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The impacts of agricultural technology use on productivity and food security among smallholder farmers in Zimbabwe: The case of Makonde district

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Zimbabwe's semi-arid regions are characterized by high incidence of poverty, low rural incomes, low agricultural productivity, and food insecurity. These all lead to difficulties in sustaining rural livelihoods. Relatively little is known about the impacts of agricultural technologies on agricultural productivity and food security in the drier pockets of land located within the wetter regions of the country. This study explored the relationships between agricultural technology use (water harvesting, conservation agriculture, fertilizer/ manure application, and irrigation) and agricultural productivity and food security among households in Ward 15 of Makonde District in Mashonaland West Province. The methodology employed involved questionnaire interviews of 55 households selected using the stratified random sampling technique. Data analysis involved the use of the Statistical Package for the Social Sciences (SPSS). Hypothesis testing was done using the independent samples t-test and one-way between groups analysis of variance. Use of conservation agriculture resulted in significantly higher maize yields among smallholders. The t-test to measure the impact of using irrigation technology on crop yields indicated that there was a significant difference between mean yields of those practicing irrigation (Mean = 2.70 ton; SD = 2.30) and those not practicing it (Mean = 0.76 ton; SD = 1.19); t = 3.35 at the 0.2% level of significance. Therefore, development resources in semi-arid areas like Makonde District should be channeled towards agricultural technologies such as irrigation and conservation agriculture.

Key words: Agricultural technologies, productivity, food security, smallholder, semi-arid, cropping patterns.

INTRODUCTION

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Zimbabwe's semi-arid regions are characterized by high incidence of poverty, low rural incomes, low agricultural productivity, and food insecurity (Nyagumbo et al., 2009). These all lead to difficulties in sustaining rural livelihoods. Technologies have been known to improve rural livelihoods in the wetter regions of the country. Unfortunately, relatively little is known about the impacts of agricultural technologies on agricultural productivity and food security in the drier pockets of land located within the wetter regions of the country.

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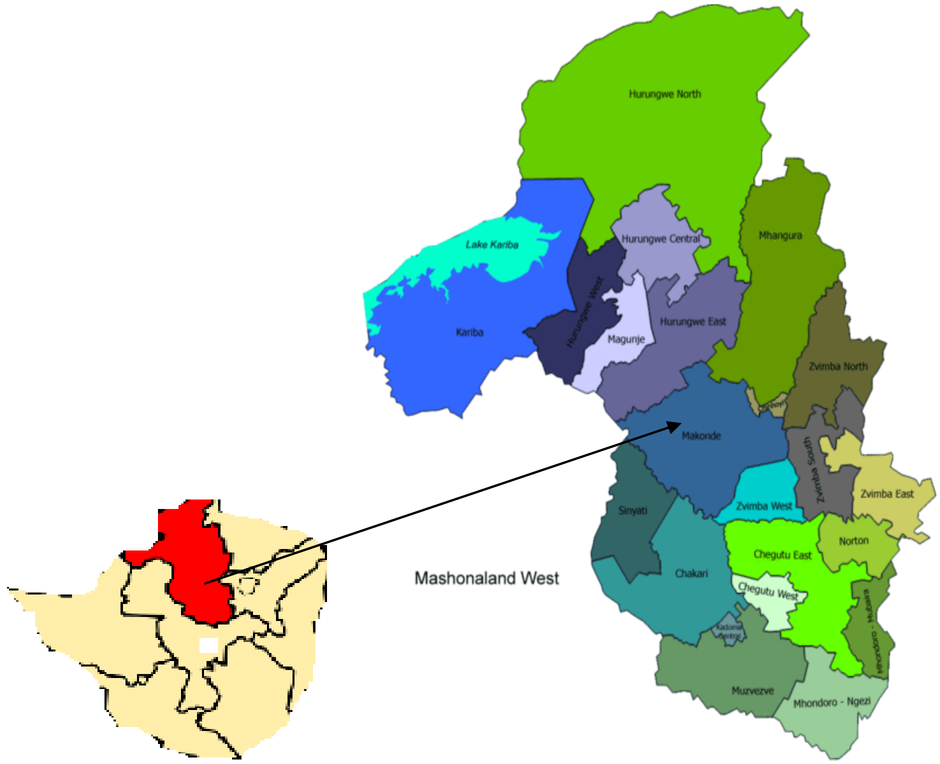

Figure 1. Map showing the location of Makonde district in Mashonaland west province of Zimbabwe.

