This article was published at Water Resources and Rural Development
Volume 9, June 2017, Pages 1-11
http://www.sciencedirect.com/science/article/pii/S2212608216300262

An assessment of smallholder soil and water conservation practices and perceptions in contrasting agro-ecological regions in Zimbabwe

K.Musiyiwa, D.Harris, W. LealFilho, W.Gwenzi,J.Nyamangara

Abstract

Improved soil and water management practices can reduce moisture stress and crop failures associated with rain-fed cropping systems. Little information exists on soil and water management technologies requirements for male and female farmers in different agro-ecological regions. The objective of current study was to investigate farmers' sources of information and perceptions on soil and water management technologies. Four sites selected from different agro-ecological regions (AERs), sub-humid (Mazowe/Goromonzi, and Kadoma) and semi-arid (Matobo and Chiredzi). Data on sources of information on soil and water management, types of technologies preferred by farmers and constraints to adoption of technologies were collected through household interviews and focus group discussions. Results showed that government extension agents, farmer-to farmer extension and non-governmental organizations were the main sources of information on soil and water management technologies at all the sites. NGOs mainly provide information on reduced tillage methods. Main technologies were mulching (61%), reduced tillage methods (53%), and contour ridges (33%) in Mazowe/Goromonzi district, reduced tillage method (83) and mulching (64%) in Kadoma, and reduced tillage methods (54%) and contour ridges (47%) in Matobo. More farmers used soil and water management technologies at the sub-humid sites than at the semi-arid sites. Soil and water conservation technologies used were similar between male-headed (MHH) and female-headed households (FHH). Soil and water conservation technologies used by farmers matched their preferences in two of the four study sites. The findings are important for targeting soil and water management practices in the various agro-ecological zones.

Key words: Climatic risk; farmers' perceptions; soil water management; sub-Saharan Africa

1 Introduction

Smallholder rain-fed agriculture in sub-Saharan Africa is inherently risky due to frequent droughts and mid-season dry spells associated with climate change and variability. Moreover, land degradation in the form of nutrient and soil loss due to erosion is also prevalent. Coupled to low rainfall, smallholder farmers practice low-input agriculture characterized by low yields averaging about 1 ton ha^{-1} for most grain crops (Rockstrom et al., 2009). On the other hand, high costs associated with development of irrigation systems in SSA (circa US$6000/ha; Brown *et al*., 2012), imply that the majority of smallholder farmers will continue to rely on rain-fed agriculture for livelihoods and food security. To overcome the hydro-climatic risks and soil-related constraints to crop production, farmers employ a variety of soil and water management technologies. In the context of the current study, soil and water management technologies is a broad term referring to various management practices aimed at manipulating the water balance to minimize runoff and soil erosion, while enhancing land and crop water productivity (Rockstrom et al., 2009; Nyamudeza, 1993; Nyakatawa et al., 1996). These technologies include in-situ or in-field water harvesting systems, and those entailing harvesting runoff for storage and subsequent use at a local scale. Such practices may also include improvement of soil fertility to optimize plant water uptake and increase productivity (Rockstrom et al., 2009). Examples include; ridges, a variety of reduced tillage methods, potholing, conservation agriculture, pot-holing and runoff harvesting and storage for supplementary irrigation at a local scale.

Literature drawn mainly from semi-arid Zimbabwe show that soil and water management technologies improve soil moisture retention, reduce runoff and soil erosion and crop productivity (e.g., Motsi *et al*., 2004). Soil and water management technologies considered effective in semi-arid regions include tied ridges/furrows (Motsi *et al*., 2004; Unganai and Murwira, 2010), reduced tillage methods (Mupangwa *et al*., 2006; Rockstrom *et al.*, 2009) and infiltration pits (Mupangwa *et al.*, 2008). In semi-arid southern Zimbabwe, dead level contours with or without infiltration pits have also been reported to increase soil moisture retention and crop yields (Mugabe et al., 2004; Mupangwa *et al.*, 2012; Mhizha and Ndiritu, 2013). Meanwhile, in three semi-arid communal lands of Zimbabwe namely, Mudzi in agro-ecological region (AER V), Gutu (AER IV) and Chivi (AER V) farmers who practiced tied ridges realized yields of about 3t/ha compared to conventional tillage treatments whose yields were about 1.5 t/ha (Motsi *et al*., 2004). In semi-arid Gwanda and Insiza, planting basin had greater potential for improving available plant water than mulch ripping and conventional tillage practices across different soil types (Mupangwa *et al*., 2008). These studies show the potential of various soil and water management technologies to boost yields in rain-fed agriculture, in both sub-humid and semi-arid smallholder areas. In contrast, Nyakudya *et al*. (2014) noted that combining infiltration and planting pits did not improve soil moisture and/or maize yield in Rushinga, a semi-arid area in landscapes with homogenous soils. However, most results show positive effects of using various soil and water management technologies.

Adopting soil and water management technologies is considered a key adaptation strategy to the impacts and risks associated with climate change and variability (Nyamadzawo *et al*., 2013). Several models/approaches including participatory approaches were developed to enhance t adoption of soil and water management technologies in smallholder areas (Hagmann and Murwira, 1996). Despite these efforts, technology adoption remains relatively low due to constraints such as lack of labour and resources (e.g. Motsi *et al*., 2004; Amsalu and de Graaff, 2007; Munamati and Nyagumbo, 2010) and farmers' perceptions of needs, investment options and risks (Giller *et al*., 2009). Low adoption due to lack of resources is particularly critical for female farmers, who often have lower capital assets than their male counterparts (Mazvimavi and Twomlow, 2009. Therefore, understanding the role socio-economic, cultural, and agro-ecological factors is critical technology development and transfer, targeting and adoption among different farmers practicing rain-fed cropping systems. However, limited information exists on use of various soil and water management technologies, preferences and selection criteria among male and female farmers in contrasting agro-ecological regions of SSA including Zimbabwe.

