Conservation Farming Unit

Comparison of maize yields obtained by different categories of smallholder farmers in Zambia in the 2012/13 agricultural Season

Victor Shitumbanuma

Department of Soil Science
School of Agricultural Sciences
University of Zambia

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A. Executive Summary

A.1 Introduction

The Conservation Farming Unit (CFU) has in recent decades promoted the adoption of conservation farming practices by farmers in the medium rainfall region of Zambia including reduced tillage practices that minimize soil disturbance, promote rain water harvesting, enable the timely preparation of land and more efficient utilisation of inorganic and organic fertilizers and lime. Associated with these tillage practices the CFU has among other interventions, also promoted the efficient use of herbicides to control weeds.

Independent scientifically based surveys have confirmed that 144,000 families have now adopted key CF practices on portions of their land ranging from 30% to 100%. In addition, a number of governmental and nongovernmental organizations have also been promoting key CF practices among small holder farmers in different parts of the country.

A number of studies and field observations have shown that the adoption of conservation farming results in significant and immediate increases in crop yields among farmers who consistently follow the recommended practices compared to those who follow conventional farming methods based on different forms of tillage that result in overall soil disturbance.

In 2012 the CFU undertook a survey to collect maize yield data from three categories of farmers in its operational regions in Zambia and commissioned the Dept. of Soil Sciences, V. Shitimbanuma to undertake analysis of the raw data. The objective of the study was to establish whether there were significant differences in maize yields obtained by farmers who (i) practised conservation farming to a high standard of management (Selected CF farmers - 56), (ii) farmers who had adopted conservation farming practices but were less experienced (Randomly selected CF farmers - 106), and (iii) farmers who had never practiced CF, (Randomly selected Conventional farmers - 113).

The survey was based on Maize which occupies over 85% of land cropped by small and medium scale farmers in Zambia. The farmers captured by the study grew and managed their Maize independently throughout the 2012/13 planting season.

A.2 Field data collection methodology

The 70 CFU field staff engaged in the study received thorough training on the procedures required to randomise the selection of farmers, to demarcate 10x10 metre sub plots, to physically measure cob weights and grain yields, to record number of missing cobs (i.e. pre-harvested) to submit samples for laboratory moisture analysis and to determine the total quantity of N applied by requesting each farmer to physically demonstrate the application method used to apply Compound D fertiliser an Urea (the only fertilisers available to farmers) and simultaneously to record the length of row over which the particular method was demonstrated. The physical weights and measures used to convert fertiliser application rates per ha^{-1} are presented in **Appendix 1.** To avoid errors of choice the 10x10m subplots were in each case sited within areas of the field which exhibited the healthiest growth.

A.3. Standardisation of Nitrogen application rates and other extraneous variables

Prior to the submission of raw yield data to UNZA-DSS, the CFU employed 2 BSc. graduates to enter data into two pre-designed spread sheets, the first to calculate total N applied/ha^{-1} and the second to arrive at gross yield/ha^{-1} by compensating for missing cobs and adjusting yields by reducing or increasing yields by 20kgs of grain for each kg of N applied above or below a threshold of 55N/ha^{-1} which equates to 100kg of D and 100 Kg of Urea applied per ha.

The generally accepted efficiency constant for smallholders of 20kg grain produced per kg of N applied is arguably rather low but would in any case disadvantage the more efficient utilizers in the study – i.e. the CA adopters.

Samples of maize grain from each location were analysed in the DSS laboratory to determine the moisture content of the grain obtained from the field and all yields were adjusted to a standard moisture content of 12%.

A.4 Summary of Statistical Analysis

The grain yields adjusted by the procedures described above was then subjected to statistical analysis to establish whether there were significant differences in the yields obtained by the three categories of farmers across different regions and within each region. The yield data checked for entry errors for any outliers. The maize yield data was transformed by taking square roots of the yield values to enable it fit the normal distribution. The transformed data was analyzed using the General Linear Models procedure to establish whether there were significant differences between the mean yields of the different categories of farmers. Duncan's Multiple Range test was used to separate treatment means. All statistical analyses were carried out using the statistical software SAS version 9.0.

