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Full-Length Research Article

Intercropping Legumes Covers with Maize on Soil Moisture Improvement in Selected Dry Land Areas of Basketo Zone, Ethiopia

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ABSTRACT

Intercropping provides sufficient scope to include two or more crops simultaneously on the same piece of land, targeting higher land productivity. There is limited experimental evidence on the benefits of intercropping systems, which remains largely unstudied. This study was conducted to evaluate the effect of intercropping on soil moisture conservation in a moisture-stressed area. For this study, a randomized complete block design was used to establish experimental plots with three replications. Five treatments were evaluated, including maize only, lablab only, cowpea only, lablab with maize, and cowpea with maize. Disturbed soil samples were collected from a depth of 0–30 cm and composited for soil moisture and physicochemical property analysis. The yield and biomass of maize and legume shrubs were collected from each plot, and the variations were analyzed using the general linear model. The land equivalent ratio (LER) was computed to evaluate land productivity. The result showed that higher soil moisture content was recorded on maize-cowpea intercrop (34.33%), followed by maize-lablab intercrop (31.20%) relative to sole maize (26.83%) at the development stage in the first-year trial. This implies the benefit of legume shrubs on soil moisture conservation, both under mono-cropped and intercropped conditions. In this trial, the highest LER values were obtained for maize intercropped with Lablab 1.44 at Angila 4 kebele, while at Angila 3 kebele, the highest LER values were obtained for maize intercropped with cowpea 1.29. Therefore, conducting similar studies for more than two years on permanent field plots is vital to achieving considerable changes in soil moisture and soil physicochemical properties, as well as helping farmers make better use of cereal-legume intercropping systems to increase yields in moisture-stress areas.

Keywords: *Intercropping; Legume; Land equivalent ratio; Soil moisture; Yield*

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1. INTRODUCTION

The global population is expected to continue to grow, resulting in a significant increase in food, feed, and fuel demand (Ramankutty *et al.*, 2018). Most smallholder farmers in sub-Saharan Africa often grow cereal crops such as maize (*Zea mays* L.) in a continuous monoculture to support their livelihood, even when productivity and profitability is limited (Baudron *et al*., 2012b). Under the current agricultural production system in sub-Saharan Africa, it might be very challenging to meet the food and nutrition requirement of the growing population, with the challenges of climate change and variability, land degradation, and infertile soils (Ngwira *et al*., 2012). As a result, agricultural production requires a shift towards more sustainable cropping systems to help reverse soil degradation and improve production and productivity (Esther *et al*., 2017).
In Ethiopia, about 90 percent of the total population depends on subsistent agriculture system. It is a leading sector as a source of income, home consumption, employment, and foreign exchange. Agricultural output is also used as an input for industries, so it can stimulate industrialization (Tariku *et al*., 2018). However, Ethiopia's agriculture land productivity has been decreasing in alarming rate. This can be ascribed to soil degradation and in efficient water resources utilization. Even in years of abundant rainfall, the country's is unable to produce enough grain to feed its population (Kassa, 2003). Sustainable intensification in agriculture seeks to optimize efficiency and reduce losses within crop production systems (Van Ittersum *et al*., 2016). Intercropping is recognized as a viable agricultural practice within semi-arid regions, with the potential to improve household food and nutrition security while minimizing the negative impacts of continuous cereal mono-cropping (Rapholo *et al*., 2020). Intercropping can increase aggregate yields per unit area, insure against crop failure particularly in dry regions and enhance the efficiency of land-use by complete and complementary utilization of nutrients (Li *et al*., 2014). Studies have shown that soybean (*Glycine max* L.) intercropped with maize increased land equivalent ratio (1.25-1.46), which indicates that intercropping can increase crop yield (Xu *et al*., 2020). In addition, intercropping is an effective way to stabilize crop yield and reduce N input (Luce *et al*., 2015).

According to (FAO, 2011) to reduce rural poverty and maintain food security, soil fertility needs to be maintained, and agricultural systems need to be transformed to increase the productive capacity and stability of smallholder crop production. Greater attention is thus being given to alternative means of intensification, particularly the adoption of intercropping. Cereal-legume intercrop systems are particularly beneficial in marginal sub-Saharan African landscapes, which are characterized by high levels of malnutrition, resource limitations, and rainfall variability. In this region, intercropping systems are indispensable for food and nutritional security in resources poor region (Smith, 2017). More importantly, intercropping with legumes is highly effective in conserving soil moisture, reducing soil erosion and sustaining soil fertility (Cheer *et al*., 2006). The use of legumes in intercropping systems can improve N-use efficiency and total biomass under reduced chemical fertilizer input (Xu *et al*., 2020). When intercropped with maize, cover legumes such as cowpea (Bayer *et al*., 2000), and lablab (Janet *et al*., 2014) could significantly contribute to soil moisture conservation and increased soil productivity compared to mono cropping.

Across moisture stress areas, like Basketo Special Woreda of Ethiopia, crop failure is common. Thus, farmers have been trying to cope with this problem by using mulches of crop residues. This is also challenging because crop residues are used as feed for animals and energy for cooking. Therefore, using the advantages and opportunities of cover legumes as an intercrop in moisture stress areas could solve the problems simultaneously. Moreover, the contribution of legume to the soil nutrient balance, to improve soil moisture content through reducing evaporation and reduce soil erosion. However, the impacts of legume intercropping have not been well tested in the study of agroecological conditions. In addition, there is limited experimental evidence on the mechanisms underlying benefits of intercropping systems and belowground interactions in intercrops remain largely unstudied. Therefore, this study aimed to evaluate the effect of intercropping different legumes (Cowpea and Lablab) with maize towards soil moisture conservation and crop yield improvement in moisture-stress areas.

