Conservation agriculture in northern Zambia

Effects of conservation agriculture on soil organic matter, soil water content and crop yield in Mpika district

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Soil Physics and Land Management Group

Conservation agriculture in northern Zambia – effects of conservation agriculture on soil organic matter, soil water content and crop yield in Mpika district

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1. Introduction

Zambia's population figures are expected to triple by 2050, according to predictions of the UN (United Nations, 2015). The current agricultural yield growth will likely not be sufficient to keep up with this rapid population rise, as farmers are facing numerous problems regarding crop production (Searchinger, et al., 2015).
Large areas in the southern and eastern part of the country suffer from decreased crop yield because of reduced soil water content or nutrient deficiency. Reduced soil water content is mainly a problem in the eastern part of Zambia, while nutrient deficiency is mainly a problem in the southern part of Zambia (Zingore, et al., 2005). Soils here are mainly nutrient-poor clayish soils. Another challenge for Zambian farmers is the imminent threat of climate change, which they notice through shifting rainfall patterns and the increasing frequency of droughts (Lobell, et al., 2008). To battle these changes in climate farmers need to adapt their way of farming to climate change, or their production could decrease significantly (Chabala, et al., , 2013).
A lot of research has been done to find ways to improve crop yield by using conservation agriculture in Zambia (Baudron, 2007; Thierfelder et al., 2013). In earlier studies, conservation agriculture (CA) has proven its ability to reduce or completely stop the decline of organic matter content and soil structure, as well as increasing infiltration and reducing evaporation (Derpsch et al., 1986; Haggblade & Tembo, 2003)**.** Conservation agriculture as a cropping system has three important principles: minimal mechanical soil disturbance, permanent organic soil cover and crop rotation (FAO, 2017).

Conservation agriculture in Zambia has gained importance since 1990, with increasing attention being paid to improving production capacity and crop yield (Mafongoyaet al., 2006). Nowadays, the Zambian government and NGO's are advising smallholder farmers to use a range of techniques to improve nutrients in the soil, such as crop rotation, mulching, ripping, fertility trenches and planting basins. Several surveys have been conducted to compare the crop yield differences between farmers who practice CA and farmers that do not. The outcome of these studies can be summarized as: farmers who do practice some form of conservation agriculture tend to have higher crop yield than traditional farmers (Baudron et al., 2007; Thierfelder et al., 2013; Kuntlusha et al., 2014). Application of conservation agriculture per the given FAO definitions can be difficult for farmers in Zambia as they use crop residues for feeding cattle, building or as fuel, or because they are afraid of termites that might enter their fields if they leave the crop residues (Baudron et al., 2007). The loss of organic matter that occurs in this way, combined with tillage by farmers that do not use CA, increases soil degradation and results in declining yields (Derpsch et al., 1991; Thierfelder et al., 2013).

Most research tends to focus on yield differences and less research has been done on the effects of conservation tillage on the amount of nutrients in the soil and adaptation of CA.
The objective of this research is to help improve the knowledge of soil fertility of small-scale farmers in Zambia's Mpika district by investigating the effects of current CA practices on soil water content, organic matter content and crop yield, investigate what motives exist for using CA or conventional farming methods and determine whether improvement through other soil conservation measures is possible.
To achieve this objective, the main research question to be answered is:
What are the effects and possible improvements of current CA practices made by small scale farmers in Zambia's Mpika district on organic matter, soil water content and crop yield?

Measuring soil water content (SWC) can tell many things about the characteristics and health of a soil, and SWC can be measured in several ways. in this research the gravimetric SWC has been measured (Bitteli, 2011).
Soil organic matter (SOM) is an important characteristic of a soil. Increasing SOM through management practices results in higher yields, two of the management practices that have shown to increase SOM are leaving crop residues on the soil and seeding without tillage (Kassam, et al., 2009).

SOM also increases soil porosity. Increased porosity allows for more rainfall infiltration in the soil. The result of this is that plants can grow longer before they suffer from water stress in dry conditions (Kassam, et al., 2009).

Based on this the following sub-questions were formulated:

- What are the effects of current CA practices made by small-scale farmers in Zambia's Mpika district, both in drylands and wetlands, on the amount of organic matter and soil water content
- What effects on soil quality and crop yield are local small-scale farmers in Zambia's Mpika district experiencing when using CA compared to conventional farming?
- What other water conservation measures would be realistically applicable in Zambia's Mpika district to increase soil properties?

To answer these questions an experiment was set up in Mpika, details on this experiment can be found in chapter 2.
A description of the study area, measurement methods and data analysis will be given, after which the results are presented. In chapter 3 and 4 the results are further discussed based on the literature. Based on the discussion, conclusions will be drawn in the final chapter.

2. Materials and methods

2.1 Study area

The Zambian ministry of agriculture has divided the country into three Agro-ecological zones (AEZs) (Gatere, et al., 2013). This division is based on the amount of rainfall that each zone receives. AEZ 1 receives less than 700 mm of rainfall, AEZ 2 receives between 800 and 1200 mm and AEZ 3 receives more than 1200 mm of rainfall annually. The study area is in AEZ 2. The soils in this AEZ are mainly clayey and sandy-loam soils (Gatere, et al., 2013).
This study was conducted in the Mpika district, which is in the Northern province of Zambia. This 45,000-sq. kilometre province has a humid subtropical climate. The elevation ranges between 1000 and 1400 meters above sea level and the growing season is 120 days. The northern part of the district is a plateau, while the southern part consists of the hillier Muchinga. Most of the visited farmers were located just south-west of the town Mpika, although some farmers also had their plot on the north and east side of Mpika.
CA is practiced in the Mpika district, but different farmers use different parts of the CA concept (Haggblade & Tembo, 2003). The most popular CA practice in Mpika is mulching (Baudron et al., 2007).