Results of the study show that there were statistically significant ($p < 0.001$) differences in the average maize yields obtained by the three categories of farmers. The highest average yield of about 7.0 metric tonne per hectare was obtained by the selected group farmers who consistently practised conservation farming to a high standard. This was followed by an average yield of about 5.0 metric tonnes per hectare, which was obtained by randomly selected farmers were practising conservation farming, and the lowest average yield of about 3.0 metric tonnes per hectare was obtained by farmers who practiced conventional farming. Results of analyses of maize yields from the four regions also showed the same consistent trend of results among the three categories of farmers.

A comparison of the average maize yields obtained from the four regions, showed the Central region had the highest overall maize yield averaging about 5 metric tonne/ha followed by the Western region with an average of about 5 metric tonnes/ha, then by the Eastern Region with an average of about 4.2 metric tonnes/ha an lastly the Southern Region, with an average of about 4.0 metric tonnes/ha.

The results of this survey also show that when conditions similar to those that prevailed in the 2012/2013 agricultural season occur the expected lowest average yield of maize 95 % of the time would result in farmers following conservation farming practices obtaining at least 2 metric tonnes of maize/ha more than farmers practising conventional farming. Such a difference in yield for a small holder farmer makes a significant difference both in terms of disposable income and food security.

Results of this study clearly show that when differences in fertiliser application rates are standardised across all categories, farmers who followed conservation farming practices obtained significantly higher yields than their colleagues who practiced conventional farming.

Table1: Mean maize grain yields with upper and lower 95 % confidence limits for three categories of farmers in Agro-ecological zone II of Zambia in the 2012/2013 agricultural season

Category of Farmers	Sample Size (n)	Mean Yield of Maize ± standard error	95 % Lower Confidence Limit of mean maize yield	95 % Upper Confidence Limit of mean maize yield
		(kg/ha)	(kg/ha)	(kg/ha)
Conventional	113	3307 ± 202	2940	3697
Random CF	106	5233 ± 203	4844	5639
Selected CF	56	6865 ± 275	6325	7427

Lastly, the CFU has over the years captured significant amounts of data on labour inputs and production costs accruing to alternative CF and conventional tillage practices which show that with few exceptions, the costs for land preparation by Min-till and Zero-till adopters, whether using hoes oxen or tractors are significantly lower than for the majority conventional farmers who expend significant amounts of time and money ploughing with oxen or tractors or digging or ridge splitting their fields with hoes.

B. Main Report

B.1 Background to the Study

Despite many surveys and reports illustrating yield and productive benefits arising from adopting conservation farming (CF) practices compared to conventional farming practices, there is still scepticism in some scientific circles about the reported benefits of CF. In order to provide further evidence of these benefits compared with conventional farming practices, the CFU undertook a survey in the 2012/2013 agricultural season. The study involved carrying out of a random survey of maize yields from three categories of farmers in four of its operational regions in Zambia. The three categories of farmers were: (i) Selected CF adopters - experienced practitioners, (ii) Randomly selected CF adopters and (iii) randomly selected conventional practitioners. The objective of the study was to establish whether there were statistically significant differences in the yields of maize obtained by farmers belonging to these 3 categories of farmers and to establish the mean yields of these farmers within 95 % confidence limits.

B.2 Materials and Methods to Obtain Yields for Statistical Analysis

Maize plants were collected from a 10 m x 10 m plot from a site in each farmer's field judged to represent the healthiest portion of crop. The number of maize plants in each plot was recorded. The number of cobs per plant was recorded, and the number of missing cobs per plant was also recorded. The weight of the unshelled maize cobs was measured and recorded after which the maize was shelled and the grains weighed and recorded. Procedures applied to obtain gross yields from plots prior to statistical analysis in order to eliminate extraneous variables such as losses from green harvest of cobs and from variations in N application rates and from variations in grain moisture content at time of weighing are described in the Executive Summary and the pre-designed data entry sheets to eliminate these factors to the extent possible are available on request.