2. MATERIAL AND METHODS

2.1. Study Area Description

The study was conducted for two consecutive years (2020 and 2021) at Basketo Special Woreda in the South Nation Nationalities and People's Regional State of Ethiopia (Fig 1). The woreda is characterized as a moisture stress area. The altitudinal location of the special Woreda ranges from

780-2200m.a.s.l. Temperature of the Special Woreda ranges from 15°C-27°C and its mean annual rainfall ranges from 1000-1400mm (Tariku et al., 2018). The experimental plots were established in Angila-3 (6°16′125″N, 36°33′34″E) and Angila-4 (6°17′17″N, 36°33′39″E) *kebeles* (Figure 1).

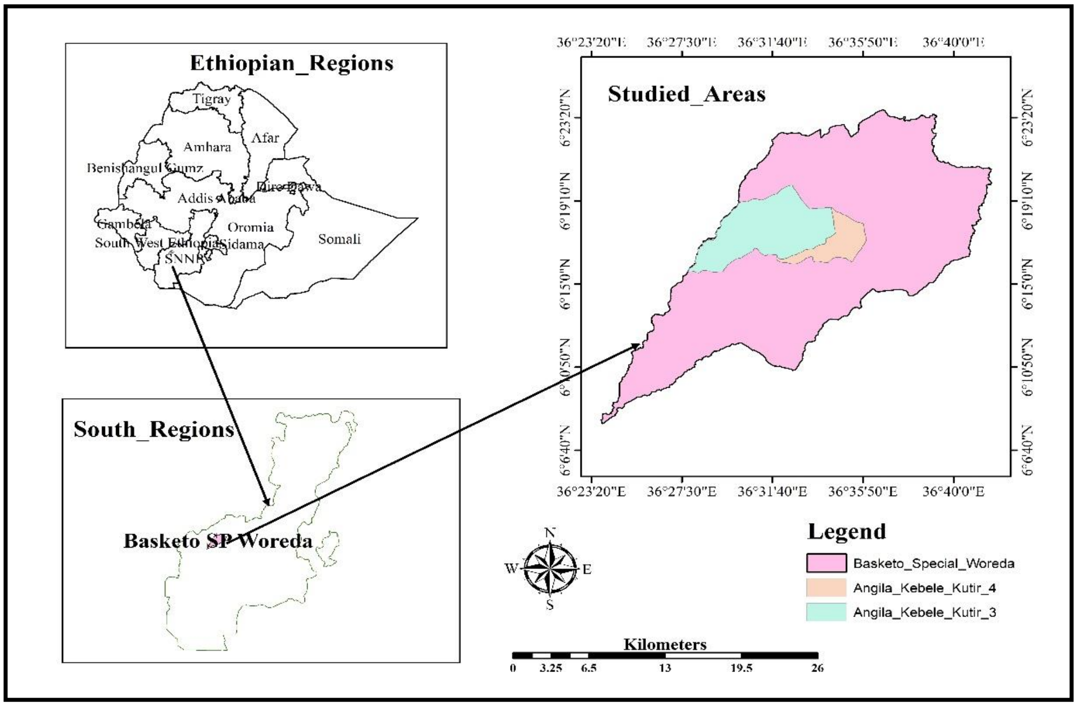

Figure 1: Location map of the study area

2.2. Research design and treatments

The study was conducted at Angila 3 and Angila 4 kebeles to test the impacts of maize-legume intercropping on soil moisture and crop yield. The experiments were laid out in randomized complete block design (RCBD) with five treatments with three replications on each farmer's training center. Five treatments were applied in this trial: (T1) maize alone, (T2) sole cowpea, (T3) sole lablab, (T4) maize intercropped with cowpea, and (T5) maize intercropped with lablab. The experimental field was prepared by using oxen driven local plow (*Maresha*). The plot size of the trial was 5m×5m (25m^2) and one meter walkway between blocks and plots. Maize was planted based on the recommended spacing (80 cm and 40 cm) between rows and plants, respectively. Leguminous shrubs (Cowpea and Lablab) were sown on one row between maize with spacing of 40 cm and 30 cm between rows and plants respectively. Seed rate used was 25kg/ha for both lablab and cow pea under monocultured conditions and 75% of leguminous seed rate under intercropped conditions. 100 kg of NPSB ha^{-1} was applied at planting. We used a total of 75 kg of Urea twice, i.e., 50 kg was applied during planting of maize and legume crops and the remaining amount (25 kg) was applied after 35 days of planting. NPSB and Urea was used as a source of Nitrogen, Sulphur, Boron and Phosphorous. For this study, we used BH-140 maize variety. All leguminous shrubs were sown simultaneously with the maize. The treatments were maintained and repeated on the same plots and for the second season by protecting the experimental plots from livestock grazing as well as crop residues after harvesting was left on the plots in the first season. All agronomic management practices, such as weeding, pest control, etc., were performed during the trial period per the research recommendations for maize and legume crops.

