Pilot study

Results from on-farm trials conducted in cropping season 2017/2018

submitted by

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October 2018

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Executive summary

To address increasing threats of climate change and declining soil fertility, a cross regional agronomic study was conducted in southern Africa, covering 19 on-farm communities in contrasting agro-ecologies ranging from around 500 mm to more than 1800mm of rainfall.

The 19 on-farm communities have been under long-term research by CIMMYT and national partners in Malawi, Zambia and Zimbabwe. The aim of this study was to assess how different climate-smart agriculture technologies perform under a variable climate and to pilot new doubled-up legume systems of groundnuts with pigeonpea in 6 selected target communities.

Yield results from all the sites showed primarily positive response of CSA as compared to the conventional control practices, although, these differences were not always significant. In 11 out of 19 communities there was a significant maize yield benefit recorded when CSA was practiced. In 9 out of 13 communities with full maize-legume rotation, the legume yield under different CSA practices had significantly greater yields than the conventional control treatment. Maize yield benefits of close to 100% were recorded in some sites, which shows great potential of these systems to withstand climate variability and change. Although these results were mostly positive towards CSA, the data from the 6 pilots were incomplete as the pigeonpea yields from the doubled-up systems were not collected in full. Farmers planted the pigeonpeas too late, had problems with beetles that attacked the pots, had challenges with harvesting, which all contributed to inconclusive result.

The adaptive capacity of CSA practices is widely acknowledged. However, the mitigation benefits is unclear and often leads to wrong statements about its potential. We therefore conducted a cross regional soil carbon study to assess how much soil carbon is being stored in the different systems. Soil carbon data from the sites was mostly the same between treatments and in some there was a positive response towards CSA. This was mainly in manual systems of Eastern Zambia and in some sites in southern Zimbabwe. In all other sites the soil carbon gain in on-farm systems was small. There are many reasons that could be responsible for the lack of carbon increase: grazing of crop residues by cattle, burning of residues by mice hunters, bush fires, and the long dry season that might have reversed the positive effect of soil carbon gain expected from CSA. Also in sites of Malawi, all cropping systems (even the conventional treatment) are in full rotation with legumes, and crop residues are often buried in the local conventional practice (e.g. the ridge and furrow system) which might have reduced this gain.

Finally, the short duration of this study did not allow for a proper assessment of carbon sequestration or resilience in the 6 pilot trials and we would recommend that this project should be continued for another cropping season to better assess the new diversification elements that have been introduced by the project in the pilots.

1. Introduction

Agricultural production in southern Africa is constrained by numerous factors. Amongst them are frequent droughts and in-seasonal dry-spells, heat stress, declining soil fertility, excessive water run-off and soil erosion, unsustainable land-use practices and limited adoption of improved agricultural technologies (Thierfelder *et al.*, 2015b). Climate projections for southern Africa until 2050 suggest temperature increases by on average 2.1-2.7°C (Cairns *et al.*, 2012), which will lead to a delay in the onset of the rainy seasons, increased heat stress and more extreme weather events (e.g. excessive rainfall and drought stress) (Burke *et al.*, 2009). Maize production, is projected to decrease by 10-30% until 2030 and up to 50% until 2080 if no measures are taken to adapt to climate variability and change (Lobell *et al.*, 2008; UNEP/GRID-ARENAL, 2016).

To address climate-related challenges, the concept of climate-smart agriculture (CSA) has been developed (FAO, 2013; Lipper *et al.*, 2014). For a cropping systems to be labelled "climate-smart" it has to deliver on three main aspects: a) it has to increase productivity and profitability; b) it has to adapt to the negative effects of climate change and build resilience; and c) it has to mitigate the negative effects by reducing greenhouse gas emissions and/or increase carbon sequestration (Thierfelder *et al.*, 2017).

Adaptation to climate change can be achieved through individual and or combinations of technologies such as agro-forestry, conservation agriculture (CA)[1], drought-tolerant and low N-stress tolerant maize and legume varieties, improved feeding and grazing systems for livestock amongst others. Yield benefit of 30-50% can be achieved by using a combination of CSA technologies under drought (Thierfelder *et al.*, 2015c) and profits increase by 40-100% (Thierfelder *et al.*, 2015a).

Due to the urgent need and projected benefits of CSA in southern Africa, the project "Out scaling climate-smart technologies to smallholder farmers in Malawi, Zambia and Zimbabwe" has been formulated to develop a business case for scaling CSA in the region. It aims at: a) understanding the vulnerability of current farming systems; b) prioritization of some "best bet" CSA technologies; and c) quantifying the benefits of selected climate-smart agriculture technologies using data from a combination of historical on-farm and on-station trial data as well as surveys conducted in different cropping seasons.

This report summarized the yield results of one year of trials in on-farm communities of southern Africa and the progress achieved in piloting some new CSA technologies in some sites. All trials were based on conservation agriculture cropping systems.

[1] Conservation agriculture is understood to be a cropping system based on the three principles of minimum soil disturbance, crop residue retention and crop rotation

 

Plate 1: Heavily droughted maize (left) and groundnut (right) fields in Eastern Zambia, February 2018

 

Plate 2: Seriously nutrient deficient and drought-affected maize in Southern Zambia (left) and Fall Armyworm in maize, Southern Malawi (right)

 

Plate 3: Droughted maize field under conventional agriculture in Monze, Southern Zambia (left) and CSA practices in low productivity systems from Zaka, Southern Zimbabwe (right)

2. Approach and Data sources

The project summarized site-specific data from 19 on-farm communities in three target countries, Malawi, Zambia and Zimbabwe, where different CSA practices have been implemented cumulatively since 2005. The on-farm communities are spread around different agro-ecologies in southern Africa and cover low and mid-altitude areas, low to high rainfall regimes and different soil types (from sandy soils to sandy clay loams).

Data included in the studies were from on-farm trial and had to satisfy the following characteristics and needs:

a. Treatments included a conventional tillage control and at least two CSA treatment interventions which were replicated at least four times in each target community in each year;
b. Trials were conducted in on-farm communities scattered around different agro-ecologies with a cluster of farms being the trial replicates at each community;
c. Trial replicates in each target community were established close to each other to reduce the influence of soil heterogeneity and rainfall variability;
d. Trials were managed by farmers with oversight by an extension officer and researchers from the national agriculture research services (NARS) and CIMMYT
e. Trials were established under rain-fed conditions in southern Africa and not irrigated;
f. The test crop in these trials was maize as the predominant food crop in southern Africa, although some treatments where intercropped with either cowpeas or pigeonpeas
g. At most sites, a full rotation of maize with legumes was practiced annually (with cowpeas, pigeonpeas or groundnuts as rotational crops).
h. In some sites, only some CSA treatment were rotated and some were under intercropping systems (e.g. manual and animal traction systems in Eastern Zambia).
i. For ease of analysis and better understanding of datasets, we grouped treatments into four major agro-ecologies and analyzed the data accordingly (Table 1).

From this larger dataset, 6 sites (Lemu, Linga, Mwansambo, Zidyana, Chiguluwe and Chipeni) were used to try a new doubled up legume system in the groundnut phase. These doubled-up legume trials in rotation with maize were truly new pilots of CSA technologies in the program. However, due to challenges on-site, only Lemu managed to have a full dataset of all components of the pilot trial, the maize yield, the groundnut yield and the pigeonpea yield. In the other sites, farmers planted the pigeonpea too late, were faced with attacks of blister beetles which affected the pigeonpea yield and generally, the management was not adequate. Due to those teething problems, the data from the pilot trials is inconclusive and requires another season of data to solidify the results.

