases Agro-ecosystem in Ethiopia. PhD, Thesis, Kenyatta University, Nairobi, Kenya.
(17) Gomez and Gomez (1984). Statistical procedures for agricultural research, 2nd edition, International rice research institute, Los Banos, Laguna, Philippines.
(18) Herweg, K. and Ludi, E.(1999). The performance of selected soil and water conservation measures: Case studies from Ethiopia and Eritrea. *Catena*, 36: 99-114.
(19) Hurni, H.,Tato, T. and Zeleke, Z.(2005). "The implications of changes in population, land use, and land management for surface runoff in the upper Nile Basin Area of Ethiopia", *Mountain Res. Dev., 25*: 147–154.
(20) Khaliq, T. (2008). Modeling the impact of climate change on maize (Zea mays L.) productivity in the Punjab, PhD, thesis: 72-74. Punjab Agricultural University, Ludhiana.
(21) Mati, BM. (2006). "Overview of Water and Soil Nutrient Management. Under Smallholder Rain-fed Agriculture in East Africa"; International Water Management Institute, Working Paper 105.
(22) National Seed Industry Agency (1998). Crop Variety Register, Issue No.1. Addis Ababa, Ethiopia: 302.
(23) Negasa, Bane.,Teklu, Erkossa., Esayas, Aga and Zuberi, M. I. (2013). MSc Thesis; Assessment of Agro-Ecology, and Management Practices Effect on Crop Water Productivity of major crops at Dapo Watershed, East Wollega Zone, Oromia Regional State, Ethiopia.
(24) Pilbean, C.J. (1996). Variation in harvest index of maize (*Zea mays*) and common bean (*phaseoulus vulgaris*) grown in a marginal rain fall area in kenya. J. Agric. Sci., 126:1-6
(25) Power, J.F. (1990). Fertility Management and Nutrient Cycling; In: Singh, R. P., J. F. Parr and B. A Stewart (Eds), *Dry Land Agriculture, strategies for sustainability. Advances in soil Science*, Springer Vol 13, Verlag, New York.
(26) Russell, A. E.,Laird,D. and Mallarino,P. (2006)."Nitrogen fertilization and cropping system impacts on soil quality in mid western mollisols," Soil Science Society of America Journal, vol. 70, no. 1:249–255, 2006. View at Publisher · View at Google Scholar · View at Scopus
(27) Sabir, M., Ahmad,R. and Shahzad, A.(2000).Effects of nitrogen and phosphorus, on yield and quality of two hybrids of maize (Zea mays L.).*Journal of Agricultural and Research*, 4:339-346.
(28) Santalla, M., Caspuero, P. and Ronde, A. (1999). Yield and yield components from intercropping improved bush bean cultivars with maize. *J. Agron. Crop Sci*., 183:263-269.
(29) Seran, H. and Brintha, I. (2009). Studies on determining a suitable pattern of Capsicum (Capsicum annum L.)-Vegetable cowpea (Vignaunguiculata L.) intercropping. *Karnataka J. Agric. Sci.,* 22:1153-1154.
(30) Starr, G., Lynn and Geist, J. Michael. (1988). Soil bulk density and soil moisture calculated with a FORTRAN 77 program, Gen. Tech. Rep. PNW-GTR-211. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, 6 p.
(31) Temesgen, Deressa., Hassan, R. M. and Ringler, C.(2008). Measuring Ethiopian farmer's vulnerability to climate change across regional states. *International Food Policy Research Institute*.

(32) Tenaw, Workayehu (2013). Legume-based cropping for sustainable production, economic benefit and reducing climate change impacts in southern Ethiopia. *Journal* of Agricultural and Crop Research Vol. 2(1):11-21.
(33) Tilahun, Amede (2003). Restoring Soil Fertility, in the Highlands of East Africa, through Participatory Research*; International Center for Research in Agroforestry*. AHI brief no.
(34) Troung, P.N.V. and Loch, R.(2004).Vetiver system for erosion and sediment control, 13th *International Soil Conservation Organization Conference;* Brisbane, 4-7 July, 2004.
(35) Vandermeer, J.(1989). The ecology of intercropping Cambridge*,* UK: Cambridge University press.
(36) Yadvinder, S., Bijay, S. and Timsina, J. (2005). "Crop residue management for nutrient cycling and improving soil productivity in rice-based cropping systems in the tropics," Advances in Agronomy, vol. 85: 269–407, 2005. View at Publisher · View at Google Scholar
(37) Abideen Ul., Zain, (2014). Comparison of Crop Water Requirements of Maize Varieties Under Irrigated Condition in Semi-Arid Environment, Department of Water Management, Faculty of Crop Production Sciences, the University of Agriculture, Peshawar-Pakistan, *Journal of Environment and Earth Science,* Vol. 4, No.6
(38) Zemadim, B., McCartney, M., Langan, S. and Sharma, B. (2013).A participatory approach for hydro meteorological monitoring in the Blue Nile River Basin of Ethiopia. Colombo, Sri Lanka: International Water Management Institute (IWMI): 32. (IWMI Research Report 155).