2.3. Data collection

2.3.1. Soil sampling

To monitor the soil moisture status of each plot, disturbed soil samples were collected from the intra-row spacing of the intercropped plots from five sampling points at a depth of 0-30 cm at three stages at (planting, development stage and harvesting). Similarly for the non-intercropped plots, a sample was collected from the intra-row spacing from there different sampling points. Then, a composite soil sample was prepared for all plots. The weight of the wet soil sample was measured at site using digital scale and then taken to the laboratory. Then, the soil was oven-dried at 105°C for 24 hour. Finally, the gravimetric method was used to determine the soil moisture content in grams, which was then converted to a volumetric base by using the following formula (RNAM, 1995).

$$= \frac{Ww - Wd}{Wd} *$$

Where SMC, soil moisture contents %; Ww, weight of wet soil (gm); Wd, weight of dry soil (gm). In addition, at sowing time composite subsurface soil sample was collected to determine the soil physico-chemical properties of the study sites. However, at harvesting time subsurface soil samples were collected separately from each plot (treatment based) for the analysis of soil physico-chemical parameters (soil pH, organic-carbon concentration (OC), total nitrogen concentration (TN), availability of Phosphorus, availability of potassium and exchangeable acidity was analysed.

2.3.2. Crop data

Grain yield and biomass of maize and legumes were determined by harvesting an area of 4m x 4m ($16m^{2}$) from the total plot area of $25m^2$ and converted into tonnes per hectare basis. Grain yield was adjusted to 12.5% moisture level; whereas plant biomass was weighed after leaving it in open air.

3. DATA ANALYSIS

The collected data were subjected to one way analysis of variance (ANOVA) using SAS software and least significant difference (LSD) was used to test significance of means differences at $p \leq 0.05$ levels.

For intercropped plots, Land Equivalent Ratio (LER) was calculated to determine total production. LER was estimated using the following relationship (Willey and Osiru, 1972);

$$\mathrm{LER} = \frac{\mathrm{YMint}}{\mathrm{YMsol}} + \frac{\mathrm{YLint}}{\mathrm{YLsol}}$$

Where, YMint = Yield of maize under intercropping conditions; YMsol = Yield of maize under sole crop conditions; YLint = Yield of legume under intercropping conditions and YLsol = Yield of legume under sole crop condition.

4. RESULT AND DISCUSSION

4.1. Effect of Intercropping on Soil Physicochemical Properties

Table 1 presents we analyzed and documented the baseline condition of soil physicochemical properties. We found that before experiment in experimental sites according to (Tekalign, 1991); Soil Organic Matter (OM) or Organic Carbon (OC) ratings, the soil property values of %OC are between 1.5-3.0, %OM is between 2.59-5.17 which are under medium rates and total nitrogen is between 0.05 - 0.12 which are under low rates accordingly, in both the study site the availability of total nitrogen was under low rates. The surface soil pH values varied from 6.25-6.56 and rated as slightly acidic. The textural classes of the surface soils at both experimental sites were silty clay loam and loam (Table 1).

Table 1:- Physicochemical properties of the soil under experimental site before the experiment (2020)

Study site	Parameters										
	P^H (H_2O)	EC (ds/m)	OC (%)	OM (%)	TN (%)	C:N ratio	A.v P (ppm)	Texture			
								%Sand	%Clay	%Silt	Textural class
Angila 3	6.25	2.39	2.79	4.79	0.11	13.95	27.9	41.6	22	36.4	Loam
Angila 4	6.56	1.85	2.44	4.13	0.10	11.62	23.2	20	38.6	41.4	Silty clay loam

Note: P^H: Power of hydrogen, NT: Total Nitrogen (%), OC: Organic Carbon (%), %OC x1.724, OM: Organic matter (%), Av. P: Availability of Phosphorus Conc. (mg/kg), Av. k: Availability of Potassium Conc. (mg/kg), and EC: Electrical conductivity (ds/m)

The result from experimental plots showed the surface soil pH values increased at the experimental site of Angila 4 and were rated as neutral in all treatments relative to maize mono-cropping (Table 2). Soil organic matter content of surface soils were varied from 2.6-5.2% at baseline condition (i.e., prior to experimental trials) (Table 1) and rated as moderate ranges (Berhanu, 1980). The result also showed high ranges >5.2% of organic matter in maize intercropping with lablab (6.67%) and in monocropped conditions of Cowpea (6.57%) in Angila 4 as well as monocropped conditions of Lablab (5.63%) in Angila 3 after the experiment (Table 2). Our finding is also similar to rating described by (Tekalign, 1991). Soil organic matter content can alter and improve the physical, chemical, and biological properties of soils, then helps to increase plant productivity. This is because of the intercropping of legume crop and the fast mineralization of nitrogen from the organic matter. The distribution pattern of total nitrogen across experimental sites were similar to that of soil organic matter, since soil organic matter content is a good indicator of the available nitrogen status in the soil. According to (Havlin, 1999) total nitrogen content of soils is categorized as low (<0.15%), medium (0.15-0.25%), and high (> 0.25%) which revealed that, in both study sites the availability of total nitrogen was rated as medium (Table 2) and it was also similar with (Tekalign, 1991) ratings.