The current study investigated three research questions: (1) which organizations disseminate information on soil and water management technologies in different agro-ecological regions?; (2) which soil and water management technologies are used and preferred by male-headed and female-headed households?; and, (3) what are the major constraints to adoption of soil and water management technologies in different agro-ecological regions.

2 Materials and methods

2.1 Description of study sites

Zimbabwe is classified into five natural regions (NR) 1 to V also commonly referred to as agro-ecological zones (AER) based on annual rainfall and agricultural potential (Vincent and Thomas, 1960). Rainfall patterns and crop production progressively decrease from AER I to V. Sites were therefore selected based on rainfall and temperature characteristics, based on at least 25 years meteorological data. The study was conducted out in four of the five agro-ecological regions (AER) of Zimbabwe. The four sites selected consisted of two from wetter AERs that comprised Mazowe/Goromonzi districts (AER II), and Kadoma district (AER III) and two from drier regions that comprised of Matobo district (AER IV and V) and Chiredzi district (AER V) (Figure 1).

Average annual rainfall for Mazowe/Goromonzi was 842.9 mm and mean annual temperature 18.2°C, and 721.7 mm and 21.8°C, respectively for Kadoma. Matobo mean annual rainfall was 567.1 mm while that of Chiredzi was 541.2 mm. Matobo mean annual temperature was 18.4°C and that of Chiredzi 21.3°C. At the drier sites (Matobo and Chiredzi) rainfall distribution is very poor, mid-season droughts and short seasons are common (Unganai and Murwira, 2010). In particular, Chiredzi is characterised by low mean annual rainfall (541.2 mm), which is highly unreliable (Zimbabwe Metrological Services Department, 2011). Soil and climatic characteristics of the four study sites are summarised in Table 1.

2.2 Data collection

Data on soil and water management used by farmers were collected through household interviews and key informant interviews (KII) and triangulated through focus group discussions (FGDs). A cross-sectional household survey was conducted between July 2011 and September 2011. A structured questionnaire was the instrument for data collection. The selection of respondents involved a multi-stage process. Firstly, at least two wards were purposeful selected at each site, with the assistance of the Agricultural Technical and Extension Services (AGRITEX) officers to include only wards with smallholder farmers (smallholder areas and old resettlement areas). Then in each ward, at least two villages were randomly selected. Thereafter, a minimum of two villages were randomly selected from each ward. Once the villages were selected, at least 150 households representing each site were purposefully selected to include at least 30% FHHs. The selection of farmers at each study site was random, and therefore included farmers that used and did not use soil and water management technologies. Respondents were mainly the heads of households. This enabled disaggregation of data by gender. There were 727 questionnaires with usable data from the four study sites, after data cleaning. During questionnaire interviews farmers were asked to respond to questions on sources of information on soil and water management technologies, soil and water technologies they were using in crop production, and constraints associated with less commonly used technologies and criteria for choice of preferred technologies. Farmers where soil and water management technologies were observed in the field were randomly selected for in depth interviews on technologies in use, during follow up visits to the study sites.

Farmer preferred soil and water management technologies were assessed during FGDs conducted in January 2013 and February 2013. The purpose was firstly to triangulate survey data, and to assess farmer preferred adaptation options. Discussions were conducted in two wards at each site with two FGDs (one for men and one for women) per ward. Each focus group consisted of a maximum of 12 farmers. These farmers were purposefully selected to include farmers of different socio-economic backgrounds, based on farm resources, as well as different age groups. The farmers also represented married and single farmers, and young farmers (less than 35 years) and older (above 35 years).

2.3 Data analysis

Proportions of MHH and of FHH that use a specific technology were compared using the Pearson's chi-square analysis at each analogue pair. Household survey responses for each question were coded manually to identify themes/categories of responses. The codes were transcribed into SPSS Version 19 program. Descriptive statistical methods were used to analyse sources of information on soil and water management technologies, management technologies commonly employed in cropping systems and qualitative content analysis to identify constraints to use of the different technologies. Use of technologies by MHH and FHH was also compared between the two wetter sites (Mazowe/Goromonzi district and Kadoma district) and the drier ones (Chiredzi and Matobo).

The multi-criteria analysis approach (Sadok *et al*., 2008, de Bruin, 2011) was adapted to identify farmers' selection criteria for soil and water management technologies. The multi–criteria decision aid tool assists with decision making in the presence of multiple criteria especially with reference to choice, ranking and sorting of options (Sadok *et al*., 2008). In this study, farmers first listed the soil and water management technologies most commonly employed in their respective wards. Farmers were then asked to identify selection criteria for soil and water management technologies. Each criterion was then scored based a scale of 1-10. In the multiple criteria analysis tool for decision-making, each criteria is first weighted, and the score for the criteria then multiply the weight of each criteria, the total weight for each decision is obtained by adding the total scores (Sadok et al., 2008). The higher scored choices represented the most preferred technology. SPSS statistical software version 21 was used for data analysis. The probability level $p \leq 0.05$ was considered as significant in all interpretations of data statistical analysis.

3 Results

3.1 Sources of information on soil and water management

Results showed that farmer-to-farmer extension, NGOs and AGRITEX were in general the most important sources of information across the study sites (Table 2). Soil and water management technologies mentioned by farmers during household interviews, included reduced tillage methods, ridges, mulching and contours. Key sources of information for each technology varied by agro-ecological region but were the same for MHHs and FHHs at each study site. Most Mazowe/Goromonzi farmers obtained information on tied ridges from farmer to farmer extension (≥ 60% of responses). Most Kadoma and Matobo households and Chiredzi MHH obtained information on tied ridges from AGRITEX (> 43%). The main sources of information on reduced tillage methods were farmer-to-farmer extension, and AGRITEX (> 35 % of responses) in Mazowe/Goromonzi and Chiredzi, and NGOs in Kadoma and Matobo (> 60% of responses) (Table 2). A similar trend on sources of information on mulching was noted for the other study sites. Meanwhile, farmer-to farmer extension and AGRITEX were the main sources of information on contour ridges at all sites except (30%) and AGRITEX for Kadoma farmers (>85% of responses). Collectively, the main sources of these technologies included non-governmental organizations (NGOs), AGRITEX, and farmer-to farmer extension (Table 2).