2.2 Data collection and methodology

As described earlier the aim of this research is to help improve the soil fertility of small-scale farmers in Zambia's Mpika district by investigating the effects of current CA practices on soil water content, organic matter content and crop yield. To achieve this objective, soil samples were taken from 40 fields, from 40 different farmers. On 20 of these fields, CA techniques were used by the farmer, on the other 20 no CA techniques were used.
In this research, a CA farmer has been defined as a farmer who has been applying the CA practices of not ploughing, permanent soil cover and in some cases crop rotation for a minimum of three consecutive years.
Two types of farmers can be found in Mpika; those farming in valleys near streams of water that run all year (henceforth called wetlands), and farmers located on the dry hills (henceforth called drylands). Both groups of 20 farmers were divided into two groups; 10 in the drylands and 10 in the wetlands. Data from a local farmers' organization, COMACO, was used to identify farmers that practiced CA. Selected farmers were those that had been practicing CA for longer periods of time, as well as the ones who shifted to this practice a shorter while ago (with three years as minimum).
The farmers who were not practicing CA were identified using data from a local NGO, called FWHC. Once the names and locations of the farmers were known, soil samples and interviews could be taken. The soil samples were taken by using a 60cm hand drill, with which two samples of soil for each farmer were collected in two separate and clearly labelled plastic bags. The samples were collected at 20 to 40cm depth. The two soil samples were taken from two random places at the same plot.

2.2.1 Analysis of soil samples

The 80 soil samples were taken to the soil labs of Mt. Makulu Research Centre, where they were analysed for both SWC and SOM. These two soil characteristics are influenced by applying conservation agriculture, so they are a good way to measure the effect that CA has (Derpsch, 1999; Sayre 1998). Each of the samples was first tested for SWC and after that the SOM was determined.
To analyse the samples for SWC, the samples were put in clearly labelled containers, which had been weighed first providing W_r. The samples were individually weighed. This weight was called the total weight (W_t). After this first weighing, the samples were dried in an oven at 105 degrees centigrade for 12 hours. The first measurement provided the total weight (W_t) of the sample. This includes the container, the soil and the water in the soil. After drying, the second measurement provided the W_t

minus the weight of the water (W_w). This was called the dry weight (W_d). In other words, the amount of water in the soil was calculated using formula 1:

Formula 1: $W_w = W_t - W_d$ *(in grams)*

The last measurement, the weighing of the containers that was used to collect the samples, was done to calculate the soil water content as a percentage of the total soil weight. When the weight of the containers (W_r) was known, the soil water content (SWC) was calculated using formula 2:

Formula 2: $SWC = \frac{W_w - W_r}{W_t - W_r} * 100$ *(in %)*

The soil samples were also analysed to find the SOM. For this, the so-called loss on ignition method was used (Huang, et al., 2009). The first step in this process was dividing the already dried soil samples in clearly labelled porcelain tins, which had been weighed before the soil was added. The weight of the tins was called G_{tin}. After the soil was added to the tin, the weight was measured again, this was called G_t. The tins with soil were then heated to 400 degrees centigrade for the duration of one hour using a furnace. The samples were then weighed another time to know the weight of the dried soil, G_{ds}. The percentage organic matter was calculated using formula 3:

Formula 3: $SOM = \frac{G_{ds} - G_{tin}}{G_t - G_{tin}} * 100$ *(in %)*

The results that were obtained using this method were statistically tested using Microsoft Excel. Within both the wetlands and drylands group CA and non-CA farmers were compared to see if their SWC or SOM were statistically different.

SWC levels in soils are highly affected by the aspects of time and environment (rain). This is why the results were compared with each other by means of a boxplot.

For both SWC and SOM the following procedure was used:

The soil data were statistically tested using a statistical T-test. The T-tests were used to test if the populations had equal means. There are two T-tests, one for data with equal variances and one for data with different variances. To know what T-test could be used, an F-test was used first. By using the F-test, data were tested for equal variances (σ). The null hypothesis with the F-tests were $H0$: $\sigma(x) = \sigma(y)$. The alternative hypothesis was formulated as $H1$: $\sigma(x) \neq \sigma(y)$. The null hypothesis with the T-tests was $H0$: $\mu(x) = \mu(y)$. The alternative hypothesis was formulated as $H1$: $\mu(x) \neq \mu(y)$. All tests were conducted with an α of 0.05. The outputs of the tests were created using Microsoft Excel.

2.2.2 Interviewing farmers

Soil sampling alone would not be sufficient to fulfil the objective of this study. Although SWC and SOM can be measured by analysing the soil, crop yield and motives for using CA or conventional farming methods cannot. Information about these topics was retrieved by interviewing farmers, as they know best what their yield is and why they farm the way they do. Farmers were asked pre-formulated questions. These questions served as the guidelines of the interviews. Annex 1 provides the list of questions that were asked to the farmers

The first group of farmers interviewed were those using CA, 40 CA farmers were interviewed of which 20 in the wetlands and 20 in the drylands. They were first asked about what their idea of CA was. This question was asked to get an idea of the knowledge of the farmer about CA. The second question was asked what method(s) of CA the farmer was using. It is important to know what CA-practices each farmer conducts, as different forms and combinations of CA-practices exist in the study area, and using different CA-techniques can cause different effects (Haggblade & Tembo, 2003). Another factor influences effects of CA is the type of crop which is grown, and if crop rotation is being applied (Thierfelder et al., 2013). This is why farmers were also asked to provide details about which crops they were growing under CA and if they practiced crop rotation. When the details regarding crop production and applied CA-techniques were known, the questions would focus on the effect the farmer saw on his plants. The farmer would be asked if he sees any effect of CA on crop yield, performance of crop under dry conditions and the amount of fertilizer needed. Because the effects may differ for each crop, farmers were also asked if they saw any difference between crops.

The second group of farmers interviewed were those who were not practicing CA, 40 farmers were interviewed of which 20 in the wetlands and 20 in the drylands. The questions were aimed at finding out why these farmers were using a conventional way of farming instead of applying CA. The first question asked to these farmers was what kind of methods they were using to cultivate their land. Next, they were asked if they had heard of CA and if they could explain what it was. All farmers were also asked what problems they were facing and on which aspect of farming improvements would be possible

2.2.3 Literature study into possibility of applying other soil and water conservation measures

Apart from investigating the current situation of farmers, their perspective on CA and the effect on SWC, SOM and crop yield, further research was done to determine whether, based on the results of soil sampling and interviews, other CA measures could be applied in this area in order to increase soil fertility and ultimately crop yield. During the interviews the farmers were asked what problems they were facing and on which aspect of farming improvements would be possible. The scope of this research was on soil and water conservation measures, as transportation, marketing and other factors did not fit the scope of this research.

The selection of soil water conservation measures that could be applied was made by combining the results of the interviews, in which farmers stated the main production problems. The measures were selected based on their proven ability to significantly reduce the most constraining factors that farmers experience. These measures were selected from a range of available soil and water conservation measures in literature like Schwilch et al., 2012.