Table 2. Physico-chemical properties of soil after experiment (2021)

Studied sites	Treatments	Parameters								
		P^H (H_2O)	EC (ds/m)	OC (%)	OM (%)	TN (%)	C:N ratio	A.v.P (ppm)	CEC (mg/kg)	Av. K (mg/kg)
Angila 3	Maize only	6.4	0.11	2.27	3.91	0.19	11.95	20.7	86.76	7.4
	Lablab only	6.3	0.14	3.27	5.63	0.22	14.86	21.0	85.86	6.17
	Cowpea only	6.3	0.11	1.93	3.32	0.20	9.65	22.0	58.46	7.0
	Maize + Lablab	6.4	0.12	2.88	4.95	0.21	15.16	18.0	76.5	7.87

Studied sites	Treatments	Parameters								
		P^H (H_2O)	EC (ds/m)	OC (%)	OM (%)	TN (%)	C:N ratio	A.v.P (ppm)	CEC (mg/kg)	Av. K (mg/kg)
	Maize+ Cowpea	6.5	0.12	2.70	4.64	0.22	12.27	19.0	55.97	8.08
Angila 4	Maize only	6.50	0.22	2.93	5.04	0.16	16.28	28.0	86.76	7.4
	Lablab only	6.85	0.20	2.38	4.10	0.18	14.0	27.6	85.86	6.17
	Cowpea only	6.91	0.22	3.82	6.57	0.19	20.11	32.0	58.46	7.0
	Maize + Lablab	6.73	0.21	3.87	6.67	0.20	22.76	33.7	76.5	7.87
	Maize+ Cowpea	6.75	0.18	2.70	4.64	0.21	12.86	27.8	55.97	8.08

Note: P^H: Power of hydrogen, NT: Total Nitrogen (%), OC: Organic Carbon (%), %OC x1.724, OM: Organic matter (%), Av. P: Availability of Phosphorus Conc. (mg/kg), Av. k: Availability of Potassium Conc. (mg/kg), and EC: Electrical conductivity (ds/m) and C: N: carbon-to-nitrogen ratio

4.2. Effect of Intercropping on Soil Moisture

Soil moisture and water availability to plants are determining factors in intercropping systems. Efficient water use leads to the use of other resources. Higher soil moisture content was recorded on maize cowpea intercrop (34.33%) followed by maize lablab intercrop (31.20%) as compared to sole maize (26.83%) at development stage in the first year trial (Figure 2). Similarly, higher soil moisture content was recorded on maize cowpea intercrop (28.16%) followed by maize lablab intercrop (25%) as compared to sole maize (19.45%) at development stage at second year trial (Figure 3). Similar study was also found by (Ayele, 2020) in Bena-Tsemay district, South omo zone; Southern Ethiopia where intercropping of maize with cowpea had better soil moisture contents during active crop development stage**.** Soil moisture content in the soil was lower in the sole crop of maize this may be due to high evaporation potential, whereas in maize intercrop with cowpea and lablab was high due to low evaporation potential in both growth stages and trial years. The study result also corresponds with a study by (Bayer *et al*., 2000); when intercropping maize with cowpea and intercropping maize with lablab (Janet *et al*., 2014) could significantly contribute to soil moisture conservation and increased soil productivity compared to sole maize cropping.

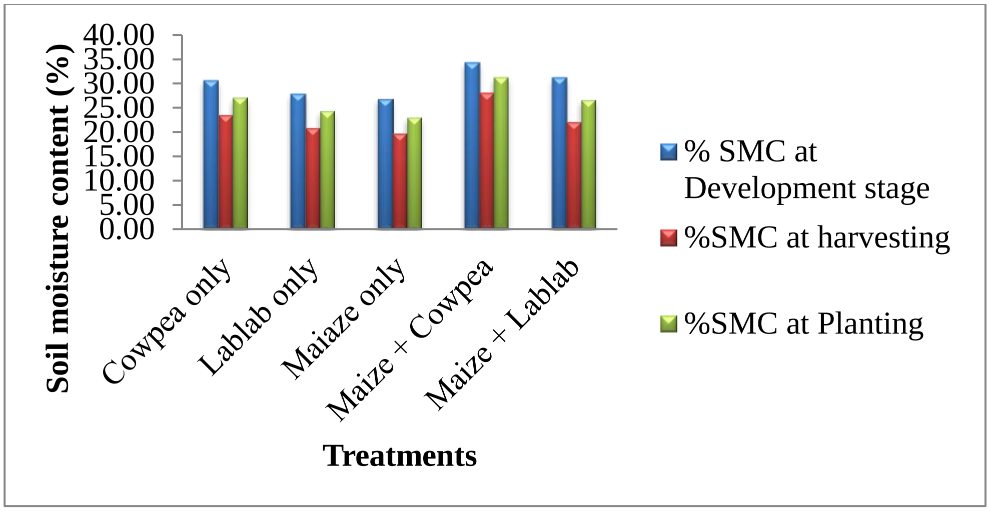

Figure 2. Effects of intercropped maize-legume covers on %SMC at first year in 2020 (Angila 4 kebele)
Note SMC is for soil moisture content