To date, much of the agricultural and technology adoption research, and studies on the impacts of agricultural technologies on agricultural productivity and food security in the semi-arid Zimbabwean smallholder sector, have been conducted principally in the southern and central parts of the country, such as Masvingo, Midlands, Matabeleland North and South (Mazvimavi and Twomlow, 2008; Snapp et al., 1997; Nyagumbo et al., 2009). Similar studies that have been conducted in the northern and western provinces have tended to focus in high-rainfall areas. The relevance of such studies to specific policy recommendations for uplifting the livelihoods of vulnerable households in the drier parts of the wetter regions therefore remains extremely limited. The drier parts of northern and western Zimbabwe remain relatively under-represented in studies on household socio-economic characteristics, agricultural technologies and climate change, and their impacts on agricultural production and food security. The implicit assumption that has attracted research activities in the semi-arid Midlands, Masvingo and Matebeleland provinces of central and southern Zimbabwe seems to be that these provinces house all the vulnerable communities residing in the drier agro-ecological regions of the country. Vulnerable households are therefore thought to reside only in the southern and central parts of Zimbabwe. While it is indeed true that the majority of vulnerable smallholder communal farms are located in these provinces, it should nevertheless be noted that there are poor, disadvantaged rural communities living elsewhere in the country. For example, even in the northern and western parts of the country which are implicitly assumed to be high rainfall areas, there are vulnerable communities residing in isolated pockets of semi-arid agro-ecological zones (Natural Region IV and V) that are sandwiched in the middle of the wetter parts of the country.

This study sought to isolate and investigate the impacts of agricultural technologies on agricultural performance and food security among vulnerable households in a semi-arid ward (Ward 15) of Makonde District. The district contains some of the drier parts (Natural Region IV) of Mashonaland West Province in northern – western Zimbabwe.

Figure 1 shows a map of Zimbabwe, indicating the location of Mashonaland West Province and Makonde District.

MATERIALS AND METHODS

Sampling technique

Agricultural land in Makonde District falls under three major land use classes. These include the Model A1 resettlement schemes, with landholdings of about 6 ha per household, and settlement being of a village-type model. The second land use category is the

Table 1. Crops planted in the 2010/ 11 season in Ward 15 of Makonde district.

Crop	Frequency of smallholders	
	Household frequency	Percent (n = 55)
Maize	31	56.4
Sorghum	7	12.7
Rapoko (finger millet)	7	12.7
Groundnuts	15	27.3
Bambara nuts (roundnuts)	7	12.7
Sunflower	7	12.7
Nyemba (cow peas)	32	58.2
Cotton	23	41.8
Total	129	234.5

Source: Survey Data, 2012.

Model A2 resettlement scheme, with much larger landholdings, of a commercial farm-type model. The third land use class consists of communal areas, with landholdings of less than 6 ha per household. This last category is the least endowed with respect to development resources such as infrastructure and telecommunications, and has the highest population densities. It is also located predominantly in semi-arid agro-ecological zones, characterized by lower rainfall and poorer, infertile soils.

The study was undertaken in Ward 15 of Makonde District in Mashonaland West Province of Zimbabwe. This ward is situated in a communal area. Field visits and data collection were conducted in February and March 2012. The stratified random sampling procedure was used in selecting households for the survey. Random sampling was first conducted among all districts in Mashonaland West with semi-arid wards (Natural Regions IV and V), and Makonde District (in Natural Region IV), was selected. Then random sampling was again performed among all the semi-arid wards in Makonde District, and Ward 15 was selected. Finally, random sampling was performed among all the households in Ward 15, to select a sample of 55 households. This sample size is about double the minimum number of observations (30) required to perform statistical tests the results of which closely approximate the parameters of the population. The survey results can therefore be interpreted to be representative of the situation among smallholder farm households in semi-arid wards in Mashonaland West Province. Questionnaires were administered to heads of the 55 selected households.

Data analysis techniques

The Statistical Package for the Social Sciences (SPSS) was used for data entry and analysis. To compare group means and determine whether there was any significant difference between them, the independent samples t-test and the one-way between groups analysis of variance (ANOVA) were used. The independent samples t-est was used to compare the means of two groups, and investigated the relationship between one categorical independent variable with two levels and one continuous dependent variable.

RESULTS AND DISCUSSION

Cropping patterns and food grain consumption

The first null hypothesis was that the households in semi-arid wards in Mashonaland West grow a diversified range of crops, to cushion themselves against the risks of crop failure. A related null hypothesis was that their cropping patterns are dominated by drought-resistant crops such as sorghum and millet which can withstand drought conditions and can survive to physiological maturity even under semi-arid agro-ecological conditions.