B.3 Statistical Analysis

B.3.1 Standardisation of Moisture Content

A sample of the maize grains from each farmer was taken to the DSS laboratory to determine the gravimetric moisture content of the grain. The results were then used to calculate the maize grain yields standardized for a moisture content of 12 %. To obtain the maize grain yield standardized to 12 % gravimetric moisture content, the formula below was used:

$$Grainwt\ at\ 12\%\ moisture\ content\ \left(\frac{kg}{100m2}\right) = \frac{(Field\ grain\ wt/100m2)}{[1 + \frac{(moisture\ content)\%}{100}]} * 1.12$$

The maize grain yield adjusted to a moisture content of 12 % per 100 m^2 area was multiplied by 100 to obtain an estimate of the maize grain yield per hectare using the formula below:

$$Maize\ grain\ yield\left(\frac{kg}{ha}\right) = Grainwt\ \left(\frac{kg}{100m2}\right) at\ 12\%\ moisture\ content\ x\ (\frac{10000m2}{ha})$$

The maize grain yield in kilograms per hectare was used to carry out statistical analyses to establish whether there were significant differences in maize yields among the three categories of farmers used in the study. It should be noted that extrapolation of crop yields obtained from small plots much less than a hectare to large areas such as a hectare is based on the assumption that the yield obtained per unit area remains the same even when the area cultivated increased. This may not always be so. It has generally been observed the levels of management generally tend to decline as the area of land cultivated increases, especially for resource constrained farmers. Therefore the yield obtained per unit area when a larger area is cultivated tends to decline relative to that obtained when a smaller area is cultivated. However this qualification should not influence the proportion and significance of yield differences between categories.

B.3.2 Statistical Analysis

Before statistical analyses were carried out, the maize grain yield data were checked to ensure that no figures that were unusually large or small were among the data set. A total of 275 records were available among which 13 had missing data and therefore could not be used in the analyses, leaving a remainder of 262 entries with maize yield data. Based on the current maize yields being obtained on research stations and on commercial farmers in Zambia with good management, we chose a upper limit of 12,000 kg/ha, as practical upper limit of currently attainable maize yields in Zambia. Yields greater than 12,000 kg/ha were considered outliers, and thus were not included among data used for statistical analyses. Similarly we chose a yield of 500 kg/ha as the lower limit of maize yields, and included such values among the outliers. Out of the 262 data entries with maize yield data only 8 were found to be outliers. These were entries with maize grain yields greater than 12,000 kg/ha.

After checking the data for entries with missing data and outliers, and removing the outliers, the remaining 254 data entries were then subjected to tests for normality to establish whether they were normally distributed. Before data can be subjected to parametric statistical analyses such as

Analysis of Variance (ANOVA), they have be subjected to a test for normality, because conclusions drawn from parametric statistical analyses such as the ANOVA are only valid if the data used are normally distributed. The total sample size after correcting for missing data and outliers was 254, which is adequate for the assumption of normality. Usually a sample size of 30 or more is considered adequate for tests for normality. However there are specific statistical tests required to ascertain whether the data in question are normally distributed or not.

When statistical tests were carried on the maize grain yield data as calculated, the data failed to meet the tests for normality using the Shapiro-Wilk and the Kolmogorov-Smirnov statistics. The results of the tests indicated that maize yield data without being transformed did not conform to a normal distribution and that the data could not justifiably be analyzed using the ANOVA in its original form. It would have to be transformed into a form that would fit the normal distribution before being subjected to the ANOVA.

