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Conservation agriculture for increasing maize yield in vulnerable production systems in central Mozambique

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Abstract Smallholder farming under rainfed low input crop production in central Mozambique is characterised by decline in soil fertility, low yields and risks of crop failure. To revert this situation, conservation agriculture (CA) based on minimum soil disturbance, crop residue retention and crop rotations has been promoted in the region since the late 1990s. This study presents the results of a CA long term trial (LTT) initiated in the year 2006 at Sussundenga Research Station (central Mozambique). The trial monitors and evaluates the effects over time of CA practices on crop yield, soil quality, weeds, pests and diseases. The LTT is designed as a completely randomized block with four replications: one conventional tilled treatment with sole maize (*Zea mays* L.), using the mouldboard plough and residue removal and nine CA treatments with residue retention using different seeding technologies and crop rotations of maize with sunflower *(Helianthus annuus* L.) and beans (*Phaseolus vulgaris* L.). Apart from mouldboard ploughing, three different seeding technologies are studied in the LTT: direct seeding with animal traction, manual planting basins and the jab planter. Local climate at Sussundenga is wet semi-arid, the soil type is a *Haplic Lixisol* (FAO soil classification system) with a sandy loam surface soil texture. High termite activity in the area prevented the accumulation of crop residues in CA plots. Therefore, field results did not show significant differences in maize yield and soil fauna activity. Infiltration was significantly higher (16-30% higher) on CA plots where beans were previously planted in maize-sunflower-beans rotation compared to the conventional tilled treatment. This study did not show immediate benefits of CA for quick adoption by smallholder farmers. However, field observation suggest significant labour gains when fields are direct seeded instead of traditionally cultivated with the mouldboard plough.

Key words: Animal traction, seeding, termite activity

Introduction

Rainfed crop production is extensively practiced in central Mozambique by smallholder farmers; however, due to the scarce and erratic rainfall in the vast semi-arid areas, the risk of crop failure is considerable, in some areas higher than 50% (Reddy, 1986). Smallholder farmers represent 90% of the total cultivated area in the country (TIA, 2008), contributes with a quarter of the gross domestic product (INE, 2010). The fact that smallholder agriculture employs about 80% of active population, according to the national census of 2007 (INE, 2010), shows the paramount importance of this sector in the national economy.

The agriculture production in Mozambique is also characterised by very low levels of inputs; the national agriculture surveys (TIA, 2003; TIA, 2008) show that the use of improved technologies in central Mozambique is as follow: animal traction (11.4%), tractor (1.3%), chemical fertiliserfertiliserfertilisers (2.5%), pesticides (5.1%), manure (1.8%). Mather (2009) showed that the use of animal traction increases total landholding by 13.8% and crop income by 33% of the smallholder farmers. Nutrient decline is also substantial in rainfed smallholder farming. For the case of maize production, Folmer *et al*. (1998) reported a decline of nitrogen, phosphorus and potassium in the order of 47.9; 9.9; and 36.5 kg ha^{-1} $year^{-1}$, respectively. Average maize yield is between 0.4 to 1.3 tonnes ha^{-1} from the potential yield of 5 – 6.5 tonnes ha^{-1} (Howard *et al*., 2003). It seems that both irregularities of rains and low input use in smallholder farming are the most important reason for low crop production. It is, however, believed that some growth in agriculture production in the country since 1994 has primarily come from agricultural extensification (increasing the cultivated area) rather that from increasing productivity (Mather, 2009).

Irregularity of rainfall, even within the rainy period, has led to a strategy of minimising seasonal risks, rather than maximising production, whereas land availability is relatively less limiting (except in the suburban zones). Thus, spreading of sowing seems a way to spread both labour demand and risks (Schouwenaars, 1988). A similar strategy is that most farmers cultivate several different plots, some plots may be near the homestead and others quite a distance away. Since most of the cropping practices rely on hand hoe, labour availability for land preparation, seeding, weeding and harvesting are limiting crop production factor. With a hand hoe, land preparation is usually cleaning of crop residues that are piled together and burnt; seeding and weeding are also done using hand hoe, which poses a lot of pressure on the need for labour. Late planting and failure to weed in time result in considerable crop yield reduction; Howard *et al*. (2003) reported average values losses of 200 kg ha^{-1} $week^{-1}$ in late planting and 200 kg ha^{-1} for the late weeding in Ethiopia.