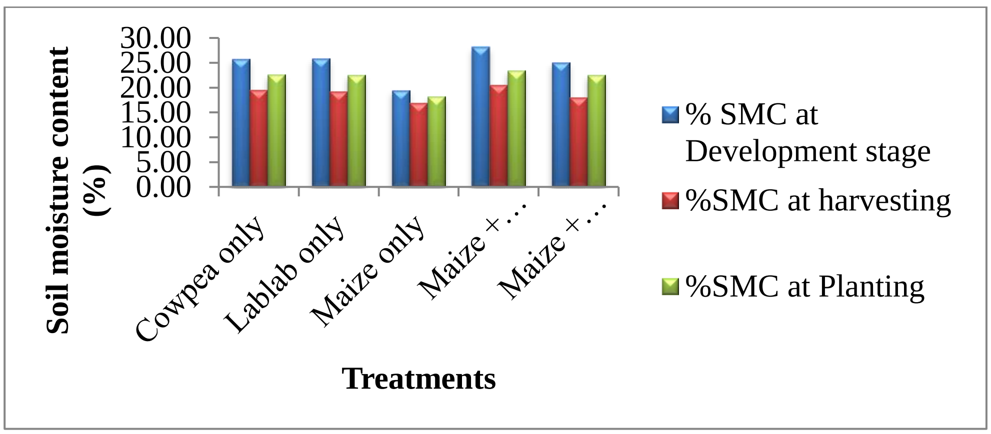

Figure 3. Effects of intercropped maize-legume covers on %SMC at second year in 2021 (Angila 4 kebele)
Note SMC is for soil moisture content

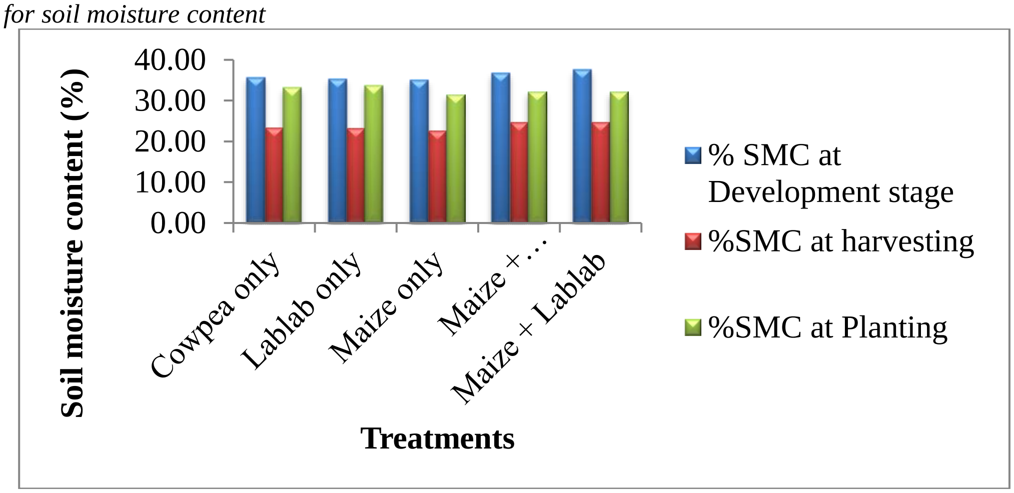

Figure 4: Soil moisture contents at different growth stage at Angila 3 kebele for one year trial in 2021
Note SMC is for soil moisture content

The soil moisture content did not differ significantly at planting and harvesting stages in Angila 3 Kebede (P <0.05). However, better result was obtained by maize-lablab intercropped conditions (37.6%) followed by maize-cowpea intercrop (36.8%) at the development stage (Figure 4). The present result was supported by a study of (Sagar *et al*., 2020) revealed the combination of maize-cowpea intercropping can assure greater light interception and check evaporation loss of soil moisture than a pure stand of maize. A study conducted by (Bagegnehu *et al*., 2021) at Misrak Azerinet woreda, southern Ethiopia also revealed that, intercropping maize with legumes have comparable soil moisture content at development stage. Soil moisture and water availability to plants are determining factors in intercropping systems, and efficient water use leads to the use of other resources. Scientific investigations have shown that the maize-legume combination registered greater water use efficiency than that of sole crops, and under water stress conditions, it could be one of the best options (Sagar *et al*., 2020).

4.3. Effect of intercropping on yield and yield components of maize

The analysis showed that there was a significant difference in grain yield of sole maize and intercropped conditions of maize with lablab and cowpea in the growing season of 2021 at Angila 4 kebele, as well as between sole maize and intercropped condition of maize with lablab at Angila 3 kebele (Table 3). A study by Sagar *et al.* (2020) noted that higher yield in maize-cowpea intercropping combination than in pure stand. The study also indicated that the plant height of maize was not significantly different (P<0.05) in both cropping seasons and sites, and other studies also reported similar results (Ayele, 2020 and Arun, 2016). In the study conducted in Bena- Tsemay Woreda, Southern Ethiopia by Biruk *et al*. (2021) reported as there is no significant effect of intercropping on plant height and cob length of maize plant. Similarly, in terms of maize biomass, the study also revealed that there was a significant difference (P ≤ 0.05) in both trial sites in the year 2021 between sole maize and intercropped condition of maize with lablab and cowpea. However, there was no significant difference in biomass among cropping systems in the first year trial (P ≤ 0.05) in Angila 4 kebele, which was inconsistent with the study by (Ayele, 2020). The study showed that higher value in grain yield and biomass was recorded under sole cropping. Non-significant effects in all growth parameters and maximum values were observed in sole cropping system over that of intercropped in the study by (Nigussie and Daba, 2022).

