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An overview of current agronomic practices of smallholder farmers in semi-arid Central and Western Zimbabwe

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Smallholder farmer productivity in developing countries is limited by diverse biophysical, political and socio-economic factors. The objective of this study was to establish current agronomic practices of smallholder farmers in semi-arid Lower Gweru and Lupane areas of Zimbabwe and to identify possible research and extension interventions that may improve crop productivity of these farmers. Focus group discussions, interviews and desktop study were used to collect data. Horticultural production is the main livelihood in Lower Gweru, while field crop and livestock production are livelihoods in both areas. Conventional tillage is the predominant tillage system. Important crops include maize (*Zea mays* L.), pearl millet (*Pennisetum glaucum* (L) R.Br.), sorghum (*Sorghum bicolor* L.) and groundnuts (*Arachis hypogea* L.). Farmers grow both hybrid and open-pollinated maize varieties (OPVs) with more farmers in Lupane than in Lower Gweru, growing these OPVs. The number of farmers growing improved varieties of small-grain crops has increased, since mid 1990s. The method and frequency of weeding depends on tillage system used and availability of equipment as well as draft power. Adoption rates for technologies such as water conservation and use of adequate soil ameliorants as well as effective crop rotations are low due to limited resources. The study identified some research and extension interventions that may be employed to improve crop productivity in semi-arid areas of Central and Western Zimbabwe.

Key words: Smallholder farmers, agronomic practices, semi-arid areas, research and extension interventions.

INTRODUCTION

The majority of the rural population in Zimbabwe are smallholder farmers located in Natural Regions (NRs) III, IV and V of the country. These regions are generally characterized by low and erratic rainfall resulting in low agricultural potential. Inherently low fertility status of the soils also contributes to low agricultural potential of these demonstrated significant year to year variability in maize yields due to seasonal rainfall variability, for these semi-

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arid areas. Despite the marginal conditions in these areas, most smallholder farmers continue to rely on rain-fed agriculture, cropping in particular, for their livelihoods.

In Zimbabwe, the term “smallholder farmers” refers to farmers working on fields in the communal and resettlement areas as well as co-operative farmers. In this study, the opinions and needs of communal area farmers are addressed. Smallholder farmers are generally characterized by a limited resource base. Waddington et al*.* (2004) characterize smallholder productivity as “low input – low output” farming, while Rockstrom (1999) describes small-scale farmers in semi-arid regions as being “generally risk minimizers rather than yield maximizers.” Ellis-Jones and Mudhara (1995) point out that smallholder farmers in semi-arid Zimbabwe face great challenges as they are required to respond to a wide range of environmental and economic variables. Notable agricultural research and extension efforts have been made to improve the livelihoods of smallholder farmers in Zimbabwe. However, expected benefits from these efforts, for example through development and dissemination of new technology are not always realized. This is due to among other reasons, inadequate knowledge of farmers’ circumstances, leading to development of inappropriate technologies, from the farmer’s point of view. Several authors including Avila (1985) and Hardaker et al. (1984) highlight the need for stakeholders to study and understand the farming system for effective adoption of technologies recommended to farmers. This study which was carried out partly to fill in some gaps in the baseline survey for the IDRC climate change project on capacity building, in Zambia and Zimbabwe, reviews agronomic practices of smallholder farmers in Lower Gweru and Lupane communal areas of Zimbabwe. These areas represent marginal areas where approximately 70% of the population resides and where crop production is practised by all smallholder farmers. The data and information collected are useful in directing crop research and extension efforts. The current status quo of the farming systems may also provide indicators of possible farmers responses to environmental changes such as climate change and increased climate variability.

MATERIALS AND METHODS

The study area comprises Lower Gweru and Lupane communal areas. Most of Lower Gweru lies in Natural Region III while Lupane is in region IV. Natural Region III is a semi -intensive farming region receiving annual rainfall of 550-700 mm while Region IV is semi-extensive and receives annual rainfall of 450-600mm (Vincent and Thomas, 1962). Both regions are subject to mid-season dry spells with region IV experiencing more severe spells as well as periodic seasonal droughts. Temperatures are generally high, with annual mean maximum temperatures ranging from 24-28°C, for Region III and 32-35°C for Region IV. The high temperatures render rainfall received less effective due to high evaporative losses. Soils in both regions range from vertisols to sands (Thompson and Purves, 1978) and most areas in these regions consist of shallow, coarse grained sands, which have a low production potential (Thompson and Purves, 1978; Grant, 1981; Mashiringwani, 1983). A considerable area of deep, fine grained sands is also found in the west of the country (which includes Lupane) (Thompson and Purves, 1978). These soils are relatively infertile and subject to severe wind erosion particularly if they are cropped.