Shifting agriculture is still a traditional strategy to cope with decline in soil fertility among smallholder farmers in central Mozambique, and slash and burn agriculture practice for the soil preparation using a hand hoe is predominant. As a result of high risk of crop failure and low crop productivity, many rural households face food insecurity in the region. In order to avert this situation, conservation agriculture (CA) has been promoted in the region by international research and development organizations such as Sasakawa-Global (2000), Howard *et al*. (2003), CIAT (International Centre for Tropical Agriculture) and CIMMYT (International Maize and Wheat Improvement Centre) among others, including a wide number of national and international partners.

CA is a production system that is based on minimum soil disturbance, the maintenance of a cover (live or dead vegetable material) on the soil surface and crop rotation (FAO, 2001; Giller *et al*., 2009), especially aiming to maintain and improve yields, stimulate biological functioning of the soil and reduce the impact of droughts and other hazards. It is then assumed that CA principles can support the basis for a sustainable crop production in smallholder farming in central Mozambique. Therefore, in order to monitor and evaluate the effects over time of CA practices on crop yield, soil quality, weeds, pests and diseases, a long term on-station trial in CA was initiated in the year 2006 in the Sussundenga agrarian station (central Mozambique). This paper presents aspects of the progress thus far.

Materials and Methods

Site description. This study was conducted at Sussundenga Agrarian Research Station which is located in Central Mozambique (Manica province): 19º 20' latitude South; 33º 14' longitude East; 620 m of altitude. The climate in Sussundenga is wet semi-arid (Reddy, 2006), average annual rainfall 1,155 mm and potential evapotranspiration 1,386 mm; average minimum temperature is 9.5 ºC in the month of July and average maximum temperature is 29.1 ºC in the month of January (Wijnhoud, 1997).

The rains show two distinct periods, the rainy season from October to March, and the dry season and the coldest from April to September; temperature and rainfall distribution show that the wet season is hot and the dry season is relatively cooler. Recommended planting dates start at the end of November after the first rain of 25 mm in a single day or 30 mm in two consecutive days in light textured soils, or just before a good rain in heavy textured soils. The rainy season presents 89% of the total annual rains, from October to March, and the dry and cold season with 11% of the rain from April to September. High rainfall variability results in a risk of crop failure under rainfed agriculture, dry spells area likely to happen (Reddy, 1986).

The soil of the study area belongs to the group of fine textured red soils, in the high plains of Chimoio (Manica Province), originated from metamorphic acid rocks (gneiss, migmatite) in *situ* weathered. The predominant soil types at Sussundenga agrarian station are Ferralsols (haplics and rhodics), Haplic Lixisols and Haplic Acrisols. In the experimental plots, the soil types are Haplic Lixisols, according to FAO soil classification system, with a sandy loam surface soil texture, the slope is generally 1-2% (Wijnhoud, 1997). The soils of the trial site present good physical characteristics; low fertility and they are moderately acid. Therefore, good harvesting under rainfed agriculture can be granted with liming and fertiliser application, especially nitrogen and phosphorus (Wijnhoud, 1997).

The trial was laid out in a randomised block design with four replications, one conventional treatment with sole maize, using the mouldboard plough (animal traction), and nine CA treatments utilising different seeding technologies and crop rotation of sunflower, beans and maize. The trial comprises 4 replication totalling 40 plots of 24x18 square meters each plot.

Treatments. Treatments included:

T1: Check plot (CP); traditional farmers practice using the mouldboard plough with animal traction, maize as a sole crop, no residue retention, stubbles incorporated

T2: Direct seeding with animal drawn seeder (DS), maize as a sole crop, residue retention (at a rate of 2.5-3 t ha^{-1} in the first year, thereafter all crop residues retained)

T3: Basin (BA), maize as a sole crop, residue retention

T4: Jab planter (JP), maize as a sole crop, residue retention

T5: Direct seeding with animal drawn seeder (MS), maize with sunflower as a relay crop, residue retention

T6: Crop rotation A1 (A1M): direct seeding with animal drawn seeder, maize-sunflower rotation (Phase1), residue retention; Maize (2006)-Sunflower-Maize

T7: Crop rotation A2 (A2S): direct seeding with animal drawn seeder, maize-sunflower rotation (Phase 2), residue retention; Sunflower (2006)-Maize-Sunflower

T8: Crop rotation B1 (B1M): direct seeding with animal drawn seeder, maize-sunflower–beans rotation (Phase 1), residue retention; Maize (2006)-Sunflower-Beans

T9: Crop rotation B2 (B2S): direct seeding with animal drawn seeder, maize-sunflower-beans rotation (Phase 2), residue retention; Sunflower (2006)-Beans-Maize.