Some conservation measures were described by explaining their impact on water availability and farming and giving an overview of pros and cons of the measure. Important to note is that it was not the aim of this research to provide detailed implementation criteria, since that would require a significant amount of time, which was not available for this research. The objective of this part of the research was aimed at policy makers in Mpika district to provide guidelines for future conservation measures

3. Results

3.1 Analysis of soil samples

3.1.1 Comparing wetland farmers

In figure 1, the boxplot, the SWC of farmers in the wetlands is shown. The vertical axis shows the percentage of soil water content in the soil samples. The boxes of CA and non-CA have been put next to each other for comparison.

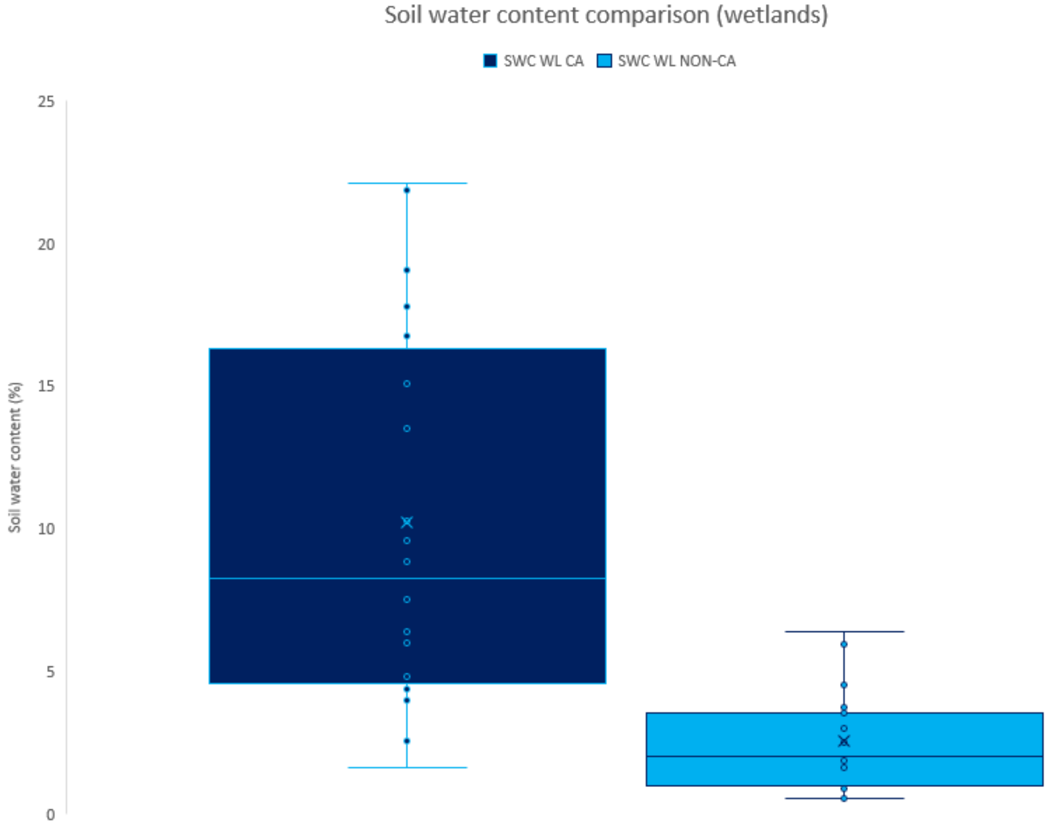

Figure 1: Soil water content comparison for the wetlands

Using the statistical method explained in chapter 2, an Excel output of this data was created in table A.1, which can be found in Annex 2.

Since $H1: \sigma(x) \neq \sigma(y)$, we need to multiply the P(F<=f) one-sided by two, which gives 5.6E-07. The F-test calculated the chance that H0 is true, or the chance that both variances are equal. That chance being 5.6E-07 (way smaller than α), the conclusion is that both populations do not have an equal σ.

Both populations were also tested using a T-test as described in chapter 2. The Excel output that was created using this test can be seen in table 1.

Table 1: T-test wetlands SWC output

T-test for equal means	*Wetlands CA*	*Wetland Non-CA*
Avarage	10.2	2.6
Variance	42.5	3.0
No. of samples	20	19
Degrees of freedom	19	
P(T<=t) one-sided	2.2E-05	
Critical area of T-test one-sided	1.7	

P(T<=t) two-sided	4.4E-05
Critical area of T-test two-sided	2.1

Since $H1: \mu(x) \neq \mu(y)$, we need to select the value for the two-sided test: 4.4E-05.
The T-test calculated the chance that H0 is true, or the chance that both means are equal. That chance being 4.4E-05 (smaller than α), the conclusion is that both means are not equal.

In figure 2, the boxplot, the SOM of farmers in the wetlands is shown. The vertical axis shows the percentage of soil organic matter content in the soil samples. The boxes of CA and non-CA have been put next to each other for comparison.