Table 1: Target communities grouped into Agro-ecologies in southern Africa

Country	District	Description	Agro-ecoregion	Site(s)	Latitude	Longitude	Altitude	Soil type	Seasonal rainfall	CSA systems
Malawi	Nkhotakota	Central Malawi	Mid altitude, high rainfall, alluvial soil	Zidyana	-13.2281	34.26341	514	haplic Luvisol	1429	Manual CA
Malawi	**Nkhotakota**	**Central Malawi**	**Mid altitude, high rainfall, alluvial soil**	**Mwansambo**	**-13.2904**	**34.13204**	**660**	**Haplic Lixisols**	**1371**	**Manual CA**
Malawi	Nkhotakota	Central Malawi	Mid altitude, high rainfall, alluvial soil	Linga	−12.80	34.20000	491	Alluvialsoils	1237	Manual CA
Malawi	Salima	Central Malawi	Mid altitude, high rainfall, alluvial soil	Chinguluwe	-13.6932	34.23582	653	Eutric Cambisols	1241	Manual CA
Malawi	Dowa	Central Malawi	Mid altitude, high rainfall, alluvial soil	Chipeni	-13.7631	34.05322	1164	Chromic Luvisols	883	Manual CA
Malawi	**Balaka**	**Southern Malawi**	**Low altitude, low rainfall, sandy soils**	**Lemu**	**-14.7801**	**35.02718**	**687**	**Chromic Luvisols**	**862**	**Manual CA**
Malawi	Balaka	Southern Malawi	Low altitude, low rainfall, sandy soils	Malula	-14.9593	34.98556	613	Eutric Fluvisols	717	Manual CA
Malawi	Balaka	Southern Malawi	Low altitude, low rainfall, sandy soils	Herbert	-14.8844	35.04552	635	Chromic Luvisols	684	Manual CA
Malawi	Machinga	Southern Malawi	Low altitude, low rainfall, sandy soils	Matandika	-15.1801	35.27642	683	Cambic Arenosols	874	Manual CA
Malawi	Zomba	Southern Malawi	Low altitude, low rainfall, sandy soils	Songani	-15.2980	35.39610	815	Ferralitic soils	1371	Manual CA
Zambia	Katete	Eastern Zambia	Mid altitude, high rainfall, Ferralitic soils	Kawalala	-14.0953	31.48860	938	Acrisols	800-1000	AT CA
Zambia	**Chipata**	**Eastern Zambia**	**Mid altitude, high rainfall, Ferralitic soils**	**Chanje**	**-13.2330**	**32.47892**	**917**	**Luvisols**	**800-1000**	**Manual CA**
Zambia	Chipata	Eastern Zambia	Mid altitude, high rainfall, Ferralitic soils	Kapara	-13.3013	32.29310	739	Luvisols	800-1000	AT CA
Zambia	Chipata	Eastern Zambia	Mid altitude, high rainfall, Ferralitic soils	Mtaya	-13.3438	32.31201	747	Luvisols	800-1000	Manual CA
Zambia	Lundazi	Eastern Zambia	Mid altitude, high rainfall, Ferralitic soils	Vuu	-12.1602	33.02291	1096	Acrisols	800-1000	Manual CA
Zambia	Lundazi	Eastern Zambia	Mid altitude, high rainfall, Ferralitic soils	Hoya	-12.0715	33.07986	1103	Acrisols	800-1000	AT CA
Zambia	Monze	Southern Zim/Zam	Low to midaltitude, low rainfall, sandy/loamy soils	Malende	-16.2545	27.41943	676	Chromic Lixisols	748	AT CA
Zimbabwe	**Zaka**	**Southern Zim/Zam**	**Low to midaltitude, low rainfall, sandy/loamy soils**	**Bvukururu**	**-20.1750**	**31.38000**	**1120**	**Arenosols**	**500-700**	**AT CA**
Zimbabwe	Zaka	Southern Zim/Zam	Low to midaltitude, low rainfall, sandy/loamy soils	Zishiri	-20.1679	31.28126	1121	Arenosols	500-700	AT CA
Supporting long-term trial stations										
Malawi	Lilongwe	Central Malawi	Mid altitude, high rainfall, alluvial soil	Chitedze	-13.9732	33.65403	1146	Chromic Luvisol	960	Manual CA
Zambia	Chipata	Eastern Zambia	Mid altitude, high rainfall, Ferralitic soils	Msekera	-13.6212	32.59765	1018	Luvisol	800-1000	Manual/AT CA
Zambia	Monze	Southern Zim/Zam	low to midaltitude, low rainfall, sandy/loamy soils	Monze	-16.2402	27.44145	676	Chromic Lixisols	748	Manual/AT CA
Zimbabwe	Mazowe	Southern Zim/Zam	low to midaltitude, low rainfall, sandy/loamy soils	Henderson	-17.5727	30.98740	1268	Arensols and Luvisols	884	Manual/AT CA
Zimbabwe	Goromonzi	Southern Zim/Zam	low to midaltitude, low rainfall, sandy/loamy soils	Domboshawa	-17.6077	31.40373	1543	Areni-Gleyic Luvisol	600-800	Manual/AT CA

Notes: Communities marked in bold will be the sites where a Vulnerability Assessment (VA) took place as representative sites of the agro-ecology. CA = conservation agriculture systems, there will be usually two CA systems with several CSA practices compared with a conventional control. Manual CA systems are done with planting stick (Dibble stick) while AT CA are seeded in riplines created by an animal traction ripper or animal traction direct seeder.

Table 2: Treatment tested in different target areas of southern Africa under the CCARDESA/GIZ project

Site cluster	Conventional system	CA option 1	CA option 2	CA option 3
Central Malawi	Ridge tillage, maize-legume rotation	Dibble stick, maize- legume rotation	Dibble stick, maize/legume intercropping-legume rotation	
	All maize is fully rotated with groundnuts since 2010 and since 2013, maize plots are sub-divided into 6 subplots testing 5 drought-tolerant maize varieties and a conventional control. Fertilizer level is 69 kg ha^{-1} N:21 kg ha^{-1} P_2O_5:0 kg ha^{-1} K_20: 4 kg ha^{-1}S. A doubled-up legume system was introduced in all trials in the groundnut rotational phase.			
Southern Malawi	Ridge tillage, maize-legume rotation	Dibble stick, maize- legume rotation	Dibble stick, maize/legume intercropping--legume rotation	
	All maize is fully rotated with pigeonpeas, cowpeas or groundnuts since 2011 depending on sites and since 2013, maize plots are sub-divided into 6 subplots testing 5 drought-tolerant maize varieties and a conventional control; Fertilizer level is 69 kg ha^{-1} N:21 kg ha^{-1} P_2O_5:0 kg ha^{-1} K_20: 4 kg ha^{-1}S A doubled-up legume system was introduced in one community (Lemu) in the groundnut rotational phase.			
Eastern Zambia (manual)	Ridge tillage, maize	Dibble stick, maize	Dibble stick, maize-legume intercropping	Dibble stick, maize- rotation
Eastern Zambia (animal traction)	Conventional mouldboard ploughing, maize	Ripline seeding/direct seeding, maize	Ripline seeding/direct seeding, maize-legume rotation	
	All maize was planted as continuous sole crop, intercrop or in full rotation; Fertilizer level is 108 kg ha^{-1} N:40 kg ha^{-1} P_2O_5: 20 kg ha^{-1} K_20			
Southern Zim/Zam	Conventional mouldboard ploughing, maize-legume rotation	Ripline seeding maize- legume rotation	Direct seeding, maize- legume rotation	
	All maize is fully rotated with cowpeas since 2008 in Zambia and since 2012 in Zimbabwe. Since 2013, maize plots are sub-divided into 4 subplots testing 3 drought-tolerant maize varieties and one conventional control; Fertilizer levels in Zimbabwe were 80 kg ha^{-1} N:23 kg ha^{-1} P_2O_5: 12 kg ha^{-1} K_20 and in Zambia 108 kg ha^{-1} N:40 kg ha^{-1} P_2O_5: 20 kg ha^{-1} K_20			

3. Results of Cropping season 2017/2018

The results presented here are a collection of data from the 19 on-farm trial communities in cropping season 2017/2018. The general cropping season was not favorable to crop production due to irregular rainfalls which disturbed planting, germination and early crop development. On the other hand, strong rains started to fall from February onwards, which mostly favored the rotational legume crops (pigeonpea and cowpeas) at some sites. As a consequence to yields were high in this cropping season.