T10: Crop rotation B3 (B3B): direct seeding with animal drawn seeder, maize-sunflower-beans rotation (Phase 3), residue retention; Beans (2006)-Maize-Sunflower.

Seeding technologies. Four seeding technologies were studied in the trial on CA in Sussundenga, the mouldboard plough with animal traction, the direct seeding with animal traction, the basins, and the jab planter.

Mouldboard plough with animal traction (CP): traditional tillage treatment was carried out with a mouldboard plough before planting. The tillage depth was about 10-15 cm and was followed by a hand seeding of sole maize and basal fertiliserfertiliser application. The seeding depth was about 10 cm depth.

Direct Seeding (DS): a technique that refers to seeding/ planting without ploughing or cultivation to prepare a seedbed. Direct seeding with animal traction direct seeder allowed a simultaneous application of basal fertiliserfertiliser at a depth of 10 cm. The direct seeder was prior calibrated to deliver the required seed and amount of fertiliserfertiliser.

Basins (BA): the basins were dug with the use of a hand hoe before seeding. The basin were approximately (15cm x 15cm) and 15 cm deep, with spacing of 90 cm between rows and 50 cm between basins in the row; the basin were dug before the starting of the cropping season.

Jab planter (JP): a manual jab planter allowed a direct seeding of maize and simultaneous application of basal fertiliser at a depth of about 10 cm. The jab planter was prior regulated to deliver the required seed and amount of fertiliser.

Data collection and trial management. Crop data were collected through direct observation and registration of crop phenology stages and crop management. In the maize crop, spacing was 90 cm between rows and 50 cm between planting stations, aiming at a seed rate of about 44,444 plant ha^{-1}. For sunflower a spacing of 90 cm between rows and 20 cm between plants was adopted (55,000 plants ha^{-1}). In beans the spacing was 45 cm between rows and 15 cm between plants aiming at 148,000 plant ha^{-1}.

Top dressing of 200 kg ha^{-1} of urea was applied as split application, 4 and 7 weeks after planting in maize and sunflower and not for beans. Weed control at seeding was done using a herbicide glyphosate at 3 litres ha^{-1} Weed control after crop emergence in the CA plots was manual. Crop yield (grain and above ground biomass) were measured.

Infiltration. Infiltration was measured using a mini-rainfall simulator described by Thierfelder *et al*. (2005). The mini-rainfall generates raindrops enabled by syringes. The mini-rainfall simulator is equipped with a Mariotte flask where rain intensity can be calibrated. The simulations were conducted during 60 minutes, with collection of run-off each 5 minutes and the final run-off; a defined soil surface area (32 cm x 40 cm) was irrigated, rain intensity during the measurements were allowed to be between 95 - 105 mm hr^{-1}. Syringes of 2.75 mm were used which lead to a mass of raindrop of 0.00992 g and a final velocity of raindrop of 4.04 m s^{-1} (Thierfelder *et al*., 2005). Three measurements were conducted per plot; the mini-rainfall simulator was installed at a height of about 1 m inside the plot boundary.

Crop residues and weeds were carefully removed from the soil surface before measurement. The simulator was calibrated at the beginning and at the end of each measurement by collecting and measuring a defined rain period of 1 minute.

Soil fauna and activity. Soil fauna activity in the trial plots was assessed by counting the (i) below ground soil fauna and (ii) termites holes on the soil surface. Below ground soil fauna was assessed by collecting and counting below ground organisms (namely termites, earthworms, beetle larvae, centipedes and other visible insects) on conservation agriculture and conventionally ploughed treatments. Soil samples were collected from the field when moist, in a monolith 25x25 cm each 10 cm up to 30 cm depth.

Intense termite's activities in the study area resulted that termites consumed all crop residues before the next cropping season started. Therefore, it was initiated termite's activity assessment through termite's holes counting; it was used a metal frame with (32 cm x 40 cm) of surface area. The diameters of the termites' holes were approximately 0.5 to 1.5 mm (Putz, 2008). In total 15 samples were taken per plot.

To assess the impact of different treatments, crop yield, measured total runoff and soil fauna activity were assessed using the analysis of variance (ANOVA) following the general linear model (GLM) procedure at the probability level of $P<0.05$; were significance was detected, then the LSD (Least Significant Difference method) test was used to compare the means using Statistix 9.0 model (Statistix, 2008).