3.2 Soil and water management technologies

The main soil and water management technologies used by farmers differed between sites and across the agro-ecological regions (Table 3). At the sub-humid sites, reduced tillage was the predominant practice in both Kadoma (83%) and Mazowe/Goromonzi (53%). This was followed by tied ridges (21%) in Kadoma and contour ridges (33%) in Mazowe/Goromonzi. At the semi-arid sites, more farmers at Matobo used reduced tillage (54%), contour ridges (47%) and mulching (29%) than those in Chiredzi (i.e., 9% reduced tillage, 27% contour ridges and 15% (mulching). Averaged across sites within an agro-ecological region, distinct trends were evident in the technologies used: reduced tillage was the commonly practised technology in the sub-humid region followed by tied ridges and contour ridges, while for semi-arid sites the order was contour ridges followed by reduced tillage then mulching.

More farmers in sub-humid sites adopted and frequently soil or water conservation practices than those semi-arid sites (Tables 3 and 4). The proportion of farmers who did not use any soil and water management technologies was highest in Chiredzi (46%) followed by Mazowe/Goromonzi (15.7 %), Matobo (10.1%) and then Kadoma (6.7 %) (Table 3). However, there were no gendered differences in use of soil and water management at each district, except in Mazowe/Goromonzi where a higher proportion of MHH (10%) compared to FHH (1.5%) used pot holing (Table 5). Correlations between number of soil and water management technologies used, and individual household variables (e.g., gender, size of cultivated area) were generally weak as evidenced by low Pearson correlation coefficient $r < 0.3$ (Table 6).

A high proportion of households had persistently used contour ridges for at least 10 years (Table 7). Other technologies that have been persistently used at all sites are tied ridges and mulching except for Chiredzi. The main reason given for using soil and water management was to improve crop yields. In addition, Matobo farmers mentioned that reduced tillage eased farming operations, and was being widely promoted by NGOs and government organisations. Some farmers mentioned that mulching was easy to implement because of the ready availability of mulching material such as tree leaves and grass. In Mazowe/Goromonzi farmers mentioned that they used reduced tillage to improve yields, and mulching for controlling pests/diseases.

3.3 Farmer evaluation of soil and water management practices

Table 8 presents farmers' ranking of various soil and water management technologies in the four study sites in Zimbabwe. Criteria used to evaluate soil and water management technologies mentioned by farmers include labour requirements, availability of resources, and effectiveness, suitability and wide promotion influenced use. Farmers from different agro-ecological regions scored these technologies differently with respect to preferences. Male farmers and female farmers also scored the technologies differently (Table 8). MHHs in Mazowe/Goromonzi scored mulching and reduced tillage as the best, while reduced tillage methods and contour ridges were highly ranked by FHH. Kadoma MHHs scored reduced tillage, and ridges/tied ridges the highest while FHHs scored reduced tillage methods and mulching the highest. Matobo farmers ranked reduced tillage methods the highest. Chiredzi farmers did not score soil and water management technologies because very few farmers used these technologies (Tables 3 and 4). Some farmers' views and reasons for using different technologies are summarised in Box.1. For example, FGDs in Mazowe/Goromonzi showed that farmers used reduced tillage to improve yields, and mulching for controlling pests/diseases. In addition, Matobo farmers mentioned that reduced tillage eased farming operations, and was being widely promoted by non-governmental organizations and AGRITEX.

3.4 Constraints to soil and water management practices

According to farmer responses during household interviews, access to labour was the main constraint to adoption of the soil and water management technologies (Table 9). Main constraints to use and adoption of each technology were similar regardless of site and gender of head of household and by site except for mulching. The main constraint to adoption and use of reduced tillage methods, contour ridges, and tied ridges at all sites was labour intensiveness . The main constraints to use of mulch included both high labour requirements in all sites, in addition to high input requirement in Mazowe/Goromonzi and Chiredzi.

4 Discussion

The current study investigated perceptions on soil and water management technologies among smallholder farmers at four study sites in two contrasting agro-ecological zones in Zimbabwe. Information on soil and water management technologies is dissemination by a number of stakeholders, chief among them being the AGRITEX, a government department mandated to provide agricultural training and extension services. This was complemented by development agencies such as non-governmental organization and farmer-to-farmer exchange of information. The dissemination of information by multiple agencies could account for the observed adoption of soil and water management technologies in the study sites. As reported in other studies, uptake and adoption of technologies depend on a number of factors amongst them extension and support services, which play a key role in influencing the use and persistence of different technologies (e.g., Bekele and Drake, 2003; Tumbo et al., 2013).