3.1 Rainfall data

Rainfall in central Malawi (Figure 1a) showed a fairly good distribution as compared to other sites and the overall amounts of rainfall reached more than 1800mm in some sites (Linga and Zidyana). In Chipeni and Chinguluwe, rainfalls tailed off prematurely after having experienced several long dry spells in the season thus leaving the farmers with a much shorter cropping season (Figure 1a), although overall the amounts were still high.

In Southern Malawi, rainfall distribution at most sites was very unevenly distributed only in few strong events (Figure 1b). Most disturbing was the early tail-off of rains at sites in Balaka (particularly Malula and Lemu) where farmers had no more rains after the end of February which marks a clearly shorted rainy season. At Malula, only 507mm were recorded which is much lower than the long-term average for this region (600-800 mm) while Songani and Matandika had fairly well distributed rainfalls which translated into higher yields (Figure 1b).

Eastern Zambia, was characterized by a cluster of sites in Sinda and Chipata that had almost similar distributed rainfalls with the site in Lundazi which is 180km north having higher rainfalls (Figure 1c). Common to the sites in Chipata and Sinda was the long dry spells in January 2018 which lasted up to one month in some cases (e.g. Kawalala) which had tremendous effects on maize productivity. Rainfalls in these sites were all below 600 mm which is approximately 400 mm lower than the long-term average for these sites (e.g. 800-1000 mm). At Hoya, rainfall reached 800mm which also translated into adequate crop yields (see below).

Finally, the sites in Zaka and Monze had possibly the most challenging cropping season, which was characterized by a very slow start with long dry spells and then fairly well distributed rainfalls afterwards and early tailing off, especially at Monze (Figure 1d). In fact all the early planted crops in Monze failed completely due to the erratic rainfalls, while the later planted crops gave higher crop yields. Unfortunately, all of our trials were seeded early thus leaving the farmers with sometimes miserably looking crops. Due to the high rainfalls in February and March, the overall amount of rainfall was adequate for crop production but the distribution was so un-even that farmers were strongly affected.

In conclusion, the rainfall distribution at different sites in southern Africa showed common features (low initial rainfalls and late onset, long dry spells in January followed by strong rainfall in February/March and early tailing off and termination of cropping season). These features are predicted to worsen in the years to come.

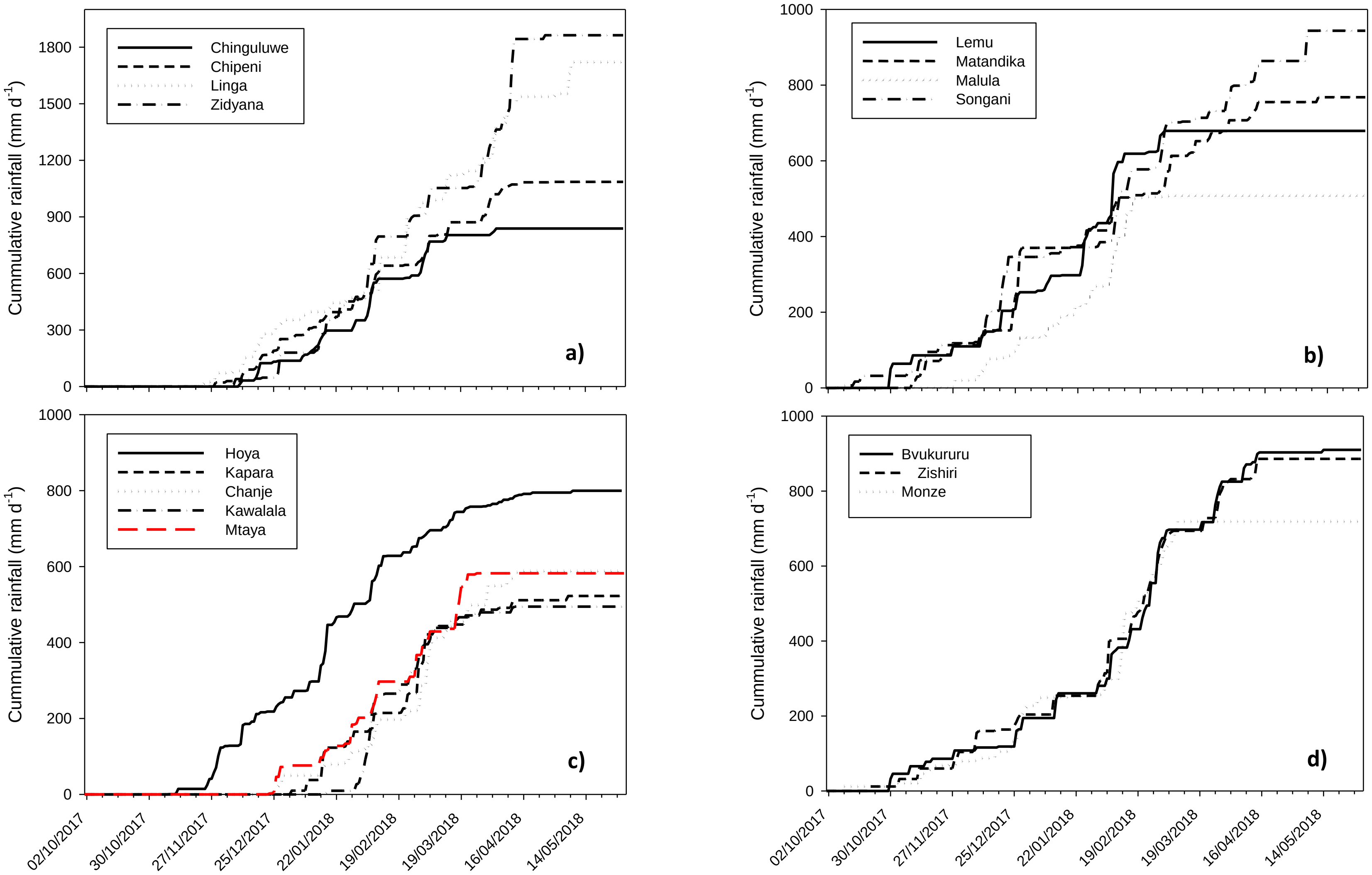

Figure 1: Cumulative rainfall distributions in Central (a), Southern (b) Malawi, Eastern Zambia (c) and southern Zimbabwe and Zambia (d)

3.2 Maize and legume yield data

3.2.1 Central Malawi

Sites in Central Malawi showed variable maize yield results in cropping season 2017/2018 (Figure 2). In four out of 5 sites there were positive yield benefits of CSA practices as compared to the conventional control treatment and the average yields were high. The reason for these relatively high yields can be explained by the relatively high rainfall amounts and a fairly well distributed rainfall regime (Figure 1a). Only at one site (Chipeni), there were no significant yield benefits to be detected. Yield benefits of up to 75% were recorded in Linga between the CA treatment with legume intercropping and the conventional control (Figure 2).

Grain legume yield benefits were also apparent in sites of central Malawi. At all sites groundnuts were seeded with pigeonpea alleys, although the pigeonpeas were seeded relatively late. The legumes are in full rotation with the maize on an annual basis. Significant yield benefits were only recorded in four out of five sites (Figure 3). Due to a better distribution of crops under CA, leading to a larger plant population, there is a clear proof of concept that the CSA practices outyield conventional treatments. Yield benefits of between 50-309% could be achieved by planting groundnuts on the flat with a closer row spacing than under conventional tillage planted groundnuts on ridges.

Additional pigeonpeas planted in alleys in these sites faced problems of late planting and pests (beetles attacking the pods). Yield results from the pigeonpeas in the doubled-up legume systems were therefore not provided by the partner.