An attempt was made to transform the maize yield data by taking logarithms of the yield data. This however was found to be not normally distributed. A second transformation of the maize yield data obtained by taking the square roots of the maize grain yield fitted the normal distribution and passed the tests statistics for normality, which included the Shapiro-Wilk statistic, the Kolmogorov-Smirnov Statistic and the Crammer –Von Mises statistic. The transformed maize yield data obtained by taking the square root of the maize grain yield passed the test for normality as a whole data set, and individual data sets from each of the four regions included in the study also passed the tests for normality distributed, indicating that the Analysis of Variance and associated parametric statistical tests could be carried out on the whole data set and for data sets for the individual regions.

Therefore, the transformed maize yield data obtained by taking square roots of the maize grain yield per hectare was used to carry out parametric statistical analyses to establish whether or not there were significant differences in the average maize yields obtained by different categories of farmers across the four regions and within each of the regions. Since the sample sizes of the different categories of farmers were unequal, we could not use the Analysis of Variance (ANOVA) which requires a balanced sample size among the various treatments. We instead used the General Linear Model (GLM), which is able to handle unbalanced designs which the ANOVA cannot. Duncan's Multiple Range Test was used to separate means when results of the analysis using the general linear model procedure indicated that there were significant differences among treatment means. For the separation of means a 0.05 level of significance was used the critical level. All statistical analyses were done using the statistical software SAS version 9.0 for windows.

B.3.3 Results and Discussion

- **Comparison of maize yields among different categories of farmers across regions**

Results of the analysis of maize yields among the three categories of farmers across the four regions are presented in Table 1 and illustrated in Figure 1. The results show that there were statistically significant ($p < 0.05$) differences among the average maize yields obtained by the three categories of farmers. The highest yields were obtained by selected CF farmers; these were followed by random CF farmers, while the lowest yields were obtained by conventional farmers. The average yields obtained by selected CF farmers were about twice those obtained by farmers following conventional farming practices. Farmers that had been practising conventional farming had average maize yields of about 3 metric tonnes per hectare while those who have been consistently following conservation farming practices obtained average yields of about 7 metric tonnes per hectare. The random picked farmers who were practising conservation farming had an average yield of about 5 metric tonnes per hectare.

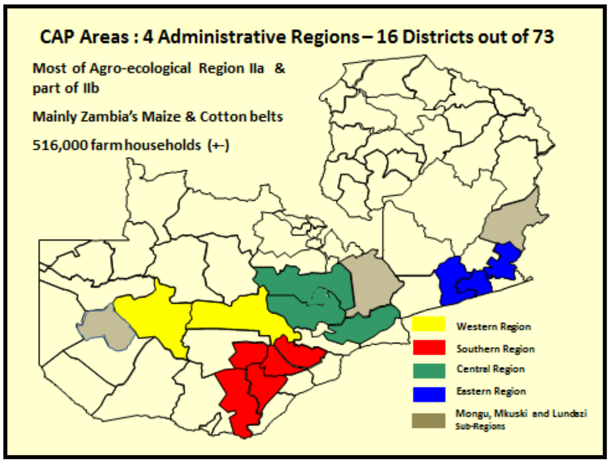
Table 1: Mean maize grain yields with upper and lower 95 % confidence limits for three categories of farmers in Agro-ecological zone II of Zambia in the 2012/2013 agricultural season

Category of Farmers	Sample Size (n)	Mean Yield of Maize ± standard error	95 % Lower Confidence Limit of mean maize yield	95 % Upper Confidence Limit of mean maize yield
		(kg/ha)	(kg/ha)	(kg/ha)
Conventional	113	3307 ± 202	2940	3697
Random CF	106	5233 ± 203	4844	5639
Selected CF	56	6865 ± 275	6325	7427

The average maize yields obtained in this survey across regions show that the two categories of farmers who follow conservation farming practices had significantly higher yields than those who were following conventional farming practices. It is evident that farmers following conservation farming practices were obtaining greater benefits in terms of maize yields than their colleagues who were following conventional farming practices.