Data and information were collected on current agronomic practices employed by the farmers in the study area. Methods used to collect data include secondary data (Bless and Higson-Smith, 2000), semi-structured interviews (Flick, 2006; Gill et al., 2008) with agricultural extension personnel, structured interviews (Punch, 2005; Gill et al., 2008) and Focus Group Discussions (FGDs) (Gill et al., 2008; Harrell and Bradley, 2009) with heads of households. Two wards were selected from each communal area and these were Mdubiwa and Nyama Wards for Lower Gweru and Daluka and Menyezwa Wards for Lupane. In each ward, three villages were selected. A total of 48 farmers were selected using random systematic sampling from a household list that had been compiled for the International Development Research Centre-Climate Change Adaptation in Africa (IDRC-CCAA) project baseline survey carried out in the four wards listed above, during 2008. The household survey was a case study, carried out to fill in information gaps that had been identified in the main IDRC baseline survey. FGDs were also held with farmers from the same wards and villages with five (5) farmers randomly selected from each village, bringing the total number per discussion group to 15. A questionnaire was developed and tested for the household survey while checklists were prepared for the FGDs and semi-structured interviews. In FGDs farmers were grouped by ward and gender. Methods of data collection in FGDs included brainstorming, time charts, matrix scoring and ranking (Chambers, 1994; Sutherland, 1998). The FGDs and household interviews were conducted and solicited data on agronomic systems and practices.

RESULTS AND DISCUSSION

Tillage systems

The predominant tillage system in both Lower Gweru and Lupane communal areas is conventional tillage where the ox and / or donkey-drawn plough, is the most commonly used tillage implement. In Lupane, more than half the farmers also use “*gatshompo*” (the use of planting basins) on some of their fields, while in Lower Gweru approximately 29% of farmers practice zero tillage (digging ahole on unploughed land in which to place the seed) on some or all of their fields. About 10% of farmers in Lower Gweru also practise ““*chibhakera*” (hand digging of the whole field and then planting) (Figure 1). Thus some of the farmers use more than one tillage systems for land preparation and planting, depending on soil type and labour availability. Most farmers plough just prior to planting while about 30% of the farmers in these areas also do winter ploughing. Planting basins are more suitable for farmers with inadequate draft power and implements which is the case in Lower Gweru and Lupane. In addition, the use of basins spreads labour for land preparation over the dry seasons, promotes timely planting and reduces the risk of crop failure, even under drought conditions, due to the concentration of water and available fertilizer in the basins (Twomlow et al., 2008). The use of mulch (if available) on the basins also enhances moisture retention and improves crop