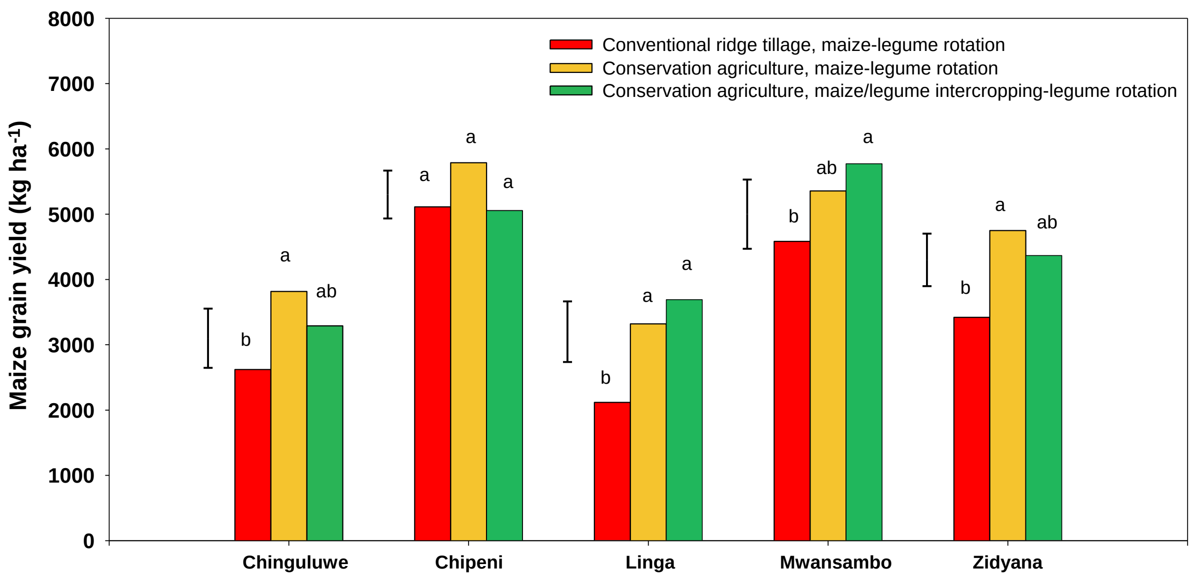

Figure 2: Maize yield response to CSA treatments in 5 on-farm communities in Central Malawi; 2017/2018; means followed by the different letters are significantly different at P<0.05 probability level; error bars show the standard error of the difference (SED).

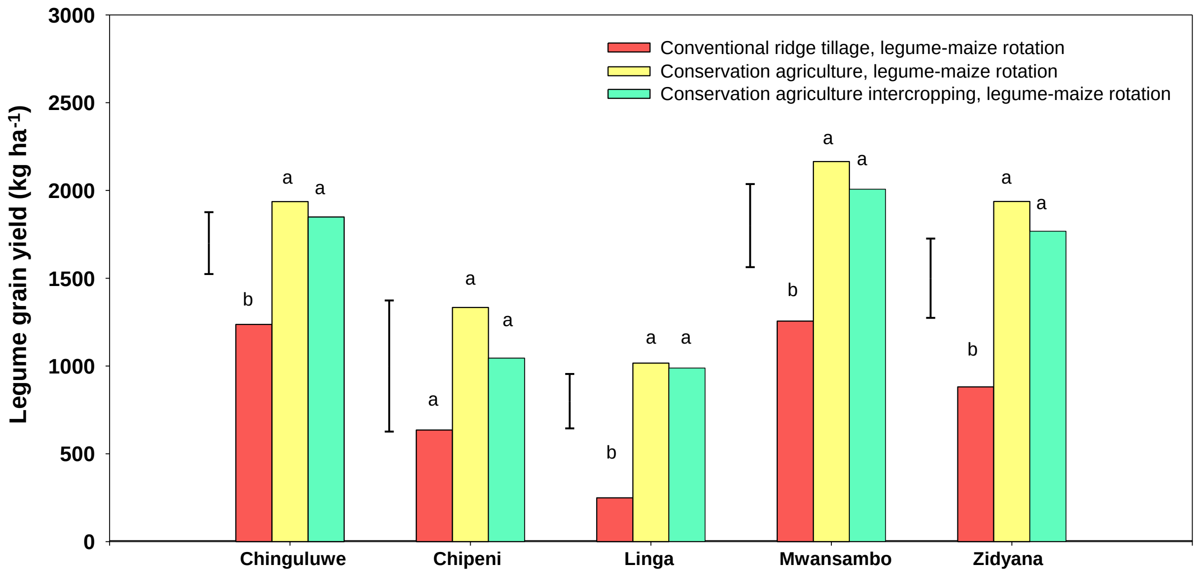

Figure 3: Legume yield response to CSA treatments in 5 on-farm communities in Central Malawi; 2017/2018; means followed by the different letters are significantly different at P<0.05 probability level; error bars show the standard error of the difference (SED).

3.2.2 Southern Malawi

Maize yield results in southern Malawi were not as uniform as the ones in central Malawi and faced many challenges during the cropping season due to long dry-spells and unevenly distributed rainfalls (Figure 1b). Two out of five sites had significant yield benefits for CSA whereas two showed no difference (Figure 4).

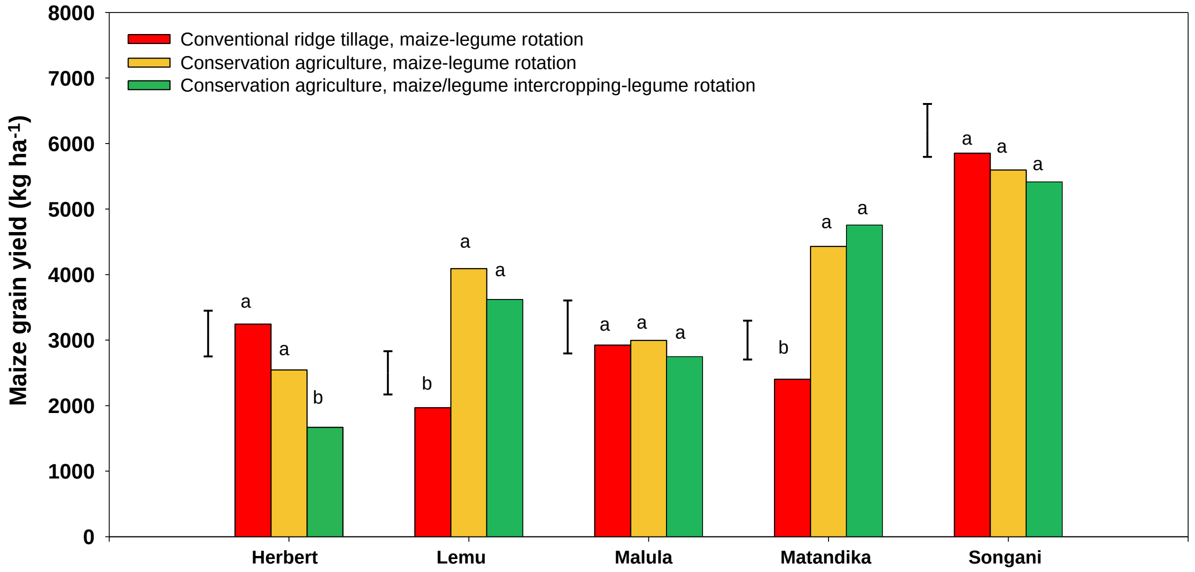

Figure 4: Maize yield response to CSA treatments in 5 on-farm communities in southern Malawi; 2017/2018; means followed by the different letters are significantly different at P<0.05 probability level; error bars show the standard error of the difference (SED).