Table 3 Grain yield and biomass of Maize under legume shrub

	Angila 4 (first year /2020)			**Angila 4 (second year/2021)**			**Angela 3 (first year/2021)**		
	Ph(m)	**Bm(t/ha)**	**Gy(t/ha)**	**Ph(m)**	**Bm(t/ha)**	**Gy(t/ha)**	**Ph(m)**	**Bm(t/ha)**	**Gy(t/ha)**
Maize + Lablab	2.31	13.8	7.2	2.24	26.13[b]	3.67[b]	2.40	25.63[b]	3.40[b]
Maize + Cowpea	2.23	11.8	5.5	2.23	27.90[b]	3.97[b]	2.33	26.23[b]	4.30[ab]
Maize only	2.16	16.14	7.35	2.15	35.53[a]	5.07[a]	2.28	33.27[a]	5.27[a]
LSD (0.05)	ns	ns	ns	ns	5.5	0.66	ns	6.4	1.7
CV (%)	5.7	15.5	14	5.1	8.1	6.7	6.5	9.9	17.8

Note: Ph is for plant height, BM is for biomass and Gy is for grain yield.
Note: Mean values with different letters within the column are statistically different at $P \leq 0.05$.

4.4. Effect of intercropping on yield and yield components of legumes

The analysis showed that there were significant differences in biomass and grain yield of legumes in both cropping systems (i.e., monocropped and intercropped) in both growing seasons and trial sites ($P \leq 0.05$). In monoculture, the yield of legumes was higher, whereas the lowest yield was obtained when legumes were intercropped with maize (Table 3). As reported by (Chemeda, 1997) higher grain yield was recorded under sole cowpea compared to intercropping. Competition for water, nutrients and shading are maybe the factors that reduced cowpea yield under high numbers of maize plants in intercrop (Lesoing and Francis, 1999). In terms of biomass as shown in (Table 3) there were significant difference between sole cowpea and intercropping cowpea with maize in both growing season and trial sites. Biruk *et al*. (2021) also reported that total biomass of cowpea was significantly influenced by cropping system. A study result by (Baudron *et al*., 2012b) described that, total biomass of (maize + cowpea) intercrops was higher than in sole maize or cowpea stands and biomass production and is seen as a benefit of intercropping in mixed crop-livestock systems, which are characterized by competing uses of crop residues mainly for livestock feed and for maintaining soil organic matter. Hauggaard *et al*. (2001) also reported that legume-cereal intercropping performance indicates yield advantages and greater yield stability as compared to legume sole cropping.

Table 4 Grain yield and biomass of cowpea and lablab

Treatments	**Angila 4 (first year/2020)**		**Angila 4 (second year/2021)**		**Angela 3 (first year/2021)**	
	Bm/ton/ha	**Gy/ton/ha**	**Bm/ton/ha**	**Gy/ton/ha**	**Bm/ton/ha**	**Gy/ton/ha**
Cowpea + Maize	28[b]	0.14[b]	16.70[b]	0.18[b]	17.0[b]	0.45[b]
Cowpea only	41.45[a]	1.06[a]	26.28[a]	0.53[a]	25.33[a]	0.96[a]
LSD (%)	10.5	0.8	6.8	0.12	7.5	0.4
CV (%)	8	37	9	9.8	10.2	17.6
Lablab + Maize	4.2b	1.46[b]	30.53	1.10	22.07	0.50[b]
Lablab only	5.77[a]	2.5[a]	38.4	1.53	33.37	0.93[a]
LSD (0.05)	0.95	0.5	ns	ns	ns	0.37
CV (%)	5.43	7.42	10.7	13.5	13.4	15

Note: Ph is for plant height, BM is for biomass and Gy is for grain yield.
Note: Mean values with different letters within the column are statistically different at $P \leq 0.05$.

4.5.Effect of intercropping on Land use efficiency

Land Equivalent Ratio (LER) is the most common index adopted in intercropping to measure land productivity. It is often used as an indicator of the effectiveness of intercropping (Seran and Brintha, 2009b). Any value greater than 1.0 represents that a yield advantage for intercropping. In this trial, as shown in (Table 5), the highest LER values were obtained for maize intercropped with Lablab 1.44 in the second trial year at Angila 4 kebele inturn, indicating that 44% more area would be required by sole cropping system to equal the yield of the intercropping pattern. While, in Angila 3 kebele there is highest LER values or yield advantages were obtained for maize intercropped with cowpea 1.29 (Table 6) which indicats that, 29% more area would be required by sole cropping system to equal the yield of the intercropping pattern. Therefore, this showed that land was effectively utilized under maize-legume intercropping and is more advantageous than for sole cropping. A LER greater than 1.0 has been reported with bean-maize intercropping by (Saban *et al*., 2007). A study by Biruk *et al*., 2021 showed that, land equivalent ratio (LER) was greater when maize intercropped with cowpea. Mashingaidze (2004) also revealed that, land was effectively utilized under intercropping and yield was improved.