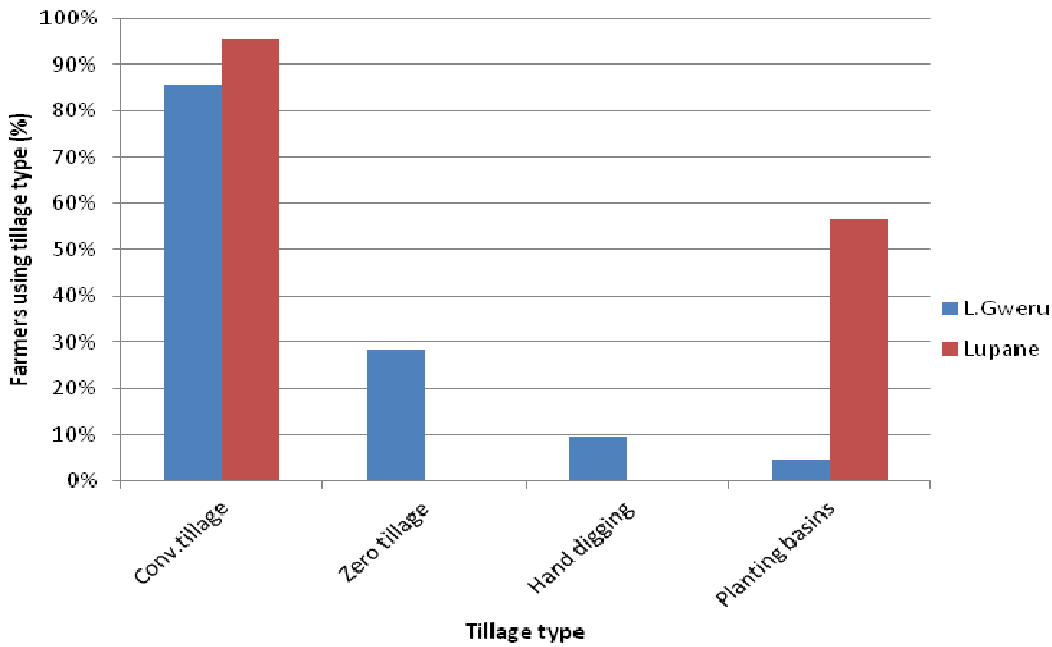

Figure 1. Tillage systems used by farmers in Lower Gweru and Lupane communal areas during the 2008/09 cropping season

enhances moisture retention and improves crop productivity. Twomlow et al. (2008) established that crop yields increased, on average, by 15 to 300% across 13 pilot districts in Zimbabwe over three seasons (2004/05 to 2006/07) of using planting basins, depending on rainfall pattern and amount, soil type and fertility. The adoption rate for use of planting basins is higher in Lupane than Lower Gweru, presumably due to more intense extension effort in Lupane where rainfall inadequacy and unreliability are more critical.

Crops grown

Farmers in Lower Gweru and Lupane grow a wide range of field crops (Figure 2) and these include maize (*Zea mays* L.), sorghum (*Sorghum bicolor* L.), groundnuts (*Arachis hypogea* L.), cowpeas (*Vigna unguiculata* (L.) Walp), bambara nuts (*Vigna subterranean* (L.) Verdc), melons (*Citrullus lanatus* (L.) Thunb), pumpkins (*Curcubita maxima* L.), sugar beans (*Phaseolus vulgaris*), pearl millet (*Pennisetum glaucum* (L) R.Br.), rapoko (*Eleusine coracana* L.) and sweet potatoes (*Ipomea batatas*.L). Farmers ranked crops they consider important according to contribution to food security, improved livelihoods and income generation as well as according to the number of farmers growing the crop and the uses to which the crop can be put. In Lower Gweru, the most important cereal crop is maize while finger millet and sorghum are grown to a lesser extent. In Lupane, the main cereal crops are maize, pearl millet and sorghum and in Daluka ward, these were ranked 1 to 3 respectively. In Menyezwa ward, pearl millet is the most important cereal, followed by sorghum and then maize. "*Amajodo*" (sour melon), a type of melon that is cooked and consumed on its own or boiled and consumed together with maize grain, was ranked first and second by men and women in Menyezwa ward respectively. Groundnut is the main legume crop in Lower Gweru, while in Lupane it is cowpea. In Lower Gweru sweet potatoes are grown for both consumption and sale, while in Lupane production of this crop is limited. Individual farmer interviews and discussions with local extension officers did not indicate that the sour melon was the number one (1) crop in Menyezwa ward as revealed in FGDs. The crop however, yields quite well in relatively dry years as compared to wet years, implying its high abundance in dry years. The most probable explanation for the highest ranking of the sour melon by the Menyezwa group of farmers is that, during the 2008/2009 season, when the FGDs were conducted, farmers in this ward depended on the crop for survival as other crops had failed. Farmer interviews did not reflect the high priority that was given to sugar beans by Mdubiwa farmers in FDGs. This is probably because not all farmers that were interviewed own irrigation plots in one of the two irrigation schemes that are in this ward.