At one site (Herbert), the conventional treatment outyielded the CA treatment with maize intercropping due to the delay in management on some of the CA trials. The extension officer at the site was new and he underestimated needs for timely weed control amongst other management steps. Greatest yield benefits and uniformity were captured in Matandika and here the yield benefits was 98% (2355 kg ha^{-1}). At Songani, where rainfall is higher and more evenly distributed, yields were similarly high as in Central Malawi (Figure 4).

Legume yield results were variable and showed a lot of differences. In Herbert the rotational legume was cowpea, in Lemu it was groundnuts in pigeonpea alleys. Malula, Matandika and Songani had pigeonpea as rotational crops. Significant yield benefits were discovered in three out five communities with greatest groundnut yield benefits in Lemu (Figure 5). The greatest yield benefit (135%) between CSA and conventional practices were found there.

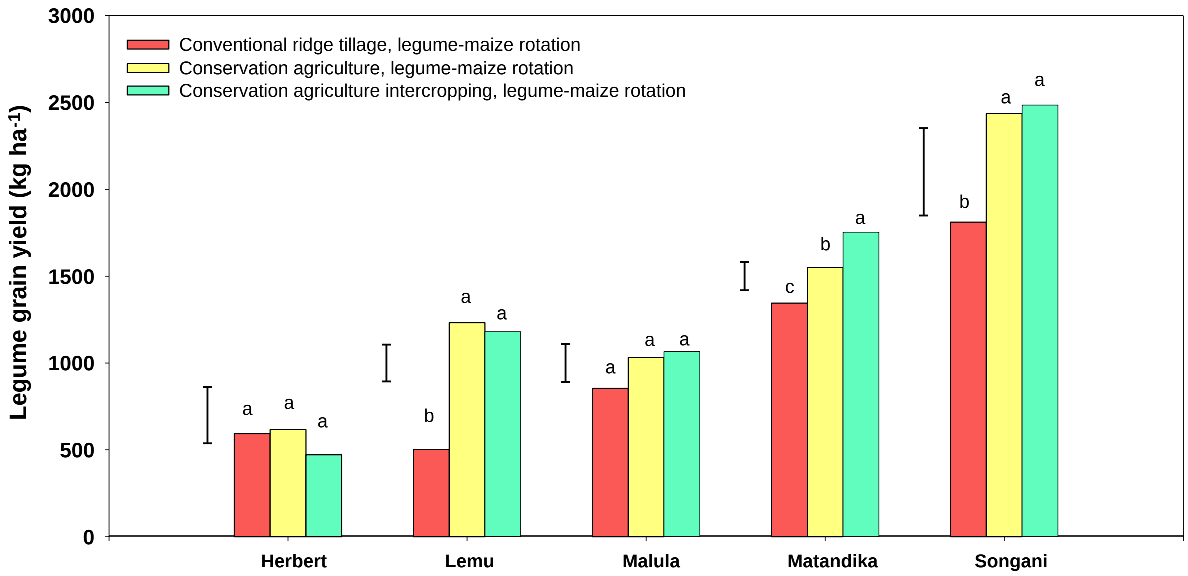

Figure 5: Legume yield response to CSA treatments in 5 on-farm communities in Southern Malawi; 2017/2018; means followed by the different letters are significantly different at P<0.05 probability level; error bars show the standard error of the difference (SED).

3.2.3 Eastern Zambia

In Eastern Zambia, treatments were tested both under manual and animal traction seeding (Figure 6 and 7). Yield benefits were apparent at two sites in manual seeding between maize-legume full rotation and the conventional control treatment (Figure 6). Intercropping was significant at one site and lower at another site depending on available soil moisture at the particular site. The site in Mtaya had an incomplete dataset which did not allow for a statistical analysis. The rotational or intercropped cowpea (data not presented) was always higher in the rotational plot due to less competition.

There was a positive trend in the animal traction systems but no significant yield benefits was discovered this year (Figure 7), which is in contrast with previous years. Yield variability between trial replicates was too high so that the SED exceeded the treatment difference.

Plate 4: Climate-smart agriculture gives appropriate yields even under drought circumstances (Central Malawi)

Plate 5: *In-sito* soil moisture measurements with farmers in Chipeni and explanations on the benefits of residue retention by TLC Zonal Manager Richard Museka (Central Malawi)

Plate 6: Successful implementation of maize-groundnut rotations (left) and cowpea intercropping (right), Central Malawi and Eastern Zambia

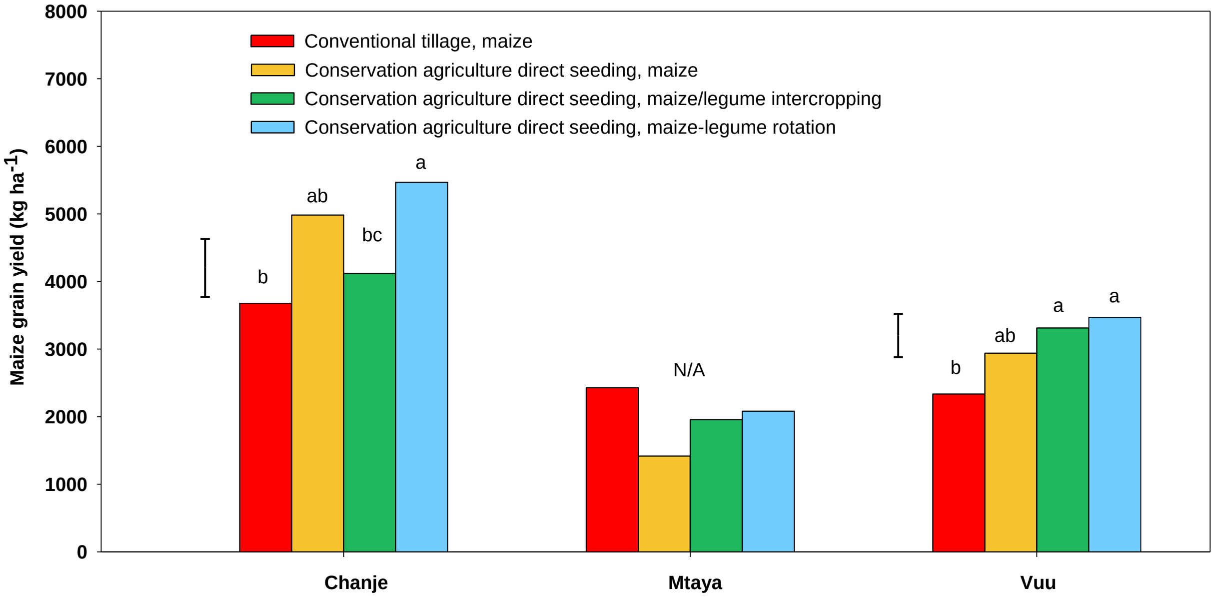

Figure 6: Maize yield response to CSA treatments in 3 on-farm communities in Eastern Zambia, planted under manual seeding in 2017/2018; means followed by the different letters are significantly different at P<0.05 probability level; error bars show the standard error of the difference (SED).