Results and Discussion

Maize yield. Maize crop yield under continuous maize cropping (Table 1) did not significantly differ among the three CA treatments and the traditional tillage studied, during the three consecutive years. The assessment was done for the grain yield as for the total above ground biomass except grain (the stover) from the second year

Table 1. Maize yield* (grain and stover) for three consecutive harvesting years.

Treatment	Description	Grain yield (Kg/ha)						Stover yield (Kg/ha)					
		2008**		2009		2010		2008**		2009		2010	
CP	Check Plot, traditional farmers practice	777.8	a	3634.0	b	1266.6	c	1117.0	a	3849.3	b	1941.1	c
DS	Directseeding, continuous maize	924.0	a	3810.0	b	1067.8	c	1363.3	a	4924.8	b	1703.2	c
BA	Basins, continuous maize	1058.0	a	3353.3	b	1163.5	c	1472.8	a	3767.3	b	1842.1	c
JP	Jab Planter, continuous maize	1032.5	a	3827.3	b	939.6	c	1478.0	a	4492.3	b	1863.8	c

* Treatments means within the same column followed by the same letter are not significantly different at probability leve of 0.05.
** Data from Christian Thierfelder, CIMMYT, Harare

after the starting of the trial. The yield variability between years is as a result mainly of rainfall variability; rain distribution was different and dry spells of different durations occurred and impacted differently the cropping seasons.

Maize (grain) yield (Table 2) was not different between the treatments in the harvest years 2008 and 2009, in the harvest year 2010 maize yield in the maize-sunflower rotation (A_M) was significantly higher than that of maize-sunflower intercropping (MS). Competition between maize and sunflower is a probable reason in this case, since water stress may have retarded maize development in this year.

Water infiltration. Results of the infiltration measurements (Table 3), show changes through the years, while in 2008 (the second year with the trial) no significant differences were detected between treatments, in 2009 and 2010 some differences appeared. In 2008, traditional tillage treatment (CP) produced more run-off than direct seeded treatment (DS) and cumulatively compared to basins (BA) in the year 2010. As expected, tillage resulted in soil compaction thus reducing its capacity to infiltrate water. It is, therefore, not completely clear why JP treatment was not different from CP. Therefore, the difference in the infiltration patterns did not produce important effect in crop yield, crop yield was not significantly different.

Using data from the crop rotation treatments (Table 4), water infiltration was significantly improved under CA were previous crop was beans (16-30% higher) compared to the traditionally tilled treatment. Although, the improved infiltration in B_M treatments was not reflected in better soil water storage comparatively to CP treatment as would be expected. Though, the results show the potential of this crop rotation type to improve water infiltration.

Soil fauna activity. The results on termites' activities 2008 - 2010 and below ground soil fauna activity 2009 – 2010 are presented in Tables 5 and 6, respectively.

The results on termites' activities (Table 5) show clear differences between the traditional tillage treatment (CP) and the CA treatments; in the year 2009. The differences were observed only between CP and two CA treatments, direct seeding (DS) and jab planter (JP) treatments but not with basin treatment (BA). Surprisingly, in the year 2010, differences did not occur between all treatments. It is possible that the prevailing soil and weather conditions during different measurements have influenced the final

Table 2. Maize yield* (grain and stover) for three consecutive harvesting years.

Treatment*	Description	Grain yield (Kg/ha)						Stover yield (Kg/ha)					
		2008**		2009		2010		2008**		2009		2010	
CP	Check Plot, traditional farmers practice	777.8	a	3634.0	a	1266.6	ab	1117.0	b	3849.3	b	1941.1	b
MS	Direct seeding, maize with sunflower as relay crop	1074.5	a	3624.3	a	985.0	b	1413.8	ab	4332.8	ab	1534.0	b
A_M	Direct seeding maize in rotation with sunflower	1226.0	a	4131.8	a	1708.8	a	1674.5	ab	5585.8	a	3070.4	a
B_M	Direct seeded maize after beans in the rotation maize-sunflower-beans	1196.8	a	3648.8	a	1413.0	ab	2133.5	a	4605.0	ab	2348.7	ab

* Treatments means within the same column followed by the same letter are not significantly different at probability leve of 0.05.
** Data from Christian Thierfelder, CIMMYT, Harare