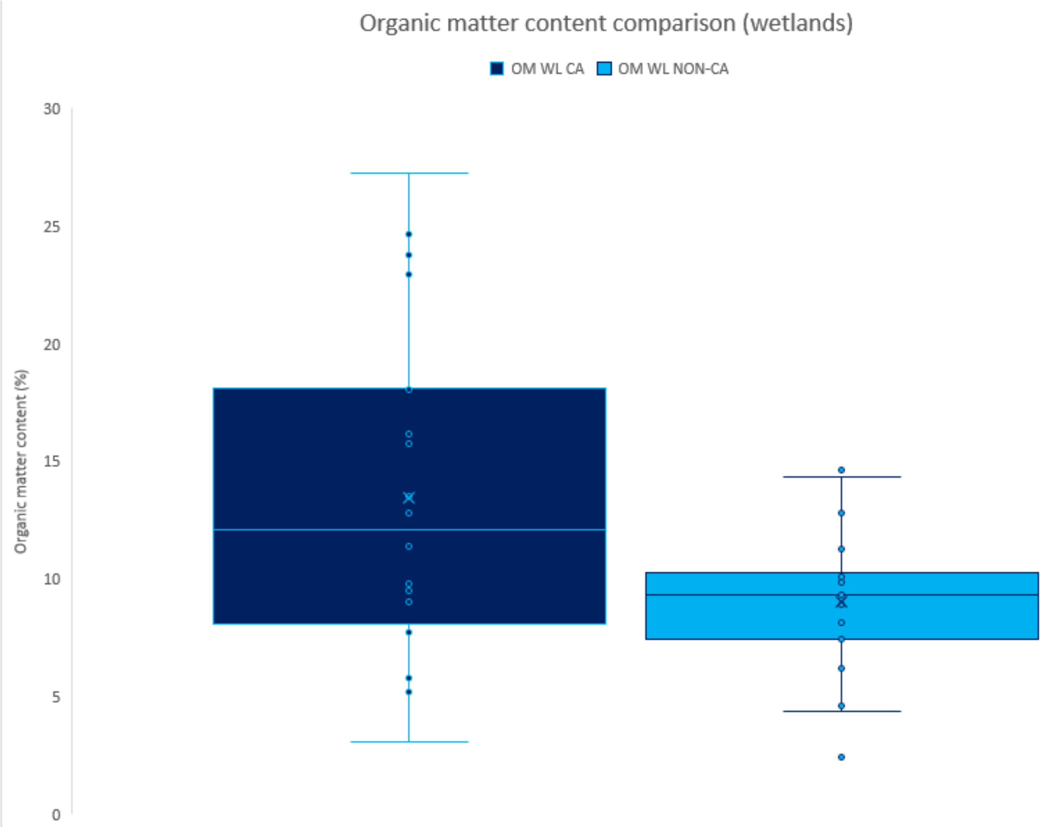

Figure 2: SOM comparison for the wetlands

Using the statistical method explained in chapter 2, an Excel output of this data was created in table A.2, which can be found in Annex 2.

Since $H1: \sigma(x) \neq \sigma(y)$, we need to multiply the P(F<=f) one-sided by two, which gives 0.0011.
The F-test calculated the chance that H0 is true, or the chance that both variances are equal. That chance being 0.0011 (smaller than α), the conclusion is that both populations do not have an equal σ.

Both populations were also tested using a T-test as described in chapter 2. The Excel output that was created using this test can be seen in table 2.

Table 2: T-test wetlands SOM output

	Wetlands CA	*Wetland Non-CA*
Avarage	13.4	9.0
Variance	51.4	10.0

No. of samples	20	19
Degrees of freedom	18	
P(T<=t) one-sided	9.2E-03	
Critical area of T-test one-sided	1.7	
P(T<=t) two-sided	0.02	
Critical area of T-test two-sided	2.1	

Since $H1\colon \mu(x) \neq \mu(y)$, we need to select the value for the two-sided test: 0.02.
The T-test calculated the chance that H0 is true, or the chance that both means are equal. That chance being 0.02 (smaller than α), the conclusion is that both means are not equal.

3.1.2 Comparing dryland farmers

In figure 3, the boxplot, the SWC of farmers in the drylands is shown. The vertical axis shows the percentage of soil water content in the soil samples. The boxes of CA and non-CA have been put next to each other for comparison.

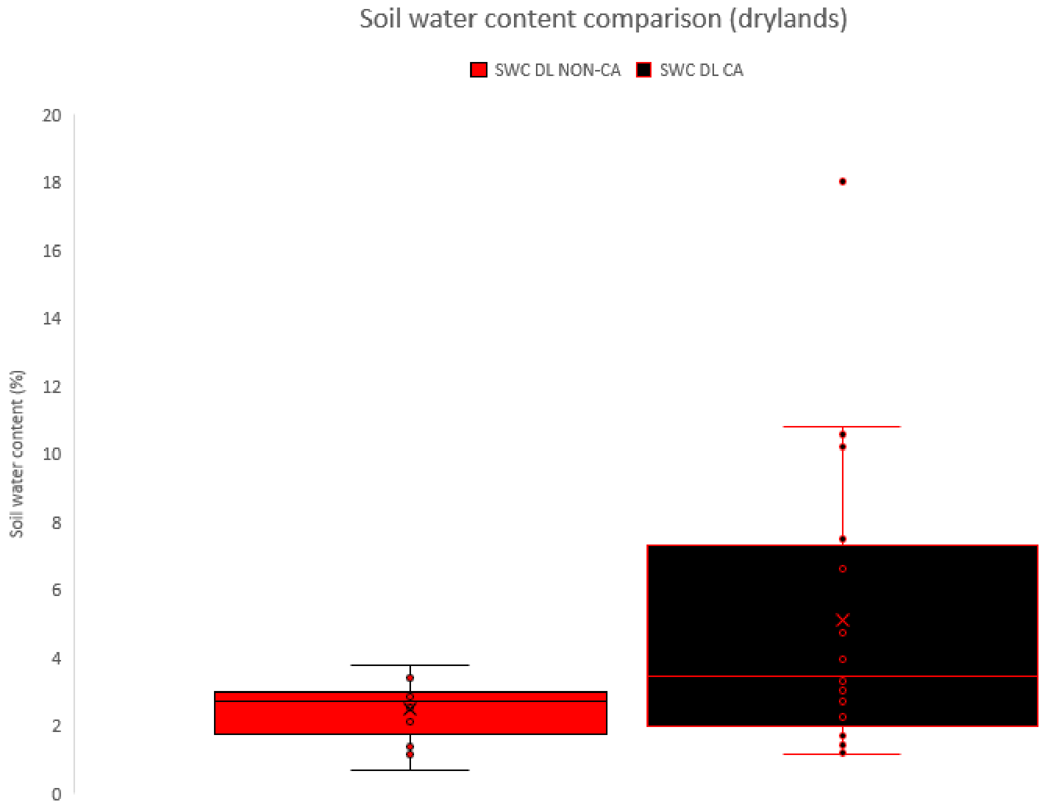

Figure 3: SWC comparison for dryland farmers

Using the statistical method explained in chapter 2, an Excel output was of this data was created in table A.3, which can be found in annex 2

Since $H1\colon \sigma(x) \neq \sigma(y)$, we need to multiply the P(F<=f) one-sided by two, which gives 2.2E-06.
The F-test calculated the chance that H0 is true, or the chance that both variances are equal. That chance being 2.2E-06 (way smaller than α), the conclusion is that both populations do not have an equal σ.

Both populations were also tested using a T-test as described in chapter 2. The Excel output that was created using this test can be seen in table 3.

Table 3: T-test drylands SWC output

	Wetlands Non-CA	*Wetland CA*
Avarage	2.2	5.1
Variance	0.8	18
No. of samples	13	20
Degrees of freedom	21	
P(T<=t) one-sided	7.9E-03	
Critical area of T-test one-sided	1.7	
P(T<=t) two-sided	0.02	
Critical area of T-test two-sided	2.1	

Since $H1: \mu(x) \neq \mu(y)$, we need to select the value for the two-sided test: 0.02.
The T-test calculated the chance that H0 is true, or the chance that both means are equal. That chance being 0.02 (smaller than α), the conclusion is that both means are not equal.