Varieties of main cereal and legume crops grown

Farmers indicated that their choice of variety is normally

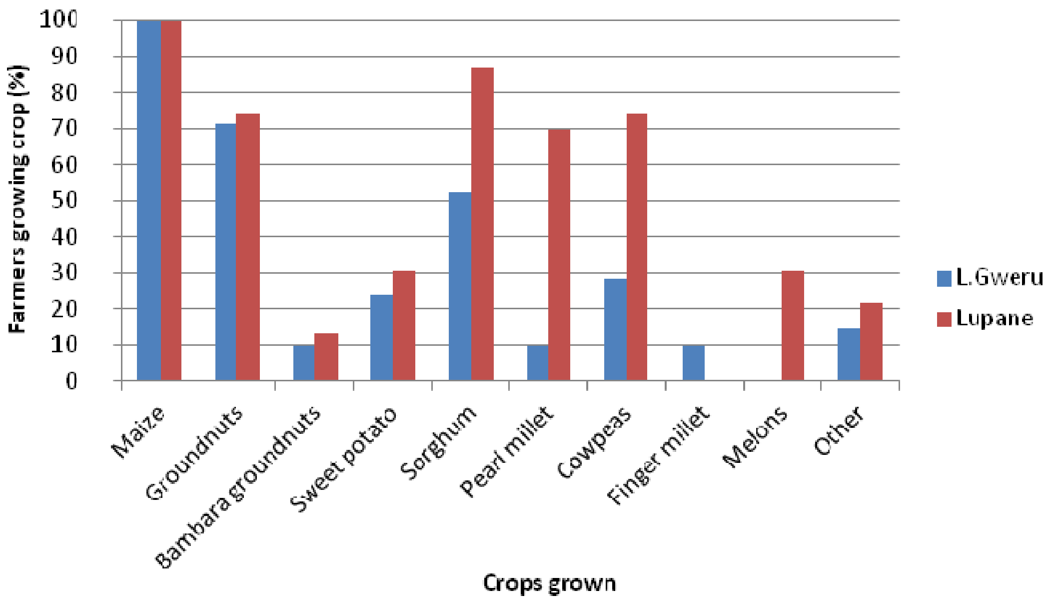

Figure 2. Percentage of farmers growing different crops in Lower Gweru and Lupane communal areas during the 2008/09 growing season.

governed by factors such as earliness to maturity, tolerance to drought, yield potential, ease of management and good storability. Short statured varieties, for example, are generally preferred to tall varieties for easy harvesting while the "red cob" an OPV of maize is preferred over other varieties, for its good resistance to weevil attack. However, in recent years, farmers have had little varietal choice and what they grow is mainly dictated by what is available, provided it suits their rainfall regimes. Farmers in the study areas use more than one crop variety in a season as a way of spreading risk of complete crop failure in these water stress environments.

In both communal areas, maize hybrids as well as OPVs are used. In Lupane the hybrids and traditional OPVs are used to about the same extent (about 75% of farmers use each of these categories of varieties), while in Lower Gweru about 90% of farmers use hybrid maize seed; traditional OPVs are used by 40% of the farmers. Improved OPVs, which generally yield higher than traditional OPVs, are used to a lesser extent compared to unimproved OPVs, being about 20 and 10% of the farmers in Lupane and Lower Gweru, respectively. Very early (110-120 d) to early maturing (120-130d) hybrids are grown in Lupane while in Lower Gweru the range stretches to medium (130-140d) maturity hybrids. Although hybrids generally have a higher yield potential than OPVs, for varieties in the same maturity group (Chiduza et al., 1994; Pixley and Bänziger, 2001), farmers in the study areas continue to choose to grow OPVs as they are relatively cheap to grow and planting seed is readily available When maize is grown from hybrid seed retained from previous harvests, there is non-uniformity of the crop in the field as well as reduction in yield due to segregation of characteristics of the individual parental plants. In contrast, OPV seed can be retained for several years without incurring significant yield reductions (Chiduza et al., 1994; Pixley and Bänziger 2001; Tinsley, 2009a). Use of seed retained from previous harvests has cushioned farmers in the study area against shortages of planting seed on the market during certain seasons, including the 2008/09 season when this study was carried out.

The use of improved varieties of small grain crops, sorghum and pearl millet by communal farmers in western Zimbabwe, including Lupane was reported to be low (Ahmed et al*.,* 1997). The study has established that about 60% of the farmers in Lupane use improved varieties of either crop, with Pearl Millet Variety 3 (PMV3) being the main pearl millet variety and Macia (white), the main sorghum variety. The most commonly grown traditional "unimproved" pearl millet variety is "*Harare*" while for sorghum it was unclear what the main traditional variety was, since some farmers were not sure of the names of traditional varieties they were growing. There is an indication that the use of improved small grain varieties has increased. This trend is most likely due to earliness of these varieties to reach maturity, a favourable trait in low and erratic rainfall areas, as well as promotion of the varieties, particularly in Lupane, by NGOs and Government extension agencies.