Table 3. Accumulated run-off in 60 minutes from the mini-rainfall simulator measured in three consecutive years (2008-2010). Simulated rain intensity was 100±5 $mm.h^{-1}$

Treatment*	Description	Total run-off in 60 minutes (mm)					
		2008**		2009		2010	
CP	Check Plot, traditional farmers practice	43.6	a	57.3	a	59.6	a
DS	Direct seeding, continuous maize	43.8	a	41.1	b	45.2	c
BA	Basins, continuous maize	60.1	a	55.9	ab	47.7	bc
JP	Jab Planter, continuous maize	53.6	a	54.7	ab	56.0	ab

* Treatments means within the same column followed by the same letter are not significantly different at probability leve of 0.05.
** Data from (Putz, 2008)

Table 4. Average results on accumulated run-off in 60 minutes from the mini-rainfall simulator measured in three consecutive years (2008-2010).

Treatment*	Description	Total run-off in 60 minutes (mm)					
		2008**		2009		2010	
CP	Check Plot, traditional farmers practice	43.6	a	57.3	a	59.6	a
MS	Direct seeding, maize with sunflower as relay crop	59.2	a	47.9	ab	51.0	ab
A_M	Direct seeding maize in rotation with sunflower	52.2	a	53.9	a	51.7	ab
B_M	Direct seeded maize after beans in the rotation maize-sunflower-beans	48.4	a	39.2	b	49.6	b

* Treatments means within the same column followed by the same letter are not significantly different at probability leve of 0.05.
** Data from (Putz, 2008)

Table 5. Average termites' holes per square meter as an indicator of termites' activities Measurements were conducted in February 2008, March-April 2009 and May 2010.

Treatment	Description	Termites' holes per square meter *					
		2008**		2009		2010	
CP	Check Plot, traditional farmers practice	8.2	b	56.3	b	7.8	a
DS	Direct seeding, continuous maize	53.2	a	81.5	a	9.3	a
BA	Basins, continuous maize	58.3	a	70.0	ab	12.0	a
JP	Jab Planter, continuous maize	64.6	a	78.8	a	10.0	a

* Treatments means within the same column followed by the same letter are not significantly different at probability leve of 0.05.
** Data from (Putz, 2008)

results. Field observation suggest that low presence of crop residues, drier soil conditions hot or relatively cold weather do not favour surface termites' activity; wet soil conditions and relatively cooler weather if crop residues are present were the observed conditions for intense termites' activities. Nevertheless, the termites in the study area preferred dry crop residues, in case of food shortage (no crop residues) termites' started eating the standing plants at the first signal of mulching. So that, dry conditions with dry spells alternated with small amounts of rain showers could create condition for short outbreak o termites' attacking the weak living plants. During this study, termites attack on living plants did not seem alarming. However, it was evident that plots under CA had comparatively more termites' activity, since crop residues were left in the plots after harvesting, while in CP plots crop residues were removed. Nevertheless, the conducted study does not allow a clear separation of the impact of termites' activity from other parameters in soil properties. (Leonard and Rajot, 2001) reported that termites' holes influences the infiltration rate through interception of surface run-off; during this study, run-off interception by the termites' boles was visible in the rainfall simulations for infiltration measurements.

Below ground soil fauna results (Table 6) show no significant differences in the soil top 10 cm; however, differences were found for the depth 0-30 cm in termites between basin (BA) and direct seeded treatments in the year 2010, with higher termites' number in BA, in the same way to a total number of soil organisms. Surprisingly, differences in total number of earthworms were observed between BA and jap planter (JP) treatments with lower number of earthworms in BA. High spatial variability was evident, as reflected by standard error, as presented in Table 6 for the example of earthworms recorded in February 2010 (standard error not shown). It seems that no clear impact was evident in below ground fauna due to the practice of CA in fields severely affected by termites under continuous maize production compared to the studied traditional tillage.

Below ground soil fauna record difference were not evident as well on the studied crop rotation treatments (results not shown). It needs to be noted that the present study compares the traditional tillage with a CA that are

Table 6. Below ground soil fauna, average number of organisms per square meter and type, record conducted in March 2009 and February 2010.