In figure 4, the boxplot, the SOM of farmers in the drylands is shown. The vertical axis shows the percentage of soil organic matter content in the soil samples. The boxes of CA and non-CA have been put next to each other for comparison.

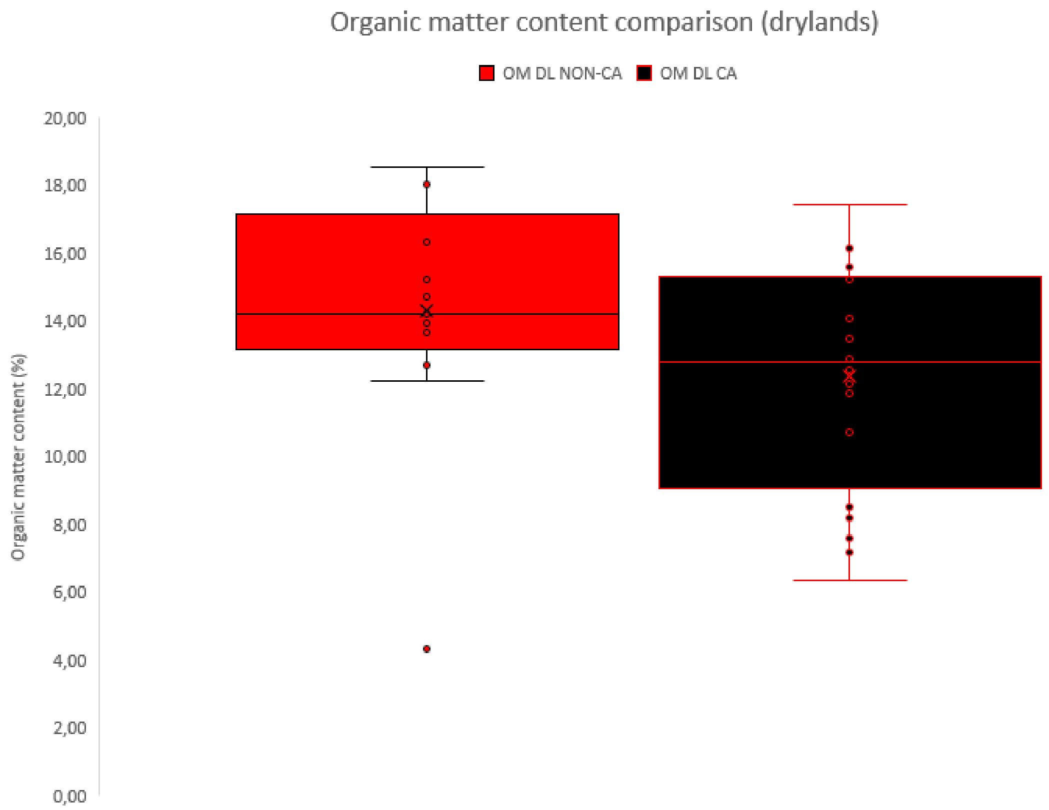

Figure 4: SOM comparison for the drylands

Using the statistical method explained in chapter 2, an Excel output was of this data was created in table A.4, which can be found in annex 2.
Since $H1: \sigma(x) \neq \sigma(y)$, we need to multiply the P(F<=f) one-sided by two, which gives 0.7.
The F-test calculated the chance that H0 is true, or the chance that both variances are equal. That chance being 0.7 (bigger than α), the conclusion is that both populations have an equal σ.

Both populations were also tested using a T-test as described in chapter 2. Because the results of the F-test point to the variances being not equal, a T-test for equal variances was used. The Excel output that was created using this test can be seen in table 4.

Table 4: T-test drylands SOM Excel output

	Dryland Non-CA	*Dryland CA*
Avarage	14.3	12.365
Variance	13.2	11.0
No. of samples	13	20
Degrees of freedom	31	
P(T<=t) one-sided	0.1	
Critical area of T-test one-sided	1.7	
P(T<=t) two-sided	0.13	
Critical area of T-test two-sided	2.0	

Since $H1: \mu(x) \neq \mu(y)$, we need to select the value for the two-sided test: 0.13.
The T-test calculated the chance that H0 is true, or the chance that both means are equal. That chance being 0.13 (bigger than α), the conclusion is that both means are equal.

3.2 Farmers interviews

This part of the paper will give an overview of how farmers answered to the questions that they were asked (these questions can be found in annex 1). The figures and text below give a representation of how the farmers answered.