Table 5. Land Equivalent Ratio of intercropping of maize with legume crops at Angila 4 kebele

	Yield (ton/ha) first year				Yield (ton/ha) second year			
Treatments	Maize	Lablab	Cowpea	LER	Maize	Lablab	Cowpea	LER
Maize + Lablab	7.2	1.46	-	1.55	3.67	1.10	-	1.44
Maize + Cowpea	5.5	-	0.14	0.88	3.97	-	0.18	1.12
Maize only	7.35	-	-		5.07	-	-	
Cowpea only	-	-	1.06		-	-	0.53	
Lablab only	-	2.5	-		-	1.53	-	

Note: LER is for land equivalent ratio

Consistently (Amede and Nigatu, 2001) received the LER value of 1.5. Similarly (Stoltz and Nadeau, 2014) showed that intercropping commonly leads to a higher protein content compared to monocropped maize and higher yield on a land equivalent ratio (LER >1) basis compared with maize monocropped. Intercropping can increase aggregate yields per unit input, insure against crop failure particularly in dry regions and enhance the efficiency of land-use by complete and complementary utilization of nutrients (Li *et al*., 2014). Esther *et al*. (2017) who have conducted both on-station and on-farm study revealed that, the total yield was higher in the intercrops than the sole crops of either maize or cowpea and most intercrop treatments had LER > 1 pointing to the greater land use efficiency of the maize-cowpea intercrop system compared to sole cropping.

Table 6. Land Equivalent Ratio of intercropping of maize with legume crops at Angila 3 kebele

	Yield (ton/ha) first year			
Treatments	**Maize**	**Lablab**	**Cowpea**	**LER**
Maize + Lablab	3.40	0.50	-	1.18
Maize + Cowpea	4.30	-	0.45	1.29
Maize only	5.27	-	-	
Cowpea only	-	-	0.96	
Lablab only	-	0.93	-	

Note: LER is for land equivalent ratio

5. CONCLUSION AND RECOMMENDATION

It is concluded that intercropping cereal with legumes plays a considerable role in enhancing soil moisture content compared to the pure stand of cereal. In terms of LER, the highest land equivalent ratio values were obtained by maize intercropped with cowpea and Lablab in both trial sites. That is why intercropping helps keep nutrients on the field and improves available soil moisture. It is recommended that farmers practice intercropping for better soil moisture content improvement by maize with Lablab and cowpea than a pure stand of maize. In the case of Angila 4 and areas with similar agro-ecology, it is recommended that farmers intercrop maize with Lablab. However, in Angila 3 and areas with similar agro-ecology, stallholders should intercrop maize with cowpea. Hence, for better productivity of the intercropping system, further study should be done by considering other factors of production.

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CONFLICT OF INTEREST

We declare no potential conflict of interests

REFERENCES

Amede, T., and Nigatu Y. (2001). Interaction of Components of Sweet potato-maize Intercropping under the Semi-arid Conditions of the Rift-Valley, Ethiopia *Trop. Agric.* 78: 1-7

Arun T. (2016). On-farm evaluation of maize and legume intercropping for improved crop productivity in the mid hills of Nepal. *LAP LAMBERT* Academic Publishing, Germany; 92p

Ayele H.M. (2020). Evaluation of the effect of maize-legume intercropping on soil moisture improvement in arid area of Bena-Tsemay district, South omo zone, Southern Ethiopia. *Int. J. Agril Res. Innov Tech.* 10(1): 80-86. https://doi.org/10.3329/ijarit.v10i1.48097

Bagegnehu B., Dagnaw A., Yenealem G., and Temesgen H. (2021). Evaluation of Intercropping Legume Covers with Maize on Soil Moisture Improvement in Misrak Azerinet Berbere woreda, SNNPR, Ethiopia. *Water Conservation Science and Engineering.* 6:145–151. https://doi.org/10.1007/s41101-021-00109-w

Baudron F., Tittonell P., and Corbeels M. (2012b). Comparative performance of conservation agriculture and current smallholder farming practices in semi-arid Zimbabwe. Field Crop Res.; 132, 117–128.

Bayer C., Mielniczu J., and Amado L. (2000). Organic matter storage in a sandy clay loam Acrisol affected by tillage and cropping systems in southern Brazil. *Journal Soil and Tillage Research*. V 54: pp101-109

Berhanu D. (1980).The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia

Biruk G., Awoke T., and Anteneh T. (2021). Effect of intercropping of maize and cowpea on the yield, land productivity and profitability of components crops in Bena- Tsemay Woreda, Southern Ethiopia. *Int. J. Agril. Res. Innov. Tech.* 11(2): 147-150. https://doi.org/10.3329/ijarit.v11i2.57268

Cheer C. M., Scholberg J.M.S., and McSorley, R. (2006). Green manure approaches to crop production: A synthesis. *Agronomy Journal.*; 98: 302-319

Chemeda, F. (1997). Effects of planting pattern, relative planting date and intra-row spacing on a haricot bean/maize intercrop. *African Crop Sci. J.* 5(1): 15-22.https://doi.org/10.4314/acsj.v5i1.27866

Esther, N. M., Justice N., and Katrien D. (2017). Maize-cowpea intercropping a viable option for smallholder farms in the risky environments of semi-arid southern Africa. *Field Crops Research journal homepage*:; www.elsevier.com/locate/fcr

FAO (2011). Climate-Smart Agriculture: A Synthesis of Empirical Evidence of Food Security and Mitigation Benefits from Improved Cropland Management, *Rome, Italy*

Hauggaard-Nielsen H., Ambus P., and Jensen E.S. (2001). Interspecific competition, N use and interference with weeds in pea–barley intercropping. *Field Crops Res*. 70: 101–109.