Site and agro-ecological region had a significant effect on the dominant spoil and water management technologies used, suggesting that each technology may have a specific niche. In addition, crop production constraints, farmer requirements and technology performance may also vary among sites and agro-ecological regions. Evidently, various factors influenced the farmer's use of a particular technology at a given site, including the need to improve crop yields and control pests and diseases. Besides farmers' choice, other factors may also account for the use of particular technologies. For example, contour ridges were initially designed to dispose of excess runoff and reduce soil erosion in crop-fields in high rainfall areas. Therefore, their use in semi-arid sites could be considered inappropriate due to limited rainfall. However, their use in all study sites could also be attributed to the fact that they were legally enforced in Zimbabwe until independence (Elwell, 1986). Similarly, the use of reduced tillage practices and mulching could be related to the role of non-governmental organizations, which have been promoting conservation agriculture in various parts of Zimbabwe under a multiple-donor funded project on conservation agriculture (Mazvimavi and Twomlow, 2009; Anderson et al., 2014). Conservation agriculture has been widely promoted in Zimbabwe and has been linked to free agricultural inputs and food aid (Anderson et al., 2014). However, as indicated by farmer responses, use and adoption of technologies could also be due to perceived or known benefits such as soil moisture conservation, soil fertility improvement and subsequently increased crop yields. The multiple benefits associated with soil and water conversation technologies have been documented in several studies in sub-Saharan Africa (Motsi eta l., 2004; Mazvimavi and Twomlow, 2009; Rockstrom et al., 2009). For instance, the high ranking of ridges by farmers have is consistent with research findings showing better in moisture retention and improved crop yield compared to conventional tillage (e.g. Motsi *et al*., 2004). Weak correlations observed between soil and water technologies used, and individual household variable suggests that the adoption of soil and water management technologies could be a complex interplay among several socio-economic and technological factors. Such inter-relationships are best investigated using multiple correlation analysis, which were beyond the scope of the current study. The low use of soil and water management technologies in Chiredzi were unexpected, given that the site is drier and experiences more frequent crop failures due to mid-season dry spells and droughts than the other sites (Nyamudeza et al., 1993; Nyakatawa et al., 1996). Several reasons could account for this observation; (1) farmers grow drought-tolerant crops such as sorghum and millets rather than the staple maize predominant in other sites; (2) low rainfall and frequent dry spells and droughts could imply that the benefits for using soil and water conservation technologies could be lower than in other sites. For example, total crop failure occurs 2-3 times in very five years regardless of whether farmers use soil and water conservation or not (Nyamudeza, 1998). Moreover, the close proximity of the site to the border with South Africa could provide other off-farm livelihood opportunities such as cross-broader trading and employment opportunities.

Despite studies that show positive effects of soil and water management technologies in semi-arid Zimbabwe (e.g. Motsi *et al*., 2004; Mupangwa *et al*., 2008), more farmers at the sub-humid sites compared to farmers at the semi-arid sites used soil and water management technologies. Similarly, Mazvimavi and Twomlow (2009) also noted that farmers from wetter agro-ecological regions adopted more components of conservation farming (CF) compared to those from drier sites (Mazvimavi and Twomlow, 2009). They attributed this observation part to more years of experience in CF (due to extension) compared to farmers at the drier agro-ecological regions. Higher use of soil and water management technologies at the sub-humid sites might be because these sites have higher potential productivity (higher rainfall) and net returns to technology are greater and could be related to a lower risk of losses following investment. These results indicate a need for more intense research on soil and water management technology for drier sites or assessment of suitability of and cost-benefit analysis (taking into consideration effectiveness, measurable socio-economic analysis, farmer perceptions) of technologies for semi-arid areas in smallholder areas of Zimbabwe.

Similar proportions of MHHs and FHHs that used each soil and water management at the study sites indicate that both groups had similar access and sources of information. Both male and female farmers mentioned that limited access to labour, inputs such as mulch reduced uptake and adoption of some soil and water management technologies, an observation consistent with other studies (Mazvimazi and Twomlow, 2009). Based on results of several studies FHHs often have lower access to labour particularly adult male labour and therefore may be more limited in adoption of technologies. Women's adoption of and performance of dead level contours, for example, was lower than that of men (Munamati and Nyagumbo, 2010). Similarly, Mazvimavi and Twomlow (2009) showed that MHH compared to FHH were adopted more components of reduced tillage methods in districts in which the technology was introduced through various initiatives. They attributed this to more labor constraints in FHH compared to MHH. In contrast, gender of farmers in the Beressa watershed, highlands of Ethiopia did not influence adoption and continued use of   stone terraces (Amsalua and de Graaff, 2007). Regression models often show that available labour does not influence adoption depending on technology (e.g. Munamati and Nyagumbo, 2010). Therefore, in this study, both men and women could have been constrained below a threshold resource level, and adoption levels were similar. In addition, the mean area allocated to the crops, and components of the technologies adopted by various farmers may differ.

Differently managed households may employ a variety of technologies to address labor challenges at farm and at community level such as hiring labor depending on financial capital. Although FHH often have less financial capital compared to MHH, women often form labor groups to assist each other (Personal communication, 20130. Proponents of technologies often encourage farmers to work in groups (Munamati and Nyagumbo, 2010) as was the case in Goromonzi. This also assists FHH who often have labour challenges. Some FHH may also get assistance from male relatives in the same or nearby villages. For example, in a *de-juri* FHH the household head aged 64 from Muzangaza Village in Mazowe/Chiweshe indicated that labour for land preparation is supplied by her brother and son, who both had their own homesteads (Personal communication, 01 October 2013, Mazowe). In contrast, a couple from Gambiza Village in Kadoma mentioned that they have been practicing CA for the past three years and have noted increases in the maize yields (Personal communication, 4 May 2013, Kadoma). They mentioned that one of their main strategies for addressing labor challenges associated with the technology was early land preparation. In addition to hiring labor, establishing labor groups and receiving assistance from relatives, farmers may adjust the area on which they practice the technology depending on resources and labor available that may imply fewer benefits from technology for households that are resource constrained. Communities evolve structures over time, which enable them to manage their cropping systems and to adapt to their socio-economic environments. Climate change may result in labor migration particularly of younger, more able men as households seek non-farm sources of livelihoods due to climate change (Morton, 2007; Davis, 2003). Therefore, despite efforts by communities to address labor challenges for different technologies, labor constraints may continue to impact smallholder agriculture.