Analysis of data obtained from the survey indicated that there is a diverse range of crops grown by smallholders in Ward 15 of Makonde District, as shown in Table 1. The most widely grown crop is *nyemba* (cowpeas) (58.2% of households), followed by maize (56.4%). However, in terms of production levels per household and total crop production, maize is far more important (0.9 ton), than cowpeas (0.1 ton) (Table 2). This can probably be explained by the fact that maize is the preferred staple grain in the communal (smallholder) farming areas, and as a result there is overriding allocation of resources in the production of the maize crop by households. It is also interesting to note that even though the area is a semi-arid zone, maize production continues to dominate household production patterns over drought-resistant crops like sorghum and finger millet. This is true in terms of the percentage of households growing the crop (Table 1), total crop production, and mean production per household (Table 2).

The low productivity of sorghum and finger millet observed in the survey results is consistent with research findings elsewhere. One of the reasons that have been suggested for smallholders not increasing the production of sorghum and millets is that the productivity of these crops is low. Their average yields are lower than those of maize even in the semi-arid areas of the Southern African Development Community (SADC) region. Although the total production costs are often lower than those for maize, the productivity of small grains measured in terms of returns to labour tends to be low (Rohrbach, 1991).

The dominance of a major staple crop (e.g. maize) and the production of minor (secondary) crops in the household cropping patterns has been reported in

Table 2. Household crop production and mean per capita grain consumption (harvest from the 2010/11 planting season).

Crop	Number of sample households growing crop	Total crop production for all sample households (Tonnes)	Mean production per household (Tonnes)	Number of persons in households growing crop	Mean per capita grain consumption*** (Kilograms per person per year)
Maize	31	26.939	0.869	182	150
Sorghum	7	0.049	0.007	49	1
Rapoko	7	0.091	0.013	49	2
Groundnuts	15	0.450	0.03	87	5
Roundnuts	7	0.028	0.004	49	1
Sunflower	7	0.007	0.001	49	0.1
Nyemba (cowpeas)	32	3.136	0.098	175	18
Cotton	23	5.210	0.227	129	n/a

n/a = Not applicable; *** assuming no alternative crop uses and zero net grain flows. Source: Survey Data, 2012.

literature to be a common trend in many communities. The dominant crop is usually grown as both a food and cash crop. The production of secondary crops is done for various purposes such as home consumption, beer brewing, sale in the informal sector, food for poultry or small livestock, food in case of drought, or informal exchange or barter during the season in return for seeds, small livestock, poultry or other goods (Truscott, 1986).

It can also be observed in Table 1 that each of the eight crops reported in the survey was grown by a substantial proportion of households (12% and above). From Table 1 it can be seen that the total frequency of households growing the entire range of crops is 129 or 234.5% of the sample size (N=55). This suggests significant crop diversification within individual household farms, with each household growing several crops in the same season. Since Ward 15 is situated in a semi-arid zone where the risk of crop failure is high, crop diversification is probably an adaptive measure for households to cushion or hedge themselves against the risk of crop failure under extreme climatic events. This observation is supported by evidence reported elsewhere in literature. The FAO (1997) reported that traditional (smallholder) farmers have generally adapted food production practices to meet environmental, economic and technological limitations. They minimize risk by planting a variety of crops that mature at different times during the year. Traditional intercropping practices, as opposed to mono-cropping, provide a cushion during seasons of insufficient food.

The per capita grain consumption levels among sample households are also shown in Table 2. By any standards, it can be observed that grain consumption figures per person per year for each crop are extremely low. Three assumptions have been implicitly made in computing per capita grain consumption. The first assumption is that there are no alternative crop uses by the household. The second is that the household consumes what it produces. The third assumption is that either the household does not engage in any external grain transactions or that if it does, net grain flows in and out of the household have a zero value. In other words it is assumed that grain inflows (purchases and transfers-in) and grain outflows (sales and transfers-out) are equal.

The low per capita grain consumption figures (Table 2) indicate a high prevalence of food insecurity in the two wards. Semi-arid wards like Ward 15 can conveniently be classified as a “disaster area” with regard to agricultural production and food security. It appears that the government of Zimbabwe and some non-governmental organizations are cognisant of this fact, as evidenced by the observed activities of the government-owned Grain Marketing Board (GMB) and Non-Governmental Organizations (NGOs) in providing food relief in this drought-prone area. The GMB for example, buys grain from surplus producing areas for onward distribution to food insecure households in grain deficit areas such as Ward 15 of Makonde District. This is done in order to avert the problems of food insecurity, hunger and starvation. Policy recommendations should include further intensification of food relief efforts from government and non-governmental organizations (NGOs).