Havlin J. L., Beaton J. D., Tisdale S. L., and Nelson W. L. (1999). *Soil Fertility and Fertilizers*. New Jersely, USA: Prentice Hall. *Inc pp.* 345-355.https://doi.org/10.1016/S0378-4290(01)00126-5

Janet M., Richard C., and Onwonga N. (2014). Efficiency and interactive effects of Tillage Practices, Cropping Systems and Organic Inputs on Soil Moisture Retention in Semi-Arid Yatta Sub County, Kenya. *Journal of Agriculture and Environmental Sciences* Vol. 3, No. 2 pp. 145-156

Kassa H. (2003). Livestock and Livelihood Security in the Harar Highlands of Ethiopia: Implications for Research and Development, PhD Thesis, Swedish University of Agricultural Sciences, Uppsala

Lesoing W.G., and Francis C.A. (1999). Strip intercropping effects on yield and yield components of corn, grain sorghum, and soybean. *Agron. J.* 91(5): 807-813.https://doi.org/10.2134/agronj1999.915807x

Li L., Tilman D., and Lambers H. (2014). Plant diversity and over yielding: insights from belowground facilitation of intercropping in agriculture. *New Phytol.* 203, 63–69

Luce M.S, Grant C.A, and Zebarth, B.J. (2015). Legumes can reduce economic optimum nitrogen rates and increase yields in a wheat-canola cropping sequence in western Canada. *Field Crops Res.* 179, 12–25.

Mashingaidze A.B. (2004). Improving weed management and crop productivity in maize systems in Zimbabwe. *[Ph.D Thesis]*. Wageningen University, Wageningen, the Netherlands

Nigussei A, and Daba D. (2022). The Influence of Cropping systems and Tillage practices on Growth, Yield, and Yield Components of Maize (Zea may L.) in Shalla District, West Arsi Ethiopia. J AgronAgriSci 5: 031

Ngwira A.R, Aune J.B., and Mkwinda S. (2012). On-farm evaluation of yield and economic benefit of short term maize legume intercropping systems under conservation agriculture in Malawi. *Field Crop Res.*132, 149–157.

Ramankutty N., Mehrabi Z., and Waha K. (2018). Trends in Global Agricultural Land Use: Implications for Environmental Health and Food Security. *Annu Rev Plant Biol*. 2018; Apr 29; 69:789-815. doi: 10.1146/annurev-arplant-042817-040256. *Epub* Feb 28. PMID:

29489395.

Rapholo E., Odhiambo J.J.O., and Nelson W.C.D. (2020). Maize–lablab intercropping is promising in supporting the sustainable intensification of smallholder cropping systems under high climate risk in southern Africa. *Exp Agric*. 56:104–17. doi: 10.1017/S0014479719000206.

RNAM. (1995). Test code and procedures for Agricultural Machinery. Technical Series 12, Regional Network for Agricultural Machinery (RNAM) of the United Nations. *Philippines*, pp 227–246

Saban Y., Mehmt A. and Mustafa E. (2007). Identification of advantages of maize– legume intercropping over solitary cropping through competition indices in the East Mediterranean Region. *Turk. J. Agric.* 32: 111- 119.

Sagar M., Tanmoy S., and Pradipta B. (2020). Potential and Advantages of Maize-Legume Intercropping System, Maize-Production and Use, Akbar Hossain, *Intech Open*, DOI: 10.5772/intechopen.91722

Seran T.H. and Brintha I. (2009b). Studies on determining a suitable pattern of capsicum (Capsicum annum L.) vegetable cowpea (Vigna unguiculata L.) intercropping Karnataka *J. Agric. Sci.*, 22: 1153-1154

Smith A., Snapp S., and Chikowo R. (2017). Measuring sustainable intensification in smallholder agro ecosystems: a review. *Glob Food Sec.* 12:127–38. Doi: 10.1016/j.gfs.11.002.

Stoltz E. and Nadeau E. (2014). Field Crops Research Effects of intercropping on yield, weed incidence, forage quality and soil residual N in organically grown forage maize (Zea mays L.) and faba bean (Vicia faba L.). *Field Crops Research*, *169*, 21–29. https://doi.org/10.1016/j.fcr.2014.09.004

Tariku S., Getachew G., and Kanko C. (2018). Identification and Prioritization of Major Factors that Challenge Crop Productivity and Production System in the Case of Gamo Gofa, Segen Area People Zone and Basketo Special Woreda. *Ann Soc Sci Manage Stud*. 1(1): 555553. DOI: 10.19080/ASM. 01.555553

Tekalign T. (1991). Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa

Van Ittersum MK. van Bussel LGJ, Wolf J., Grassini P., van Wart J., and Guilpart N. (2016). Can sub-Saharan Africa feed itself? *Proc Natl Acad Sci USA.* 113:14964–9. doi: 10.1073/pnas.1610359113

Willey, R.W., and Osiru, D.S.O. (1972). Studies on mixtures of maize and beans (*Phaseolus vulgaris*) with particular reference to plant population. *J. Agric. Sci. Cambridge.* 79: 519-529. https://doi.org/10.1017/S0021859600025909

Xu, Z.; Li, C.; Zhang, C.; Yu, Y.; van der Werf, W.; Zhang, F (2020). Intercropping maize and soybean increases efficiency of land and fertilizer nitrogen use. A meta-analysis. F*ield Crops Res*. 246: 107661