Smallholder farmers are mostly resource and labour constrained (e.g. cattle for draft power), particularly at onset of rain. As such, technologies that reduce labor and resource requirements at onset of the rain season may be more attractive for some farmers. Mazowe men scored CA and ridging similarly in high labor requirements. According to Mazowe women, CA resources such as mulch were more readily available compared to resources for other technologies. In addition, both male and female farmers in Mazowe mentioned that CA was the most effective soil and water management technology that they knew of. Most farmer groups mentioned that they used reduced tillage methods because they had no draft power for land preparation, and the technique enabled early land preparation thus allowing planting with the first effective rains, which is also an important moisture management strategy. Some farmers applied herbicides for weed control in CA. Soil and water management technologies evolve over time, however these results show the need to consider needs for different agro-ecological regions and different farmers, to increase adoption.

5 Conclusions and Outlook

The study investigated smallholder soil and water conservation practices and perceptions in contrasting agro-ecological regions in Zimbabwe. Results showed that the main sources of information include farmer-to-farmer extension, Agricultural and Technical Extension Services and non-governmental organizations. Non-governmental organizations are mainly involved in dissemination of information of reduced tillage methods. This study showed that main sources of information on soil and water management varied across the study sites but were the same for male- and female-headed households at each study site. More farmers used soil and water management technologies in sub-humid agro-ecological regions compared to semi-arid agro-ecological regions. Proportions of male- and female-headed households that used each technology were mainly similar at each study site. Effectiveness of technology was the most important selection criteria at the wetter sites. Farmers at all sites perceive labour constraints, for all technologies. Although there are labor constraints for most technologies, the results show that farmers are practicing the technologies that they prefer except in Kadoma where farmers mentioned that winter ploughing is the most effective in moisture retention. Reduced tillage methods such as conservation agriculture and mulching are used more at wetter sites compared to drier sites. Implications are that there is need for promoting and targeting different technologies for different agro-ecological regions, for example reduced tillage methods for sub-humid agro-ecological regions. There is need for further research on soil and water management technologies for drier agro-ecological regions in particular Chiredzi, and for reducing labor requirements of soil and water management.

Acknowledgements

We would like to thank ICRISAT, for facilitating field work, the Zimbabwe Meteorological Services Department, Government Agricultural Extension officers, and farmers from the study sites. We would like to acknowledge the *Deutsche Gesellschaft fur Internationale Zusammenarbeit* (GIZ) for funding this study conducted in the framework of the research project "*Adapting agriculture to climate change: Developing promising strategies using analogue locations in Eastern and Southern Africa*" (CALESA – Climate Analogue Locations in Eastern and Southern Africa) Project implemented by ICRISAT and its partners. The sponsor played no role in study design, data collection, analysis and interpretation of data, in the writing of the report; and in the decision to submit the article for publication. We also that the editor-in-chief and the two anonymous reviewers for their helpful comments that greatly improved the manuscript.

References

Amsalu, A., De Graaff, J., 2007. Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. Ecol. Econ. 61, 294-302.

Bekele, W., Drake, L., 2003. Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. Ecol. Econ. 46, 437-451.

Davis, J. R., 2003. The rural non-farm economy, livelihoods and their diversification: Issues and options. *NRI report* (2753).

de Bruin, K., 2011. An economic analysis of adaptation to climate change under uncertainty. PhD Thesis, Wageningen University, Wageningen, NL

Elwell, H.A., 1986. Soil Conservation. College Press. Harare.

Giller, K.E., Witter, E., Corbeels, M., Tittonell, P., 2009. Conservation agriculture and smallholder farming in Africa: the heretics' view. Field Crops Res, 114, 23-34.

Hagmann, J., Murwira, K., 1996. Indigenous SWC in Southern Zimbabwe: a study of techniques, historical changes and recent developments under participatory research and extension. *Sustaining the Soil: Indigenous Soil and Water Conservation in Africa. London: Earthscan*.

Mazvimavi, K., Twomlow, S., 2009. Socioeconomic and institutional factors influencing adoption of conservation farming by vulnerable households in Zimbabwe. Agric. Syst, 101, 20-29.

Mhizha, A., Ndiritu, J.G., 2013. Assessing crop yield benefits from in situ rainwater harvesting through contour ridges in semi-arid Zimbabwe. *Physics and Chemistry of the Earth, Parts A/B/C*, *66*, 123-130.

Morton, J. F. 2007 The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the National Academy of Sciences,* 104, 19680-19685.

Motsi, K.E., Chuma, E. , Mukamuri, B.B., 2004. Rainwater harvesting for sustainable agriculture in communal lands of Zimbabwe. Phys. Chem. Earth, Parts A/B/C, 29, 1069-1073.

Mugabe, F., 2004. Evaluation of the benefits of infiltration pits on soil moisture in semi-arid Zimbabwe. Jour. Agron, 3, 188-190.

Munamati, M., Nyagumbo, I., 2010. In situ rainwater harvesting using dead level contours in semi-arid southern Zimbabwe: Insights on the role of socio-economic factors on performance and effectiveness in Gwanda District. Phys. Chem. Earth. Parts A/B/C, 35, 699-705.

Mupangwa, W., Twomlow, S., Walker, S., 2008. The influence of conservation tillage methods on soil water regimes in semi-arid southern Zimbabwe. Phys. Chem. Earth. Parts A/B/C, 33, 762-767.

Mupangwa, W., Twomlow, S., Walker, S., 2012. Dead level contours and infiltration pits for risk mitigation in smallholder cropping systems of southern Zimbabwe. Phys. Chem. Earth. *Parts A/B/C*, *47*, 166-172.

Nyakatawa EZ, Brown M, Maringa D (1996). Maize and sorghum yields under tied ridges of fertilised sandy soils in semi-arid South-east Lowveld of Zimbabwe. Afr. Crop Sci. J., 4(2): 197-206.