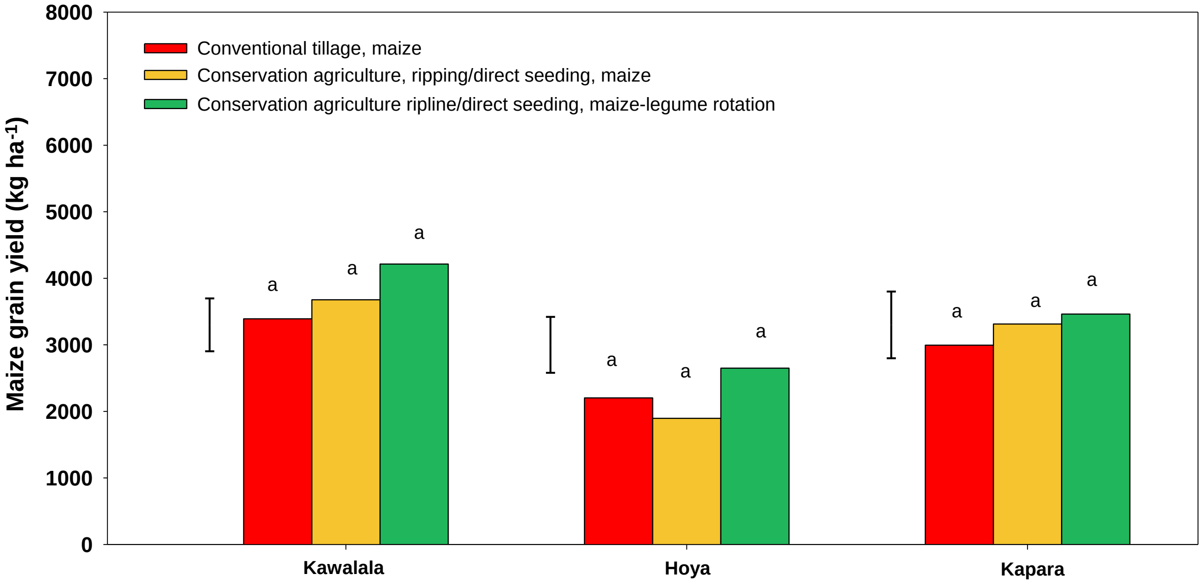

Figure 7: Maize yield response to CSA treatments in 3 on-farm communities in Eastern Zambia planted under animal traction seeding in 2017/2018; means followed by the different letters are significantly different at P<0.05 probability level; error bars show the standard error of the difference (SED).

3.2.4 Southern Zimbabwe and Southern Zambia

Significant yield benefits were found in both southern Zambia and southern Zimbabwe during cropping season 2017/2018 (Figure 8). However, the hardest hit site was the site in Monze, southern Zambia where maize was planted in November 2017 and was fully subjected to an in-season drought from Mid-December 2017 to Beginning of February 2018 (Figure 1d). This had serious consequences. The maize crops at this site were stunted and drought-prone. Despite these adverse conditions, maize yields on direct seeding exceeded the conventional tilled control practice. In the two Zimbabwe sites in Bvukururu and Zishiri, the significantly highest yielding treatment was the basin treatment as compared with the two animal traction CA treatments (Figure 8). Surprisingly high maize grain yields were achieved in this drought-prone environment which could be explained by some few rainfall showers during the dry-spells (Figure 1d) which consequently affected the site less than others. Greatest yield benefits in Monze were 49% between direct seeding and the conventional practice, while yield benefits of 77-84% were recorded between the basin treatment and ripline or direct seeding in Bvukururu and Zishiri, respectively.

Cowpea grain yield from rotational crops were significant in Monze between ripline seeding and conventional tillage (Figure 9). No significant yield benefit was recorded in the two Zimbabwean sites.

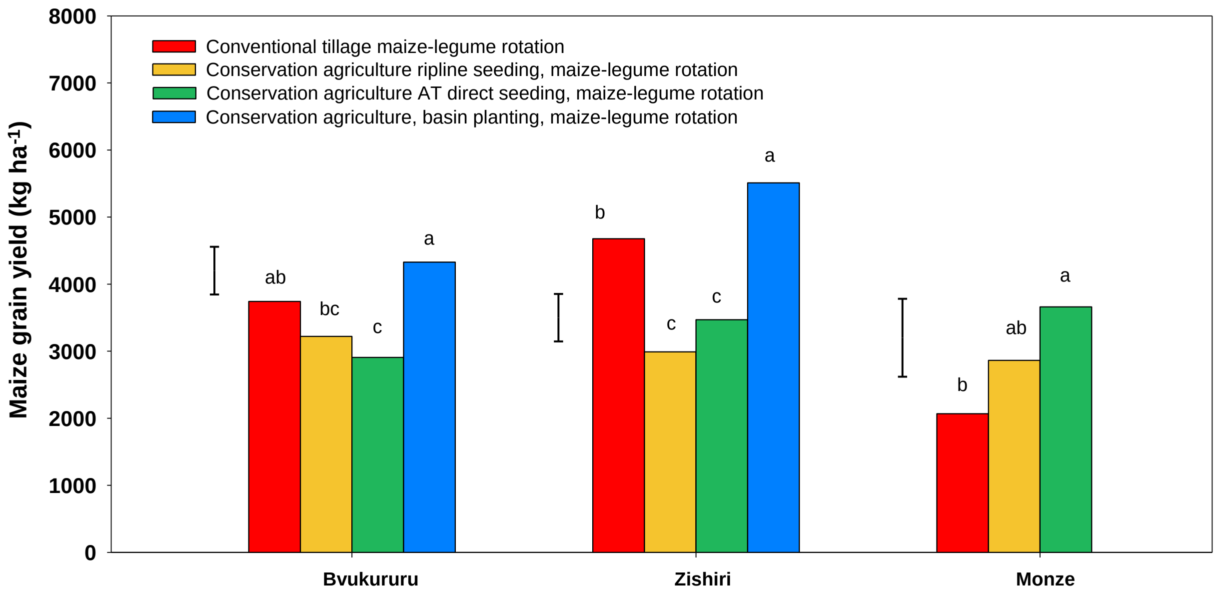

Figure 8: Maize yield response to CSA treatments in 3 on-farm communities in Southern Zimbabwe and Zambia, planted under manual and animal traction seeding in 2017/2018; means followed by the different letters are significantly different at P<0.05 probability level; error bars show the standard error of the difference (SED).

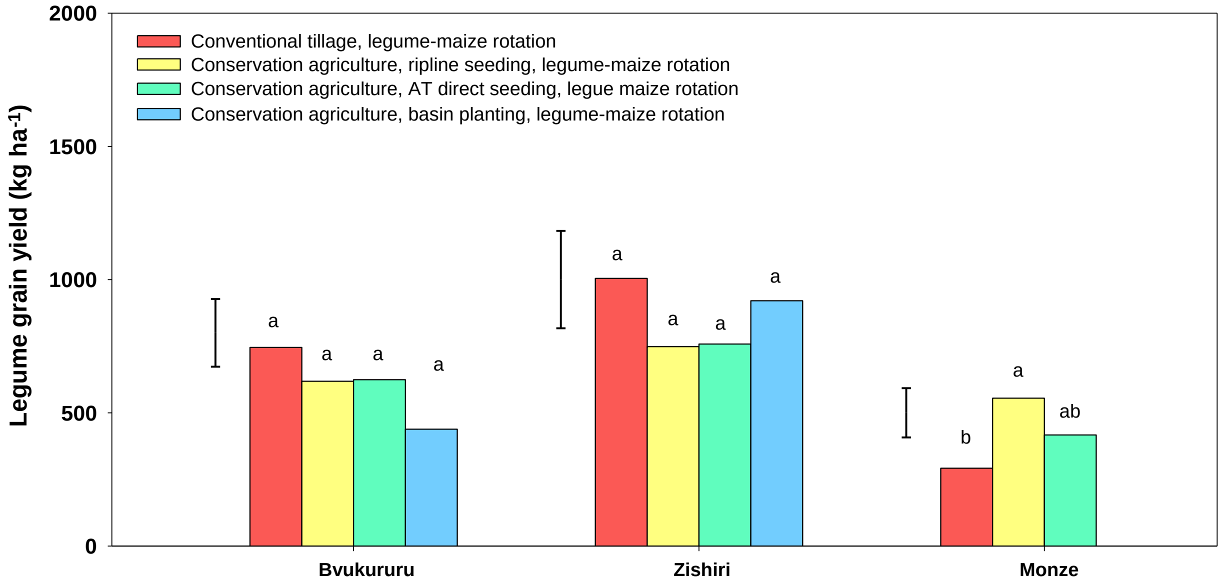

Figure 9: Legume yield response to CSA treatments in 3 on-farm communities, planted under manual and animal traction seeding in 2017/2018; means followed by the different letters are significantly different at P<0.05 probability level; error bars show the standard error of the difference (SED).