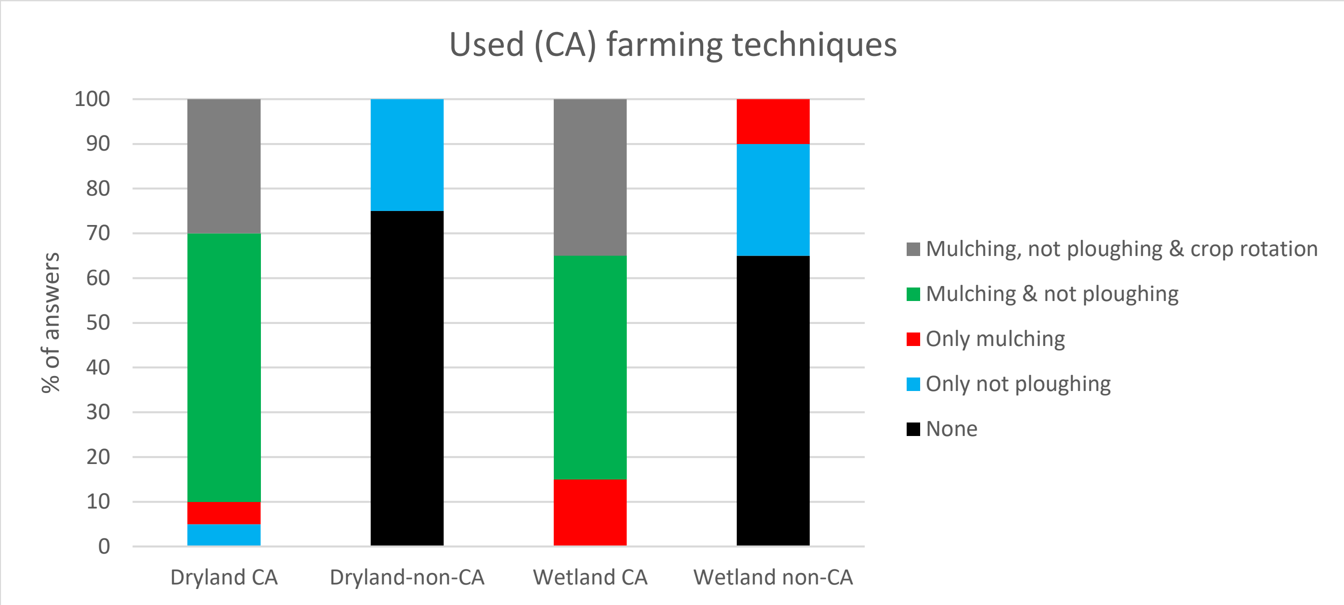

Figure 5: Overview of which farming techniques are used

Figure 5 shows the difference in farming techniques between CA and non-CA farmers, as well as the difference between dryland and wetland farmers. A clear difference between CA and non-CA farmers is visible. In the wetlands there is a group (35%) of farmers that do apply one CA technique. In the drylands there is also a group (25%) of farmers who are not ploughing their fields.
From the soil data collected and the type of farming technique used by the farmers it is possible to create a table showing the mean SWC and SOM content for farmers using different farming techniques. For this, table 5 has been inserted. Since there are only a handful of farmers who are practicing 'only mulching' and 'only not ploughing', these groups have not been taken into account.

Table 5: Overview of management practices and SWC, SOM of farmers

Type of (CA) farming technique used	Mean dryland SWC (%)	Mean dryland SOM (%)	Mean wetland SWC (%)	Mean wetland SOM (%)
None	2.5	14.8	3.5	10.3
Mulching & not ploughing	2.9	14.6	3.4	14.7
Mulching, not ploughing & crop rotation	4.3	14.9	5.2	12.4

From the table it seems like combining mulching, not ploughing and crop rotation is effecting SWC in the drylands and wetlands, as the values that farmers with these practices get on average are slightly higher compared to other management practices.
SOM seems not to be effected by management practices. In the drylands the difference between the different management practices is very small, in the wetlands there seems to be some difference.

3.2.1 CA-farmers

CA farmers were asked what effect of CA on their crop yield they had seen, the results can be seen in figure 6. The small-scale farmers in Mpika do not keep exact records of their crop yield so the only way to find out is by asking them. From their answers, the effect of CA in the wetlands compared to the drylands seems bigger.

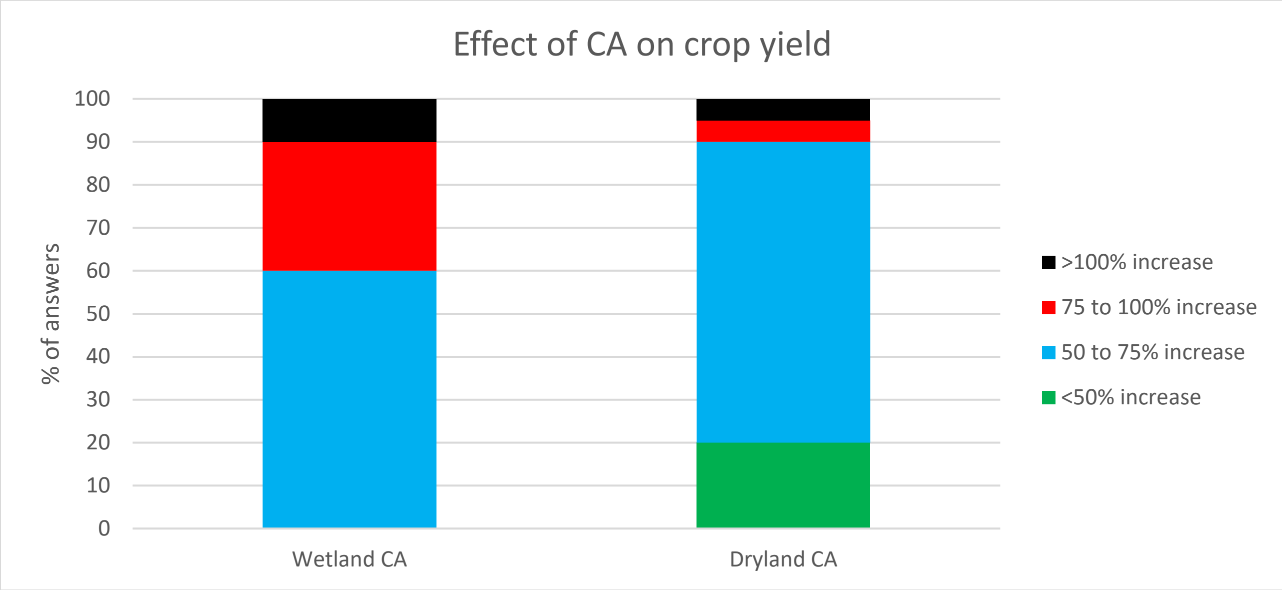

Figure 6: Effects of CA on crop yield

Using soil sampling data, table 10 was constructed. This table shows the same categories of crop increase as figure 6, combined with the average SOM that farmers experience. For example, dryland farmers that notice 50 to 75% increase in crop yield have an average SOM of 10.6%

Table 6: Comparing yield increase with average SOM percentages for drylands and wetlands

Reported crop yield increase	Average SOM (%) drylands	Average SOM (%) wetlands
<50%	9.5	No data
50 to 75%	10.6	8.7
75 to 100%	13.9	18.2
>100%	15.0	24.5

From table 10 it is clear that there is an upwards trend between the percentage of SOM and the yield increase. Both for the drylands and wetlands, the increase in yield seems to be higher when the percentage SOM is higher

CA farmers were also asked if they saw any effect of CA on their crops (apart from yield increase). These farmers reported two effects that almost all of them (90%) noticed:

- Crops look greener and do not dry out during dry spells (periods of drought during the rainy season). Crops of non-CA farmers do dry out and get a yellow colour during these times
- The farmers have to use less fertilizer to get good yields

The last question that was asked to both CA farmers in the wetlands and drylands was if they experienced any problems regarding farming and crop production. Farmers in the wetlands didn't really have problems with crop production. Their main problem was market access and the low prices they get for their produce.
Farmers in the drylands however did report some problems. The main reported problems were:

- Water shortage (30%): during the planting season (which coincides with the rain season), longer periods without rain keep occurring during stages where the crop is vulnerable