Groundnut seed is often in short supply and farmers normally grow any varieties made available to them. About 30% of farmers grow Natal Common variety; 20%, Valencia Red and 5%, Valencia White. A substantial number of the farmers were not sure of the names of varieties they were growing. Most farmers have been

Table 2. Inter-row spacing and plant densities achieved when planting behind the plough with animals harnessed to a cultivator yoke and with the plough width adjusted to 30 cm, for major cereal and legume crops (Source: Lower Gweru and Lupane farmer interviews, 2009).

Crop	Number of furrows skipped before next planting row	Inter-row spacing achieved (cm)	Intra-row spacing used (cm)	Plant population (plants/ha)
Maize	2	90 *(90)*	25-30 *(30)*	37 000-44 000 *(37 000)*
Sorghum	1	60 *(90)*	10-25 (after thinning) *(7-10 after thinning)*	66 000-167 000 *(111 000-160 000)*
Pearl millet	1-2	60-90 *(50-75)*	10-25 (after thinning) *(20-30 after thinning)*	~44 400-167 000 *(53 300-100 000)*
Groundnuts	0-1*	30-45 *(50-75)*	7-10 *(5-7.5)*	~ 222 200-476 000 *(178 000-400 000)*
Cowpeas (upright varieties)	0-1*	30-45 *(45)*	10-15 *(15)*	~150 000-333 300 *(~150 000)*

Figures in brackets and italics are recommended spacing and populations from the Ministry of Agriculture.
* When a row is skipped the plough width is maintained at standard width of 20 cm

growing these varieties for a long time and their continued use contributes to the general decline in groundnut yields in the smallholder farming sector of Zimbabwe (Shumba, 1983). Improved varieties such as Nyanda and Falcon, released in the 1980s and 1990s, have been in short supply since their release and it was unclear whether farmers in Lupane and Lower Gweru grow them or not.

Both the spreading and upright varieties of cowpeas are grown by the farmers. However, most farmers prefer the upright variety IT18, popularly known as "*mupedzanhamo*" (poverty terminator) as it matures quite early (about 90 days), providing food, before most crops are ready for consumption. The variety is also high yielding.

Planting methods and times

The majority of farmers who use conventional ploughing either plant behind the plough or open up planting furrows in ploughed fields. With the former method, variable row spacings are achieved, depending on the type (size) of yoke to which the animals are harnessed and the number of furrows skipped before the planting furrow. As an example, when draft animals are harnessed to a cultivator yoke, skipping one furrow before the planting row gives a row spacing of 60 cm whereas when two rows are skipped, the resultant inter-row spacing is 90cm (Table 1). Thus a higher plant population is achieved where less furrows are skipped, if the same intra-row spacing is maintained (Table 1). In contrast, harnessing animals to a plough yoke, which is shorter than the cultivator yoke, gives narrower inter-row spacings. A plant population of about 37 000 ha^{-1} is recommended for maize in medium to low agricultural potential areas such as Lower Gweru and Lupane. By using an inter-row spacing of 90 cm and an intra-row spacing of 25-30 cm farmers achieve a population range whose lower limit is equal to and upper limit about 20% higher than the recommended population (Table 1). Farmers should adopt the recommended intra-row spacing of 30 cm for upland maize production, while an intra-row spacing of 25 cm may be used by farmers such as those in Nyama Ward, who grow maize in wetlands where soil water is less limiting.