4. Soil carbon data

Soil carbon data measured on all plots in all target communities and agro-ecologies showed very variable results (Figure 10-12). In the overall average (Figure 10, 0-40 cm soil depth), only manually seeded sites in Eastern Zambia and Southern Zambia had significant carbon differences. The more diversified direct seeding in rotation and intercropping were significant from the no-tillage without diversification element in Eastern Zambia, whereas a basin treatment with rotation had significantly higher carbon values as compared to the conventional tilled treatment in Southern Zimbabwe. All other sites had no significant results (Figure 10).

In the upper soil layer (0-20 cm) only one site had significant results (Figure 11). Here again the basin treatment had significantly higher carbon percentages than the conventionally tilled and the direct seeded treatment.

In the lower soil layer (20-40 cm), the manually seeded CA treatments with intercropping and rotation in Eastern Zambia had significantly higher carbon levels (Figure 12). In Southern Zambia, animal traction direct seeding had higher carbon levels than the conventional tilled control treatment.

The reason for lack of difference in soil carbon between some treatments and sites can be explain by the lack of contrast (e.g. all treatment are continuously rotated with legumes, except in systems of Eastern Zambia), and the site specific residue management. In addition, often a trend towards increased carbon level was observed at the different sites but heterogeneity between on-farm replicates caused the statistical model failing to predict a significant carbon difference.

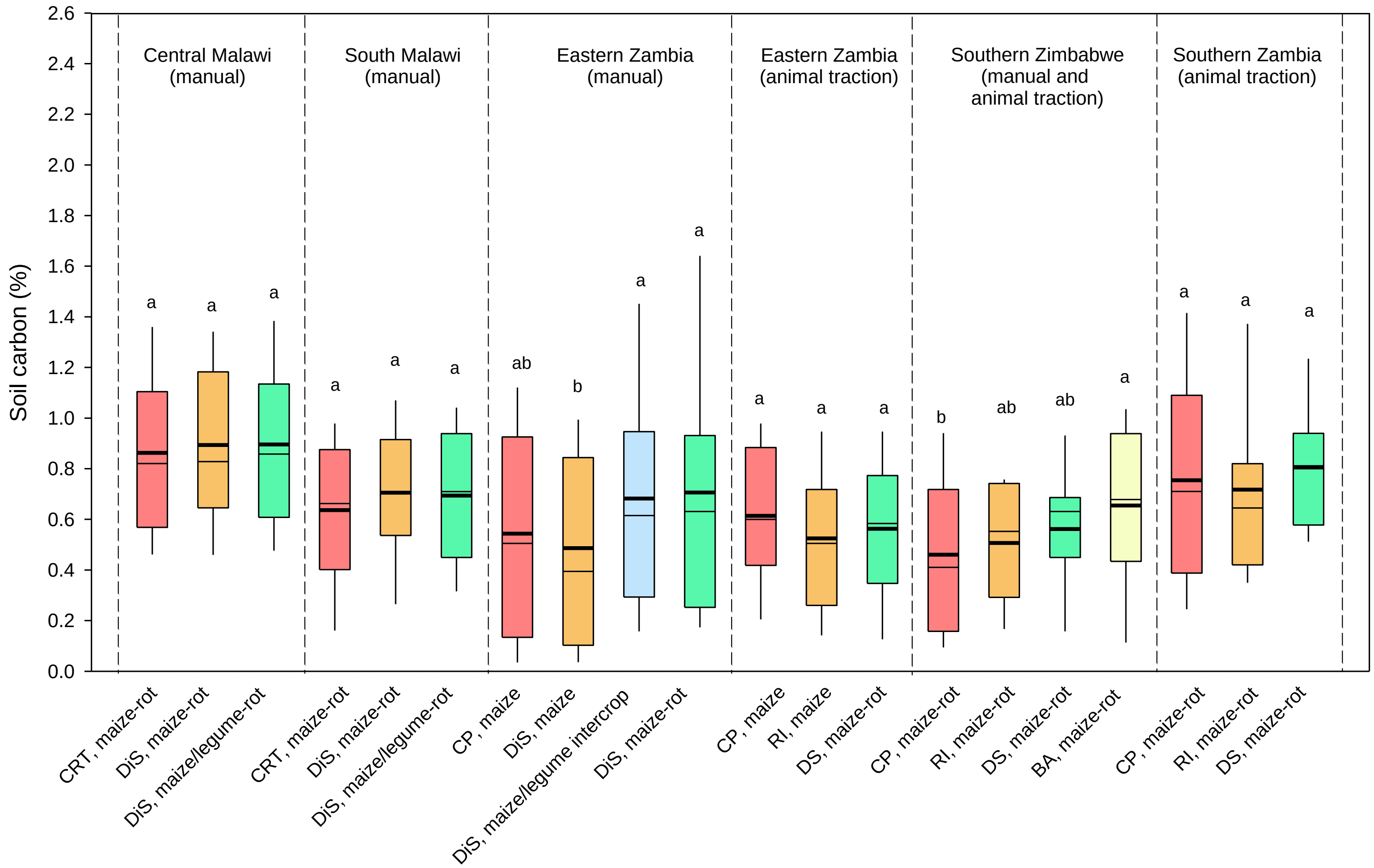

Figure 10: Soil carbon percentages in 0-40 cm soil depth in target agro-ecologies of southern Africa, cropping season 2017/2018. Means followed by the different letters are significantly different at P<0.05 probability level.