(mainly the flowering stage), directly impacting crop yield. Although CA helps these crops to last longer, the periods of drought also become longer (up to 12 consecutive days)
- Wildfires (65%): (only a problem in the dryland): although CA farmers don't want to burn their land, they don't have fire breaks to stop wildfires. These fires are started by people with the intend to burn land for charcoal but often spiral out of control due to heavy winds
- Market access (25%): although CA farmers live in less-remote areas than non-CA farmers, market access is still a problem as the roads and means of communication are bad

3.2.2 Non-ca-farmers

Non-CA farmers were asked if they had heard about CA. In the drylands, 50% of farmers had heard about CA. In the wetlands this number was 70%. Farmers that had heard about CA mostly lived quite close to the main city (Mpika) or in a village close to a main road. They were told of CA by family members, COMACO of local NGO's. Not all farmers had a clear idea of what CA was, resulting in them applying only one part of CA (for example only not ploughing their lands). Conventional farmers in places close to the road or city are surrounded by CA farmers and do see the results of CA farmers, which is motivating them to switch as well. This has resulted in a transition of conventional farming to CA. According to the DACO (district agriculture commissioner), the district minister of agriculture and representatives from COMACO , this transition has been happening in Mpika for the last years[1]. Farmers that had never heard of CA live in remote areas, where no organization has been to tell them about CA. Organizations start with easy-to-reach farmers to teach them about CA. These communities are small, not connected to other villages and produce mainly for their own consumption.

The main problems that all non-CA farmers reported during the interviews were:
- Water shortage: this limits the planting date and the number of crops and land they can cultivate. When droughts occur (during the crop growth cycle), crop yield decreases dramatically (30 to 50%)
- Declining crop yield: maize yield is low and farmers are struggling to maintain acceptable yield levels. Over the years yield has been slowly declining

[1] These data were derived from personal observations and conversations with the Mpika DACO, the local ministry of agriculture and representatives from COMACO

3.3 Other possible soil and water conservation measures

Based on the results of the soil sampling and interviews with farmers and own field experiences it is clear that there is room for improvement in terms of water availability for farmers in the drylands. One of the goals of CA is to retain moisture in the soil. CA has been applied in the Mpika region, with farmers noticing results on crop performance. Even when applying CA measures however, CA farmers in the drylands sometimes experience crop water shortages. This is caused by prolonged droughts during the rainy season (Tadross, et al., 2009). When these droughts last for more than a week during the flowering stage of a crop, the crop will suffer even if CA practices are applied. It would help these farmers to have extra water available that they could irrigate their land with.

A solution to the problem of water availability during droughts could be a rainwater harvesting system (RHS). Farmers in the Northeast part of Zambia start planting when the first rains occur, which is early December (Chabala et al., 2013). A specific system that could work here is a roof rainwater harvesting system. These systems consist of a corrugated roof which is connected to a dug water pit (Schwilch er al., 2012). This water could be collected when the first rains start and can be used during dry periods to irrigate the crops. NGO's and governmental organizations should help set up these water collection points, as set-up is quite costly. These organizations should also educate people on how to clean and use this water. Constructing these RHS's would also help to decrease the usage of groundwater boreholes (British Geological Survey, 2001), which are now widely used resulting in a dropping groundwater table (source: own observations). This RHS could retain rainwater during the first rains of the season, when farmers start planting. The water that is collected could be used during a dry spell within the rain season.

Irrigated farmlands in the wetlands of Mpika are often irrigated using irrigation channels. While this is an easy way to irrigate, a lot of water evaporates. If the amount of evaporation can be reduced, the efficiency of water application can increase, and more area of crops can be watered (van der Kooij, et al., 2013 & Postel, 2000)). This water conservation technique could be especially helpful in the wetlands of the Mpika district. Water could be drawn from the various streams by means of pumps and distributed over the croplands. During the dry season the water in the streams declines, which makes efficient water usage necessary to cultivate land. The costs of this measure are relatively high, so NGO's and governmental organizations should play an important role in deploying drip irrigation. To feel the urge of installing drip irrigation, all stakeholders should be convinced that water saving through drip irrigation means more water is available for crops so crop production area can be expanded. Maintenance is also a key factor, as it is quite complex. Drip systems have been applied in Kafue and Kabwe districts in Zambia. The results of this project were that farmers need to be helped in setting up the drip system, also receiving enough financial support and that they should be equipped and educated on how to use drip systems (Magwenzi, 2011). If these factors are accounted for, drip systems have a chance of working in Mpika district.

Another water conservation measure that can be used to improve water availability to crops is digging planting pits. These pits can be used in combination with CA. Crops are planted in small pits with a diameter ranging between 20 and 50 cm, where rainwater will form small ponds when it rains. Concentrating the rainwater in these pits allows for more infiltration and less runoff, hence further increasing the soil moisture (Liniger & Critchley, 2007). This will help increase the soil water content even more, when CA farming is already being used.

4. Discussion

4.1 Materials and methods

This research was conducted using methods that are common for research into SWC and SOM (Huang, et al., 2009). The main constraint of this research is the relatively small sample size. Forty farmers were sampled, of which twenty CA and twenty non-CA farmers. Due to time and budget restraints it was not possible to take samples from than forty farmers.
The sample population was chosen as homogenous as possible: farmers had to use CA farming techniques for at least 3 consecutive years before they were considered CA farmers and distinction has been made between the two different environments (drylands and wetlands). Farmers that were sampled as CA farmers used no tillage and permanent soil cover, some also used crop rotation. In an ideal situation only farmers applying the three CA techniques would have been selected. Because of the low population of farmers that used all three CA techniques and travel time to reach them, this was not realistic for this research.

4.2 Results

Results from the wetlands indicate that there is a difference between CA and non-CA farmers in soil water content. It should be noted that there is a large variation in SWC for the wetlands CA farmers. This could be due to irrigation timing. Farmers in the wetlands use irrigation schemes in the dry season to water their lands. It could be that some plots had been irrigated just before sampling, whilst others could have been irrigated earlier.
The results for organic matter content in the wetlands also indicates that there is a difference between CA and non-CA farmers. It should be noted though that organic matter results are exceptionally high compared to other research that has been done, both in the wetlands and drylands (Baudron et al., 2007; Thierfelder et al., 2013; Kuntlusha et al., 2014).