- **Comparison of maize yields among different categories of farmers in different regions**

The Conservation Farming Unit operates in the medium rainfall region of Zambia. It has subdivided its operational areas into four regions, namely Central, Eastern, Southern and Western Regions which are shown in the diagram below.



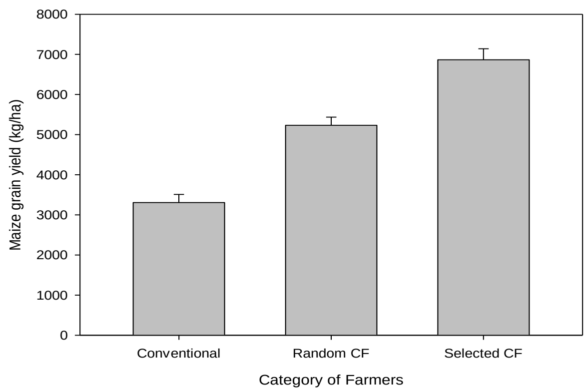


Figure 1. Average maize yields from different category of farmers accross regions in Zambia in the 2012/2013 agricultual season

Results of the maize yields obtained from the three categories of farmers in the four regions are summarized in Table 2 and illustrated in Figure 2. A detailed summary of the average maize yields of different categories of farmers in the four regions which also include the 95 % confidence limits of the maize yields is presented in Table 3.

Table 2: Mean values of maize yield (kg/ha) for different categories of farmers in different regions

Category of Farmer	Region			
	Central	Eastern	Southern	Western
Conventional	4192b	2833c	2793b	3692c
Random CF	6318a	4880b	4545a	5664b
Selected CF	8124a	6750a	5784a	7212a
Regional Mean	5598	4211	4009	5038

Note: Mean values of maize yield within each region followed by the same letter are not significantly different statistically using Duncan's Multiple Range Test at 0.05 level of significance.

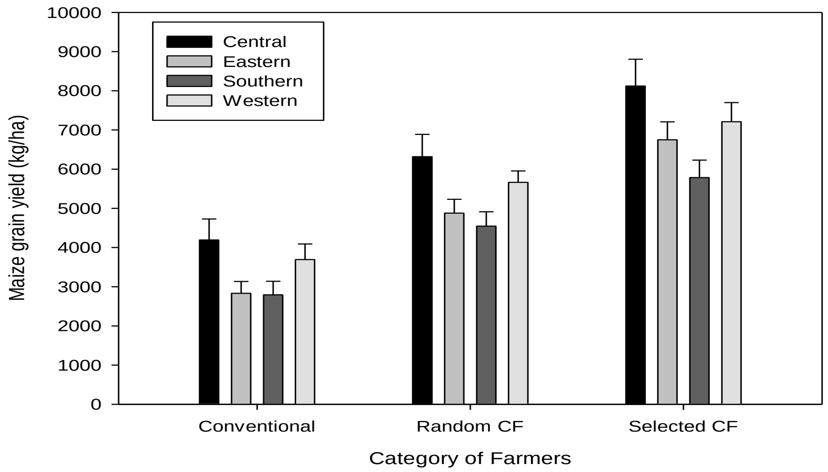


Figure 2. Average maize yields for different categories of farmers in four CFU operational regions in Zambia in the 2012/2013 agricultural season

Table 3: Mean maize grain yields with 95 % confidence limits for three categories of farmers in different regions of Zambia for the 2012/2013 agricultural season