The results of the analysis of cropping patterns in the semi-arid ward showed that the production levels of drought-resistant crops (sorghum and finger millet) were lower than that for maize. To make sorghum and millets competitive it is necessary to improve their productivity with an assured quality of grain. The area under sorghum and millets (hence total harvest) will not increase significantly unless productivity of these grains is improved substantially.

Therefore there is an urgent need to improve the production technologies for these grains (sorghum and millet), and to disseminate this knowledge to the farmers. Only in this way can these cereals compete locally with maize. Identifying a few well-researched alternative uses for sorghum and millet would yield new avenues for increased utilization and thus act as a catalyst to improve productivity and production.

Agricultural technologies

Use of agricultural technologies was hypothesized to improve agricultural productivity (null hypothesis). The impacts of four agricultural technologies on crop productivity were investigated. The technologies investigated were water harvesting, conservation agriculture, fertilizer/ manure application, and irrigation.

Conservation agriculture

Conservation agriculture is generally defined as any tillage sequence that minimizes or reduces the loss of soil and water. In the drylands of southern Africa, the basic components of conservation farming being promoted by NGOs among smallholder farmers are winter weeding, digging small planting basins, application of crop residues, application of manure and fertilizer in the planting basin, timely weeding, and crop rotation (Twomlow et al., 2008). The aim of promoting conservation agriculture in the marginal rainfall regions is to promote crop production by conserving fragile soils and extending periods of water availability to the crop (Gollifer, 1993; Twomlow and Hagmann, 1998).

An independent samples t-test was conducted to compare yields realized by those farmers practicing conservation agriculture and those who were not practicing it. The t-test indicated that there is a significant difference between the mean maize output per household of those practicing conservation agriculture (Mean = 7.31 ton, SD = 10.4) and those not practicing conservation agriculture (Mean = 1.04 ton; SD = 1.42); t = 3.79; p = 0.00 (Sig., 2-tailed). Thus households practicing conservation agriculture had a significantly higher mean maize output per household of 7.31 ton. Those not practicing conservation agriculture had a significantly lower mean crop output per household of 1.04 ton.

Irrigation

The main aim of irrigation development is to increase crop yields through the application and management of water in crop production.

An independent samples t-test was conducted to compare mean crop output levels realized by households practicing irrigation and those who were not practicing it. The t-test indicated that there was a significant difference between the mean output of the maize crop for those households practicing irrigation (Mean = 2.70 ton; SD = 2.30), and those not practicing irrigation (Mean = 0.76 ton; SD = 1.19); t = 3.35; p = 0.002 (sig., 2-tailed). Thus, the use of irrigation technology resulted in farmers realizing a significantly higher output of 2.70 ton per household, compared with a mean output of only 0.76 ton among households not practicing irrigation. These results led to an acceptance of the null hypothesis that the use of agricultural technology leads to higher agricultural productivity.

Similar results were obtained elsewhere in studies evaluating the impacts of irrigation technology use on crop production. For example, an analysis of maize yields was conducted for 10 smallholder irrigation schemes in seven provinces of Zimbabwe and the yields were compared with maize yields from adjacent dryland areas. The results indicated that maize yields in the irrigation schemes were much higher than those on nearby smallholder farms in rain-fed communal areas (Jimat, 2008).

Water harvesting

An independent samples t-test was conducted to find out if there was a significant difference between the means of maize crop yield among households practicing water harvesting as an agricultural technology, and among those who did not practice it. The level of use of water-harvesting technology was found to be very low. Only 4% of households reported that they were practicing water harvesting. Although numerically water harvesting appeared to double agricultural output, the t-test indicated that there was no statistically significant difference between crop yield levels of those practicing the technology (Mean = 0.38 ton; SD = 4.69) and those not practicing water harvesting (Mean = 0.17 ton; SD = 3.99); t =0.73; p = 0.47 (sig. 2-tailed).

There are two probable explanations for the absence of a statistically significant difference in the means of crop yield between households practicing water harvesting and those not practicing it. First, the soil biophysical conditions in (semi-arid) Ward 15 of Makonde District were probably not suitable for effective water harvesting by farmers. This can be explained using data from two studies conducted among smallholder farmers in the semi-arid Natural Regions IV and V of Zimbabwe. The results of a study on *in-situ* water harvesting technology in semi-arid southern Zimbabwe by Nyagumbo et al. (2009) showed that medium to heavy textured soils are considered more effective for water harvesting compared to lighter textured soils. Gently sloping areas and deeper soils with slightly indurated “spongy” parent material overlying impermeable bed rock were also more conducive. Conclusions drawn suggest that maximum benefits (in terms of crop yields) from *in-situ* water harvesting technologies can be derived from conditions with gentle slopes, medium to heavy textured soils and the existence of bed rock at soil depths greater than 70 cm. Shallower soils with impermeable materials expose the water retained during water harvesting to evaporative losses in semi-arid environments and are therefore not ideal for efficient water harvesting.