Nyamudeza P (1993). The effects of growing sorghum (*Sorghum bicolor*) in furrows and on the flat at three populations and three row widths in a semi-arid Region of Zimbabwe. 1. Grain yield and yield components. Zimb. J. Agric. Res. 31(1): 1-10.

Nyamudeza P (1998). Water and fertility management for crop production in semi-arid Zimbabwe. PhD Thesis. The University of Nottingham, Nottingham. UK.
Nyakudya, I.W., Stroosnijder, L., Nyagumbo, I., 2014. Infiltration and planting pits for improved water management and maize yield in semi-arid Zimbabwe. Agric. Water Manage, 141, 30-46.
Nyamapfene, K., 1990. The Soils of Zimbabwe. Nehanda Publishers, Harare.
Rockström, J., Kaumbutho, P., Mwalley, J., Nzabi, A.W., Temesgen, M., Mawenya, L., Barron, J., Mutua, J., Damgaard-Larsen, S., 2009. Conservation farming strategies in East and Southern Africa: yields and rain water productivity from on-farm action research. Soil Till. Res. 103, 23-32.
Sadok, W., Angevin, F., Bergez, J.É., Bockstaller, C., Colomb, B., Guichard, L., Reau, R., Doré, T., 2009. Ex ante assessment of the sustainability of alternative cropping systems: implications for using multi-criteria decision-aid methods-a review. Sust. Agric. (753-767). Springer Netherlands.
Tumbo, S.D., Mutabazi, K.D., Masuki, K.F.G., Rwehumbiza, F.B., Mahoo, H.F., Nindi, S.J., Mowo, J.G., 2013. Social capital and diffusion of water system innovations in the Makanya watershed, Tanzania. Jou. Socio-Econ, 43, 24-36.
Unganai, L.S., Murwira, A., 2010. Challenges and opportunities for climate change adaptation among smallholder farmers in southeast Zimbabwe. In *2nd International Conference: Climate, Sustainability and Development in Semi-arid Regions, Ceará Convention Center*, *Fortaleza* (16-20).
Unganai, L.S., 1996. Historic and future climatic change in Zimbabwe. Climate Res, 6, 137-145.

List of Tables and Captions:

Table 1: Rainfall, temperature and soil characteristics of the four study sites in Zimbabwe

Sites	Mazowe / Goromonzi	Kadoma	Matobo	Chiredzi
Mean Annual T°C [1]	18.2	21.8	18.4	21.3
Mean Annual Rainfall (mm) [1]	842.9	721.7	567.1	541.2
Soil types [2]	Greyish brown sands and sandy loams	Greyish brown sands and sandy loams	Greyish brown sands	Heavy clays, vertisols sands, sandy loams

[1] Means of data from 25-30 years. Source: Zimbabwe Metrological Services Department (ZMSD), 2011

[2] Source: Nyamapfene, 1990

Table 2: Sources of information on various soil and water management technologies in four study sites in Zimbabwe. Data shown are proportions of total responses for each technology [6]

Technology	Site	Mazowe/Goromonzi		Kadoma		Matobo		Chiredzi	
	Agro-ecological region	II		III		IV		IV	
	Gender HHH[1]	MHH[2]	FHH[3]	MHH	FHH	MHH	FHH	MHH	FHH
	Sources of information								
Tied ridges	Farmer-to-farmer extension	60	84.6	2.6	5.6	53.3	25	40	0
	AGRITEX[4]	35	15.4	92.3	88.9	43.3	58.3	50	0
	Research institutions	0	0	0	0	0	0	0	0
	NGOs[5]	5	0	5.1	5.6	0	16.7	10	0
	Others (e.g. school)	0	0	0	0	3.3	0	0	0
	n	*20*	*13*	*39*	*18*	*30*	*12*	*10*	0
Reduced tillage methods	Farmer-to-farmer extension	29.5	23.7	0	5.6	11.3	15.4	48.1	50
	AGRITEX	50	49.2	16.3	25	18.8	15.4	37	37.5
	Research institutions	0	0	0	0	2.5	5.1	3.7	0
	NGOs	20.5	25.4	81.6	69.4	65	64.1	11.1	6.3
	Others (e.g. school)	0	1.7	2	0	2.5	0	0	6.3
	n	*78*	*59*	*98*	*36*	*80*	*39*	*27*	*24*
Mulching	Farmer-to-farmer extension	39.5	35.6	2.5	3.3	30.5	7.4	46.4	0
	AGRITEX	43.4	57.6	34.6	53.3	25.4	29.6	42.9	0
	Research institutions	0	0	0	0	1.7	7.4	0	0
	NGOs	13.2	6.8	60.5	43.3	35.6	48.1	10.7	0
	Others (e.g. school)	3.9	0	2.5	0	6.8	7.4	0	0
	n	*76*	*59*	*81*	*30*	*59*	*27*	*28*	0
Contour ridges	Farmer-to-farmer extension	62.9	65.4	9.4	0	39.4	44.4	55.2	59.1
	AGRITEX	31.4	34.6	87.5	100	39.4	44.4	43.1	31.8
	Research institutions	0	0	0	0	0	0	0	0
	NGOs	0	0	3.1	0	12.7	11.1	1.7	4.5
	Others (e.g. school)	5.7	0	0	0	8.5	0	0	4.5
	n	*35*	*26*	*32*	*11*	*71*	*27*	*58*	*22*
Pot holing	Farmer-to-farmer extension	53.8	0	0	0	0	0	0	50
	AGRITEX	38.5	0	0	0	0	0	0	33.3
	Research institutions	0	0	0	0	0	0	0	0
	NGOs	7.7	0	0	0	0	0	0	8.3
	Others (e.g. school)	0	0	0	0	0	0	0	8.3
	n	*13*	0	0	0	0	0	0	*12*
Rain water harvesting	Farmer-to-farmer extension	30	0	0	0	29.4	0	0	0
	AGRITEX	60	0	0	0	64.7	0	0	0
	Research institutions	0	0	0	0	0	0	0	0
	NGOs	0	0	0	0	0	0	0	0