Region	Farmer Category	Sample Size (n)	Mean maize yield ± standard error	95 % Lower Confidence Limit of maize yield	95 % Upper Confidence Limit of maize yield
			(kg/ha)	(kg/ha)	(kg/ha)
Central	Conventional	26	4193 ± 537	3223	5291
	Random CF	24	6317 ± 570	5213	7529
	Selected CF	13	8123 ± 682	6517	9908
Eastern	Conventional	35	2832 ± 302	2277	3449
	Random CF	32	4880 ± 352	4190	5616
	Selected CF	18	6750 ± 456	5842	7723
Southern	Conventional	26	2793 ± 346	2137	3537
	Random CF	26	4545 ± 367	3834	5316
	Selected CF	13	5784 ± 447	4851	6800
Western	Conventional	26	3692 ± 400	2916	4559
	Random CF	24	5664 ± 290	5058	6352
	Selected CF	12	7212 ± 486	6219	8279

In all the four regions, farmers who had been consistently following Conservation Farming practices obtained statistically significant ($p < 0.001$) higher maize yields than those who followed conventional farming practices. Randomly selected farmers who had been following conservation farming practices also obtained statistically significant higher yields than farmers who practised conventional farming. The results again clearly show that in the 2012/2013 agricultural season in the regions where the survey was conducted farmers following conservation farming practices obtained significantly higher maize yields than their counterparts who used conventional farming practices.

The general trend in maize yields obtained by the three categories of farmers was that selected CF farmers had the highest yields followed by randomly selected CF farmers, while farmers following conventional farming practices had the lowest yields. In the Central and Southern Regions no statistically significant ($p > 0.05$) difference was observed between the average maize yields obtained by selected CF and Random CF farmers, although both categories of farmers had statistically significant ($p < 0.001$) higher yields than farmers who followed conventional farming practices.

Result of the 95 % confidence limits of the mean yields of maize obtained by different categories of farmers across regions presented in Table 1 show the lowest and highest average yields of maize that would be expected 95 % of the time for the three categories of farmers under conditions similar to those that prevailed in the 2012/2013 agricultural season. The expected lowest average maize yield would be about 6 metric tonnes/ha for selected CF farmers, about 5metric tonnes/ha for randomly selected CF farmers, and about 3 metric tonnes for farmers practising conventional farming. These results clearly show a significant yield difference of at least 2 metric tonnes between farmers who practice conservation farming and those practising conventional farming. A yield difference of 2 metric tonnes is a significant difference for a small scale farmer, both from the point of view income generation and food security.

The results of average maize yields summarized in Table 3 show the average yields and 95 % confidence limits of maize yields expected from the three categories of farmers in the four CFU operational regions. The lowest expected average yields 95 % of the time for the three categories of farmers in seasons similar to the 2012/2013 agricultural season show that farmers who consistently follow conservation farming practices would get at least 2 metric of maize/ha more than farmers who practise conventional in all the four regions, which translates to extra income of at least k 2,600.00 per hectare compared to farmers practising conventional farming practices, if both sold their maize to the Food Reserve Agency at the price of K65.00 per 50 kg bag of maize grain. From a food security point of view, a farmer that consistently practices conservation farming can be expected at least 40 x 50 bags more bags of maize grain than his or her colleague practising conventional farming when both obtain their expected lowest yields.

From the maize yield data presented above, it is quite clear that farmers who followed conservation farming practices obtained significantly higher yields than their colleagues who practiced conventional farming. This was observed in all the four CFU operational regions, clearly indicating that following conservation farming practices resulted in higher maize yields than following conventional farming practices among small holder farmers in the 2012/2013 agricultural season. It was beyond the scope of this study to isolate the individual factors within the conservation and conventional farming practices that may contributed to these observed significant differences in crop yield.

- **Comparison of average maize yields among different regions**

Figure 3 shows a comparison of average maize yields obtained from the four CFU operational regions. The results show that the Central region had the highest average maize yield of about 5600 kg/ha, followed by the Western region, then the Eastern Region and lastly the Southern Region with about 4000 kg/ha. The average maize yield in the Central and Western Regions were significantly higher statistically ($p<0.05$) than those obtained in the Southern Region. It was beyond the scope of this study to establish why there were such differences in crop yields among the different regions, although there are a number of possible reasons that could be given if this were the focus of the study. For now, it will suffice to point report that the Southern Region had the lowest average maize yield among the four regions in which the CFU operates.