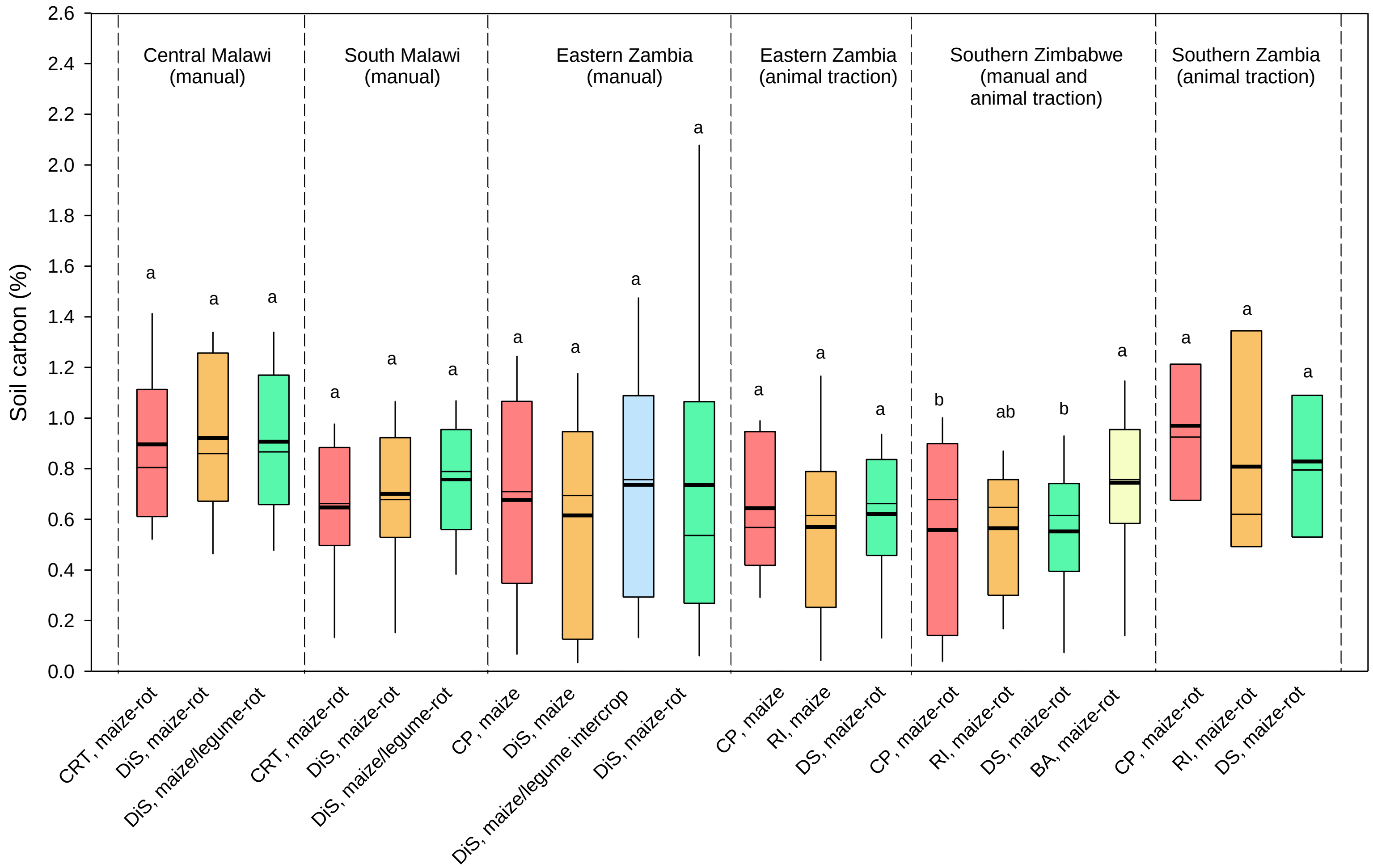

Figure 11: Soil carbon percentages in 0-20 cm soil depth in target agro-ecologies of southern Africa, cropping season 2017/2018. Means followed by the different letters are significantly different at P<0.05 probability level.

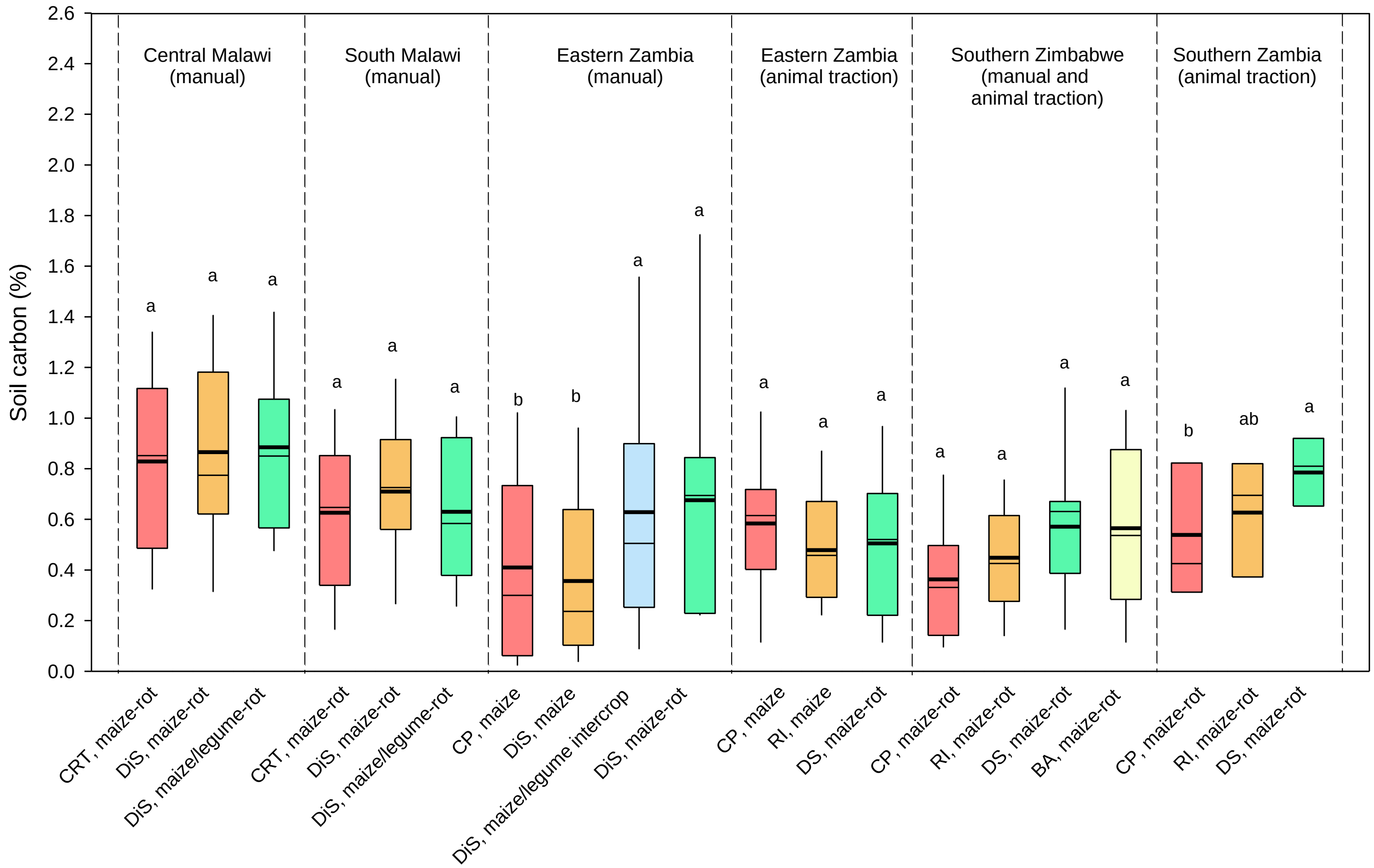

Figure 12: Soil carbon percentages in 20-40 cm soil depth in target agro-ecologies of southern Africa, cropping season 2017/2018. Means followed by the different letters are significantly different at P<0.05 probability level.

Conclusion

The biophysical results from on-farm pilot communities in 2017/2018 showed variable results. In 11 out of 19 communities there was a significant maize yield benefit when practicing CSA whereas in 9 out of 13 communities with full rotation of maize with legume systems, the legume yield under different CSA practices had significantly greater yields than the conventional control treatment. Where yields were significant, benefits of close to 100% were recorded, using the same varieties and level of fertilizer in the paired comparisons.

However, not all sites had a clear trend due to lack of uniformity on-site. The reasons for lack of uniformity were mainly heterogeneity between sites, uneven management by smallholder farmers and the Fall Armyworm, which heavily affected some sites in Southern Malawi.

Groundnut yields were extraordinary high under CSA treatment due to a better spatial arrangement between plants as compared to planting under ridge tillage where only half the population is possible. Unfortunately, only one site could harvest the pigeonpea in alley due to beetles and late planting, which influenced the grain yield.

The overall performance of trials shows great promise for CSA systems even after long dry-spells and erratic rainfalls. However, the data on the actual pilots is still incomplete and requires one more year of data.

Soil carbon data was collected alongside the trials in all 19 target communities. There were only few significant differences between cropping systems but in some there was a positive response towards CSA. This was mainly in manual systems of Eastern Zambia and in some sites in southern Zimbabwe. In all other sites the soil carbon gain was marginal or there was no gain. There are many reasons that could be responsible for the lack of carbon increase: grazing by cattle, burning by mice hunters, bush fires, and the long dry season that might have reversed the positive effect on soil carbon. Also in sites of Malawi, all cropping systems are in fully rotation with legumes and residues are burried in the conventional practices which might have equalized soil carbon gains.

The increased diversity in the 6 pilots that were introduced by this project did not lead to an increased carbon sequestration or greater resilience as yet. This will require more seasons' data and we recommend that the trials in the pilots should be continued.


Plate 7: Performance of CSA systems in eastern Zambia (left) and doubled up-legume systems with groundnuts and pigeonpea (right)


Plate 8: Mulch cover in CSA plots in Southern Malawi (left), maize-pigeonpea intercropping in Eastern Zambia


Plate 9: Pigeonpea grain yield in a drought year can improve food security and nutrition even if the maize fails (left), yield results from CSA trials (right), Eastern Zambia

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