	Others (e.g. school)	10	0	0	0	5.9	0	0	0
	n	*10*	0	0	0	*17*	0	0	0
Winter ploughing	Farmer-to-farmer extension	0	0	52.9	0	33.3	0	0	0
	AGRITEX	0	0	47.1	0	50	0	0	0
	Research institutions	0	0	0	0	0	0	0	0
	NGOs	0	0	0	0	8.3	0	0	0
	Others (e.g. school)	0	0	0	0	8.3	0	0	0
	n	0	0	*17*	0	*12*	0	0	0
Total[7]	Farmer-to-farmer extension	42	40.7	5.9	3.9	29.8	24.6	51.9	52.6
	AGRITEX	43.6	46.9	43.9	56.9	33.5	32.2	40	33.7
	Research institutions	0	0	0	0	1.1	3.4	0.7	0
	NGOs	11.5	11.7	48.7	39.2	30.2	38.1	6.7	5.3
	Others (e.g. school)	2.9	0.6	1.5	0	5.5	1.7	0.7	8.4
	n	*243*	*162*	*271*	*102*	*275*	*118*	*135*	*95*

[1] HHH = head of household [2]MHH= male-headed households [3] FHH = female-headed households [4] The Agricultural Technical and Extension Services (AGRITEX) [5] Non-governmental organisations. [6] there were no responses for some technologies hence the gaps, [7] includes other technologies not described in detail

Source of Data: Household survey carried out in Zimbabwe, 2011

Table 3: Per cent of farmers using number of technologies at each of the four study sites in Zimbabwe

	Number of technologies used by a household					
Site	0	1	2	3	4	5
Mazowe/Goromonzi (n=153)	15.7	22.9	35.3	22.2	2.6	1.3
Kadoma (n=150)	6.7	21.3	51.3	16.7	3.3	0.7
Matobo (n=159)	10.1	38.4	34.6	17	0	0
Chiredzi (n=165)	46.1	40.6	10.9	1.8	0.6	0
Total	20.1	31.1	32.5	14.2	1.6	0.5

Source of Data: Household survey carried out in Zimbabwe, 2011

Table 4: Comparisons of proportions of households who frequently use soil and water management technology at each of the four study sites in Zimbabwe

	Sub –humid sites			Semi-arid sites		
Technology	Mazowe/ Goromonzi (AER II; n=153)	Kadoma (AER III; n=159)	χ2	Matobo (AER IV; n=159)	Chiredzi (AER V; n=165)	χ2
Tied ridges	11.8	21.3	5.033	11.9	3.6	7.859*
Rain water harvesting	5.9	2.7	1.907	3.8	2.4	0.493
Pot holing	6.5	0.7	7.458	0.6	5.5	6.304*
Contour ridges	32.7	4.7	38.917**	47.2	26.7	14.648**
Reduced tillage	52.9	82.7	30.869**	53.5	9.1	74.700**
Mulching	60.8	64	0.334	28.9	15.2	9.786
Winter ploughing	3.3	14.7	12.988*	10.7	1.2	13.181***
Multiple weeding	0	0	n.a	1.3	4.9	n.a

* Significant at the 5 % level; **Significant at the 1% level

n.a - not available

Source of Data: Household survey carried out in Zimbabwe, 2011

Table 5: Comparisons of use of soil and water management technologies by gender at each of the four study sites in different agro-ecological regions (AER) of Zimbabwe. Values shown are percentages of total number of interviewees.

	Mazowe /Goromonzi (AER II)			Kadoma (AER III)			Matobo (AER IV)			Chiredzi (AER V)		
Gender of HHH[1]	MHH[2]	FHH[3]	χ^2	MHH	FHH	χ^2	MHH1	FHH[2]	χ^2	MHH	FHH	χ^2
n	87	66		111	39		105	54		102	63	
Technology												
Tied ridges	13.8	9.1	0.799	23.4	15.4	1.111	10.5	14.8	0.638	5	1.6	1.245
Water harvesting	10.3	0	n.a	2.7	2.6	0.002	3.8	3.7	0.001	2.9	1.6	0.302
Pot holing	10.3	1.5	4.790	0.9	0	n.a	0	1.9	n.a	0	14.3	-
Contour ridges	34.5	30.3	0.298	6.3	0	2.58	51.4	38.9	2.25	33.7	14.3	7.531
Reduced tillage	49.4	57.6	1.626	82	84.6	0.14	53.3	53.7	0.002	8.9	9.5	0.018
Mulching	58.6	63.6	0.396	62.2	69.2	0.626	31.4	24.1	0.938	13.9	15.9	1.77
Winter ploughing	3.4	3	0.788	15.3	12.8	0.144	10.5	11.1	0.015	1	1.6	n.a
Multiple weeding	0	0	n.a	0	0	n.a	1.9	0	n.a	3	7.9	n.a

[1]Household head
[2]Male-headed households
[3]Female-headed households
* Significant at the 5 % level; **Significant at the 1% level
n.a - not available because there were no responses for some technologies
Source of Data: Household survey carried out in Zimbabwe, 2011

Table 6: Spearman's correlation coefficient (r) for correlation of use of soil and water management technologies versus household variables in four study sites in Zimbabwe