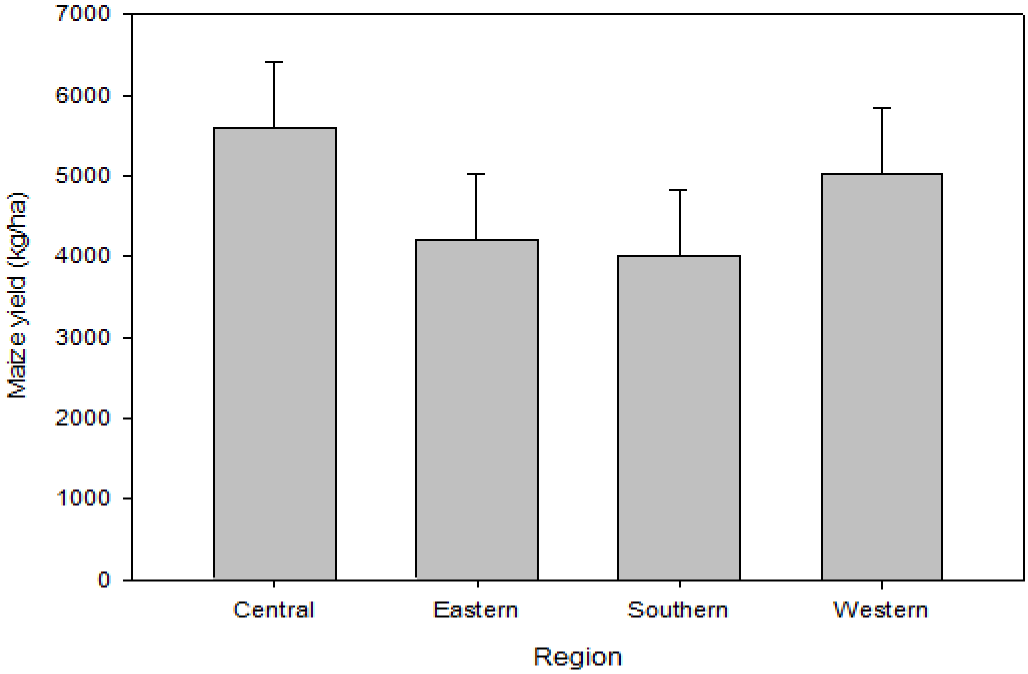


Figure 3. Average maize yields from small holder farmers in four regions of Zambia in the 2012/2013 agricultural season

B.4 Conclusions

Results of the survey carried out by the CFU to compare yields of three categories of small holder farmers in Agro-ecological region II of Zambia in the 2012/2013 presented in this report show that there were statistically significant differences in the average maize yields obtained the three categories of farmers. Farmers who had been consistently following conservation farming practices had the highest average maize grain yield of about 7 metric tonnes per hectare, followed by randomly selected farmers who were practising conservation farming who had an average of about 5 metric tonnes per hectare, while farmers who followed conventional farming practices had the lowest yield averaging about 3 metric tonnes per hectare. This trend of results was observed in all the four regions where the CFU carried out this survey.

A comparison of the average maize yields obtained from the four regions, showed the Central region had the highest overall maize yield averaging about 5 metric tonne/ha followed by the Western region with an average of about 5 metric tonnes/ha, then by the Eastern Region with an average of about 4.2 metric tonnes/ha and lastly the Southern Region, with an average of about 4.0 metric tonnes/ha.

The results of this survey also show that the expected lowest average yield of maize 95 % of the time when conditions similar to those that prevailed in the 2012/2013 agricultural season occur would result in farmers following conservation farming practices obtaining at least 2 metric tonnes of maize/ha more than farmers practising conventional farming, which has a makes a significant difference both in terms of household income and food security.