The results of the soil samples taken in the drylands do not show a difference in soil water content between CA and non-CA farmers. There are some samples which show much higher values than the others, but it should be noted that these samples were all taken after a few showers. These samples were not taken into consideration for analysis. Apparently, the drylands are so dry that using CA doesn't make a difference. Another factor in the drylands that may have influenced the outcome of the results is the occurrence of wildfires. This factor of influence wasn't apparent upon visiting the farmers but was discovered afterwards.

The interviews that have been taken shows that CA farmers do experience significantly higher tangible yields from their own observations, greener crops during periods of droughts and less fertilizer usage. These farmers are convinced by organizations teaching them the benefits of CA. These results are in line with field experiences. During the interviews farmers only answered questions very generally. In other words, the answers they gave were of a basic level. One thing that was not asked to the farmers was if they ever experienced out of control bushfire on their lands. Afterwards it became apparent that this is the case. This fire factor could have influenced the measurements taken and should be elaborated on in further research.

The combination of soil samples and interviews results in a two very general trends that are visible; the relationship between used farming technique(s) and the SWC and SOM levels and the relationship between yield increase and percentage SOM. These results were taken from sub-groups of farmers (the population was divided based on yield increase level or used farming technique). This results in the population size being very small in these two comparisons. Therefore the results are highly indicative and do only give a rough direction or relationship.

To conclude, the results obtained from soil sampling do come from a small population and tend to have high variances within sample groups. These results can be used as an indication of the effects of CA on the soil properties of CA farmers in this area. Results from the interviews give a clearer picture of the effects of CA that farmers see on their crops and yield.

5. Conclusions

This research aimed to help improve the knowledge of soil fertility of small-scale farmers in Zambia's Mpika district by investigating the effects of current CA practices on soil water content, organic matter content and crop yield, investigate what motives exist for using CA or conventional farming methods and determine whether improvement through other soil conservation measures is possible.

The effects of CA on organic matter and soil water content indicate that there is a difference between CA and non-CA farmers in the wetlands. The results are not clear as to whether there is any effect between CA and non-CA farmers in the drylands. Because of the financial and time limits of this research the results should be interpreted as indications of a possible relationship between CA and the measured soil characteristics in Mpika district. Because no research had been done on this topic in the Mpika district before, these indications could be a good reason for local NGO's or governmental organizations to set up a large research into effects of CA. Taking into account the effects of climate change that are already apparent in the region, investing in research to further help adapt local small-scale farmers to these changing circumstances is advisable.

The Zambian government, supported by local NGO's, is already investing in reaching out to small-scale farmers and teaching them the benefits of CA (through organizations like COMACO). However, there is still room for improvement here. Until this point farmers that have been reached by these teaching programmes mainly live near bigger villages or main roads. Farmers learn to adopt CA farming techniques and are supported to try them. When they do, they notice significant effect in terms of crop yield and health, especially during dry spells. In a certain way, CA is also contagious; most non-CA farmers that notice the effects of CA on their neighbour's farm are tempted to switch. In this way, the adoption of CA has a self-reinforcing effect.
On the other hand, farmers living in remote places or small villages which are harder to reach do not yet know of CA and its benefits. The reason for this is that these places have yet to be reached by education campaigns. These remote farmers are the ones who are, at the moment, struggling the most in terms of crop production. The focus of CA training programmes should shift more towards these farmers. If these are educated on the matter of CA farming, there is potential for an increase in agricultural production and living standards.

Farmers, both CA and non-CA, are facing the consequences of climate change. One of the most threatening effects to agricultural production is the increasing occurrence of dry spells during the rainy season. When droughts occur at times at which crops are most vulnerable (e.g. during flowering), there can be a significant effect on crop production. To prepare farmers, both CA and non-CA, for the probability of further rainfall instability in the future, water harvesting solutions are needed. Solutions like roof rainwater harvesting and drip irrigation have proven to be effective in other parts of the world, do show potential to work in Mpika district if applied well and are recommendable investments into the future. Further research into the exact sociocultural and financial implications of these measures needs to be done. By equipping farmers or communities with these tools, they are more capable to resist the negative effects of climate change.

A factor that is seriously threatening the effects of CA in the Mpika drylands is the occurrence of uncontrolled wildfires. CA farmers do not want to burn their lands as part of their conservation farming efforts but are unable to stop out-of-control wildfires from consuming their land. Further research into the extend of this problem and possible solutions is strongly advised.

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Annexes

Annex 1 – Farmers interview questionnaire

General questions

During the interview, farmers were asked the following questions:

- What (CA) farming techniques are you using?
- For how long have you been applying these (CA) farming techniques

Questions for non-CA farmers

- Have you heard about CA, can you explain what it is?
- Are there farmers near to your field(s) who are using CA?
- What is the reason you do not use CA farming?"
- Do you see any effect of CA on the plots of the farmers who are using it?
- What is the main problem for you regarding farming and crop production

Questions for CA farmers

- What CA farming techniques are you using?
- Did you notice effects of CA on?
    - Crop yield
    - Soil fertility
    - Crop health
- What is the main problem for you regarding farming and crop production

Annex 2 – F-test tables

Table A.1: F-test for the wetlands, comparing wetlands CA and non-CA farmers for SWC

F-test for equal variances	*Wetlands CA*	*Wetland Non-CA*
Avarage	10.2	2.6
Variance	42.4	3.0
No. of samples	20	19
Degrees of freedom	19	18
F	14.3	
P(F<=f) one-sided	2.8E-07	
Critical area of one-sided F-test	2.20	

Table A.2: F-test for the wetlands, comparing wetlands CA and non-CA farmers for SOM

	Wetlands CA	*Wetland Non-CA*
Avarage	13.4	9.0
Variance	51.4	10.0
No. of samples	20	19
Degrees of freedom	19	18
F	5.1	
P(F<=f) one-sided	5.2E-04	
Critical area of one-sided F-test	2.2	

Table A.3: F-test for the drylands, comparing drylands CA and non-CA farmers for SWC

	Drylands CA	*Drylands Non-CA*
Avarage	2.5	5.1
Variance	0.8	19
No. of samples	13	20
Degrees of freedom	12	19
F	0.04	
P(F<=f) one-sided	1.1E-06	
Critical area of one-sided F-test	0.4	

Table A.4: F-test drylands SOM output

	Dryland Non-CA	*Dryland CA*
Avarage	14.3	12.4
Variance	13.2	11.0
No. of samples	13	20
Degrees of freedom	12	19
F	1.2	
P(F<=f) one-sided	0.4	
Critical area of one-sided F-test	2.3	