	All sites	Mazowe/Goromonzi	Kadoma	Matobo	Chiredzi
Farm size	.074	.233	.023	.073	.028
Cultivated area	.088	.280	-.071	.136	.082
Household size	.076	.185	.201	.020	-.102
Family labour*	.069	.181	.137	-.034	-.028
Estimated income for the season	.066	0.00	.211	.018	.064
Tropical livestock units	.101	.198	.009	.069	.109
Level of education of household head	.059	.033	.116	-.002	.091
Number of years spent in school by household head	.043	.026	.094	159	.094
Farming experience of household head	-.017	.017	-.018	-.034	-.055
Age of head of household	.098	-.013	-.027	-.28	0.98

Source: Household survey data, Zimbabwe, 2011
*adult units

Table 7: Proportions of farmers who used various soil and water management technologies for more than 10 years in four study sites in Zimbabwe

Study sites	Tied ridges		Rain water harvesting		Pot holing		Contour ridges		Reduced tillage		Mulching		Winter ploughing	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Mazowe & Goromonzi	18	66.7	9	88.9	10	40.0	48	68.8	81	2.5	94	33.0	4	75.0
Kadoma	29	51.7	4	75.0	1	0	7	71.4	124	0.8	96	4.2	22	77.3
Matobo	19	63.2	6		1		73	47.9	86	2.3	46	10.9	17	70.6
Chiredzi	6	16.7	4	25.0	9	55.6	44	38.6	13		26	38.5	2	

Source of Data: Household survey carried out in Zimbabwe, 2011

Table 8: Farmers' ranking[1] of soil and water management technologies at each of the four study sites in Zimbabwe

	Mazowe/Goromonzi				Kadoma				Matobo	
	Male FGs[2]		Female FGs		Male FGs		Female FGs		Male FGs	Female FGs
	1	2	1	2	1	2	1	2	1	2
Reduced tillage	5.4	8.2	n.a	8	n.a	7.3	5.4	7.8	8	8.4
Contours	n.a	n.a	7.3	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Cultivation	n.a	n.a	n.a	n.a	6.4	n.a	n.a	n.a	n.a	n.a
Deep ploughing	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	6.4	n.a
Manure	5.8	5.8	n.a	n.a	n.a	n.a	5.8	6.3	n.a	n.a
Mulching	8.2	n.a	6.3	4.2	5.2	7.8	8.2	6.8	n.a	n.a
Ridges	7	n.a	n.a	n.a	7.2	5.8	7	7.5	n.a	n.a
Tied ridges	5.6	n.a	n.a	n.a	7.2	n.a	5.6	n.a	n.a	n.a
Water harvesting pits	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	4.2	n.a
Winter ploughing	n.a	n.a	n.a	n.a	7.2	6.3	n.a	n.a	6.4	6.6

[1] Ranking used multiple criteria analysis (MCA): Selection criteria for each technology was scored on a scale of 0-10, and the scores were then averaged. Highest score is the most preferred/best performance/rank

[2] FGs = Focus groups

n.a - not available because of very few farmers or farmers did not mention it at all.

NB: There is no data for Chiredzi because soil and water management technologies are currently used by very few farmers

Source of Data: Household survey carried out in Zimbabwe, 2011 and focus group discussions conducted in 2013

Table 9: Constraints to soil and water management technologies mentioned by farmers in four study sites in Zimbabwe (% of total responses)

	Site	Mazowe/ Goromonzi		Kadoma		Matobo		Chiredzi	
	Gender HHH[1]	MHH[3]	FHH[2]	MHH	FHH	MHH	FHH	MHH	FHH
Reduced tillage	Labor intensive	82.6	71.4	87.5	0	89.5	100	63.6	60
	Input constraints	0	7.1	0	0	0	0	0	0
	Unreliable rainfall/ temperature	0	0	0	0	0	0	0	0
	Lack of knowledge	13	14.3	12.5	0	5.3	0	36.4	40
	Lack of cattle	0	0	0	0	0	0	0	0
	Markets not favorable	4.3	7.1	0	0	0	0	0	0
	Not suitable	0	0	0	0	5.3	0	0	0
	n	23	14	8	0	19	8	11	10
Mulching	Labor intensive	50	0	76.9	0	60	75	30	38.5
	Input constraints	43.8	0	23.1	0	24	16.7	40	30.8
	Unreliable rainfall/ temperature	0	0	0	0	0	0	10	15.4
	Lack of knowledge	0	0	0	0	4	0	0	7.7
	Lack of cattle	0	0	0	0	8	8.3	0	0
	Markets not favorable	0	0	0	0	0	0	0	0
	Not suitable	6.3	0	0	0	4	0	20	7.7
	n	16	0	13	0	25	12	10	13
Contour ridges	Labor intensive	0	0	92.9	100	0	0	21.1	28.6
	Input constraints	0	0	0	0	0	0	0	0
	Unreliable rainfall/ temperature	0	0	0	0	0	0	0	0
	Lack of knowledge	0	0	7.1	0	0	0	10.5	28.6
	Lack of cattle	0	0	0	0	0	0	0	0
	Markets not favorable	0	0	0	0	0	0	0	0
	Not suitable	0	0	0	0	0	0	68.4	42.9
	n	0	0	14	9	0	0	19	14
Tied ridges	Labor intensive	0	0	87.5	100	0	0	0	0
	Input constraints	0	0	0	0	0	0	0	0
	Unreliable rainfall/ temperature	0	0	0	0	0	0	0	0
	Lack of knowledge	0	0	12.5	0	0	0	0	0
	Lack of cattle	0	0	0	0	0	0	0	0
	Markets not favorable	0	0	0	0	0	0	0	0
	Not suitable	0	0	0	0	0	0	0	0
	n	0	0	8	11	0	0	0	0

NB: There were no responses for some technologies due to lack of knowledge and/or lack of use.
Source of Data; Household survey carried out in Zimbabwe, 2011

Figure caption:

Figure 1: Location of the five study sites in various agro-ecological regions of Zimbabwe. **A**: Chiredzi, **B**: Matobo; **C**: Kadoma; and **D** Mazowe/Goromonzi.