Year	Treatment*	Description	Soil depth 0-10 cm			Soil depth 0-30 cm		
			Termites	Earthworms	Total**	Termites	Earthworms	Total**
2009	CP	Check Plot, traditional farmers practice	57.5 a	2.5 a	158.8 a	237.3 a	5.5 ab	380.3 a
	DS	Direct seeding, continuous maize	36.3 a	3.8 a	169.5 a	89.5 a	8.0 ab	428.0 a
	BA	Basins, continuous maize	42.5 a	1.3 a	180.0 a	150.8 a	1.3 b	352.3 a
	JP	Jab Planter, continuous maize	45.5 a	5.3 a	152.0 a	132.0 a	18.5 a	365.3 a
2010	CP	Direct seeding, maize with sunflower as relay crop	78.7 a	9.3 a	149.3 a	273.4 ab	12.0 a	369.3 ab
	DS	Direct seeding maize in rotation with sunflower	76.0 a	4.0 a	149.3 a	192.0 b	18.7 a	324.0 b
	BA	Direct seeded maize after beans in the rotation maize-sunflower-beans	62.7 a	14.7 a	170.7 a	338.7 a	20.0 a	474.7 a
	JP	High Fertilized Plot trial	125.4 a	10.7 a	221.3 a	290.7 ab	20.0 a	428.0 ab

* Treatments means within the same column and year followed by the same letter are not significantly different at probability level (Alpha=0.05).
** Total refers to all soil fauna found in the indicated soil depth

Table 7. Average soil organic matter (SOM), total nitrogen and available phosphorus P-Olsen measured in July 2009, at the end of the third crop season from beginning of the long-term trial.

Treatment*	Description	Soil depth 0-10 cm			Soil depth 10-20 cm		
		SOM (%)	Total N (%	-Olsen (ppn	SOM (%)	Total N (%)	-Olsen (ppn
CP	Check Plot, traditional farmers practice	1.48 b	0.04 a	23.2 a	1.44 a	0.04 a	14.9 a
MS	Direct seeding, maize with sunflower as relay crop	1.76 a	0.05 a	12.1 a	1.61 a	0.04 a	11.5 a
A_M	Direct seeding maize in rotation with sunflower	1.63 ab	0.05 a	11.1 a	1.54 a	0.05 a	10.6 a
B_M	Direct seeded maize after beans in the rotation maize-sunflower-beans	1.57 ab	0.05 a	11.6 a	1.39 a	0.06 a	14.3 a

* Treatments means within the same column followed by the same letter are not significantly different at probability leve of (Alpha=0.05).

separated by a narrow difference. The tested CA techniques, due to high termites' activities, lacked one of its basic components, the crop residues cover; the studied traditional tillage, very different from conventional tillage, is regarded as a reduced tillage derived from the low tillage frequency (only once, before seeding) not followed by a secondary tillage, the tillage depth (10-15 cm), and the use of animal traction instead of heavy tractors.

Soil organic matter, nitrogen and phosphorus. Soil fertility parameters from July 2009, after three cropping seasons from the beginning of the long-term trial in CA agriculture are shown in Table 7. Only in the top 10 cm soil organic matter were significantly higher in MS treatment (maize-sunflower intercropping) than in CP treatment (traditional tillage). It seem that the maize-sunflower intercropping produced more total organic matter and that in general, high termites' activities hinder soil organic matter accumulation and do not contribute to an increase in soil fertility. The studied soil parameters (organic matter, total nitrogen and labile phosphorus) were not different in the crop rotation treatments compared to traditionally till one.

Conclusion

This study presents the results of a long term trial in conservation agriculture in Sussundenga, central Mozambique, from the year 2008 to 2010; maize crop under rainfed production was assessed with special emphasis to grain yield and stover. In the trial, continuous maize cropping and maize in rotation with sunflower and beans, were used with different seeding technologies.

(i) The results with four years of the long term trial in CA, initiated in the year 2006 in Sussuendenga, in which CA plots lacked crop residues cover as a result of high termites' activities, did not show significant differences in maize yield compared to the traditional practice.
(ii) This research did not show significant improvements in soil fertility indicators with the practice of CA, the high termites' activity in the study area was the most evident reason for these results.
(iii) The field results that showed no yield differences between the traditional tillage and different seeding

technologies under CA, without crop residues, led to the conclusion that CA practices under the study conditions will not favour short term benefits. So, the adoption process among smallholder farmers, in central Mozambique, may face challenges as they oversee substantial and immediate results.

(iv) Field observations in the long term trial with CA in Sussundenga suggested that the use of animal traction as a low energy option, in direct seeding, will contribute to labour saving at seeding. In this way, direct seeding will reduce the risk associated with a later or too early planting (spreading of sowing) traditionally practiced in smallholder farming to manage the risk of crop failure.

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