Another study by Anderson et al. (1993) established

Table 3. Summary of survey results.

Agricultural technology	Mean maize output (tonnes)		Significance level of output differences (2-tailed)	Significant at the 0.05 level? (yes/no)
	Use	Non-Use		
Conservation agriculture	7.31	1.04	0.00	Yes
Irrigation	2.70	0.76	0.00	Yes
Water harvesting	0.38	0.17	0.47	No
Fertilizer/ Manure	2.03	1.67	0.89	No

that the most common soils occupied by smallholder farms in Natural Regions IV and V are sandy, lighter textured soils derived from low-nutrient granite parent material. The survey ward (Ward 15 of Makonde District) was located in Natural Region IV. There is therefore a very high likelihood that the smallholder farms surveyed are situated on such soils. In addition, field observations and transect walks indicated that the land on which the farms are located is not gently sloping but rather uneven and steep. Observations also indicated large expanses of surface rocks and rocky soils, indicating the likely existence of shallower soils. Practicing water harvesting on these unsuitable soils could therefore not benefit the crops and resulted in no noticeable differences in crop yields.

The second possible explanation of the results obtained above in the independent samples t-test is that the precipitation in the ward was probably too low, that is, it was below the minimum threshold level required for crop yields to respond positively to water harvesting technology.

Fertilizer/ manure application

An independent samples t-test was conducted to compare the yields realized by households practicing fertilizer/ manure application and those who were not. The t-test indicated that there was no significant difference between the yield levels of households practicing fertilizer/ manure application (Mean = 2.03 ton; SD =2.12); and of those households who were not practicing it (Mean = 1.67 ton; SD = 4.18); t =0.17; p = 0.89 (sig., 2-tailed). Although households practicing fertilizer application realized nominally higher yields, the yield differences between them and those not applying fertilizer were not significant at the 0.05 level. These results were surprising because the yield-response of fertilizer for most crops was expected to be high. As such, it was expected that fertilizer use would have resulted in significantly higher yields for farmers employing fertilizer technology.

There are several feasible explanations for the anormally in the results obtained from the survey. The first one is that for crop plants to be able to assimilate the fertilizer nutrients, they need water in adequate amounts to dissolve the solid fertilizer particles and absorb them in solution in the root zone. Water is not readily available because of low precipitation levels in the semi-arid zone.

Another possible explanation is that the households were probably not applying adequate quantities of fertilizer and/ or manure to their crops, for a variety of reasons. For example, one of the contributing factors for minimal investment in soil technologies among smallholder farmers in dryland areas of southern Africa is the variability of returns, or high economic risks associated with fertilizer use in drought-prone climates (Snapp et al., 1997).

A third probable reason could be associated with limited availability and cost of fertilizers and manure, which place the accessibility of these inputs beyond the reach of most smallholders. Survey results elsewhere showed that cattle manure, crop residues, soil from termite mounds, and litter from forest vegetation, are becoming increasingly scarce as soil fertility amendments (Chibidu, 1995; Hagmann and Murwira, 1996; Ahmed et al., 1995). In addition, Bisanda and Mwangi (1996) attribute low fertilizer use among smallholders to the high cost and unavailability of inorganic fertilizers.

All these are factors that could have led to low levels of fertilizer and manure application among smallholders in the semi-arid Ward 15 of Makonde District in Natural Region IV. Low fertilizer use results in no significant benefits in terms of yield increases of crops on smallholder farms in such areas.The results of the survey are summarized in Table 3.

Conclusion

The results obtained from the survey indicated that adoption of agricultural technologies such as conservation tillage and irrigation resulted in larger crop yields among smallholder farming households. However, the rate of adoption of these technologies among sample households was found to be relatively low. This is one of the possible reasons why the ward is a food deficit area, as indicated by the low per capita food production and consumption statistics found in the analysis. Therefore, further research needs to be conducted into factors leading to low adoption of agricultural technologies, with a view to increasing their uptake by farmers. Higher adoption rates of agricultural technologies would increase grain yields and output, and so lift the households out of poverty and avert the problems of food insecurity, hunger and malnutrition.

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