Sorghum and pearl millet are drilled in 60 and 60-90 cm rows respectively and plants are then thinned to about 10-25 cm within the row. For both pearl millet and sorghum, the population range that farmers use falls outside the recommended range (Table 1), with much discrepancy in the upper and lower range values for pearl millet and sorghum, respectively. Recommendations from the Ministry of Agriculture stipulate that sorghum plant populations below 90 000 plants ha-1 should be avoided (Ministry of Agriculture, Mechanization and irrigation Development in Zimbabwe, 2011). On the contrary, Ismail and Ali (1996) in their study on effects of plant population on sorghum yield in dry-land farming systems suggest that populations less than 90 000 plants ha^{-1} could still give reasonable grain yields in low cropping potential areas such as Lower Gweru and Lupane. The variations in plant populations between farmer and recommended practices (varying from seemingly small e.g. for maize to large e.g. for pearl millet), may require on-farm field experiments to verify whether there are significant grain yield differences due to the different plant populations and to establish the associated economic implications (e.g. higher unnecessary input costs). Winter ploughing followed by opening up planting furrows on the onset of rains or a few weeks before onset of rains (dry planting), is also commonly practised by farmers in the study area. They open the furrows using a plough drawn by animals harnessed to the cultivator yoke or plough yoke depending on the intended inter-row spacing. With this method of planting it is relatively easy to achieve the desired inter-row spacing as there is no requirement for adjusting the plough width. Farmers should be encouraged to plough their fields in winter as this practice conserves moisture from the previous season, promotes early crop establishment and reduces weeds (Sibanda, 2005; Mpatane et al., 2012). Over and above recommendations from the Ministry of Agriculture, farmers are also guided by the method of weed control they use, in their choice of inter-row spacing, e.g. if the animal-drawn cultivator is used, a wider spacing is required than when the hand hoe is used. Other planting methods used by farmers include planting in basins and marking out planting lines using wires, followed by hoe planting. Both methods are suitable for relatively small fields. Planting basins which are most commonly used for maize, are spaced either 75 cm x 75 cm or 90 cm x 60 cm and the recommendation is to plant three seeds per station. Thinning may then be done after emergence to remain with two plants per station, giving a target population of about 37 000 plants per ha. This practice may be considered wasteful by farmers particularly for hybrid seed which is relatively expensive and sometimes not readily available. To reduce the loss, extension officers encourage farmers to thin out extra plants when the soil is wet and transplant them onto another piece of land (Musasanuri and Pawadyira, 2013) - personal communication).

Farmers indicated that planting dates were dependent on a number of factors including availability of soil water, seed and draft power. Farmers are aware of the importance of early planting, given their water stress environments. They thus, aim to plant most of the crops with the first rains or dry plant before the rains. In Lower Gweru maize, groundnuts and rapoko are sown first, while in Lupane it is maize and pearl millet that have first priority. Shumba (1989) shows that delaying planting of maize by up to 21 days after first effective rains reduces yield by about 30%. Due to late planting, the crop is unable to intercept full sunlight radiative load available since, by 22 December when the sun is overhead, the crop will not have developed full canopy. Other disadvantages of delayed planting are reduced soil and water conservation due to delayed crop cover (Norton, 1995). Dry planting which is also meant to reduce labour demand for planting at the start of the rainy season, is mostly done in October. In Lupane, almost all of the pearl millet is dry planted. Farmers in this area argue that dry planting of this crop results in early establishment of the crop and allows it to mature at the same time as wild grasses, a factor that reduces crop damage/loss from bird attack as the birds will not only be feeding at that time, on the crop, but on wild grasses as well. Staggering of planting dates is a characteristic feature of the planting process for most farmers. Cropping calendars drawn up by the farmers showed that planting stretches from as early as late October (mostly dry planting) to as late as the first dekad of January in both study areas, depending on rainfall pattern. In general most of the planting is done during the period from the second dekad of November until the second dekad of December.

Weeding

Crop competition with weeds is always a major constraint as weeds use water, nutrient and solar radiation resources and yet they do not contribute to production, but rather reduce crop yield. Hand hoeing is carried out by all the farmers in the study areas; this is consistent with the findings of Chatizwa and Nazare (2000) that all farmers in the different farming sectors of Zimbabwe use hand weeding. Farmers with draft animals and equipment also use cultivators to remove weeds in-between plant rows and in both Lower Gweru and Lupane communal areas, about 50% of the farmers use these cultivators. However, for farmers who use planting basins, the weeding method is predominantly hand hoeing.

Approximately 70% of farmers in the study areas weed twice while less than 10% weed once or thrice, under the conventional tillage system. The practice of weeding twice is in agreement with the Zimbabwe Ministry of Agriculture recommendation to combine fertilizer application with weed free management through three tillage operations per crop (Snapp et al., 2003). The three operations being ploughing and planting plus two weeding operations. Mudhara (1995) also established that most farmers in semi-arid Chivi communal area in Southern Zimbabwe weed twice. A survey conducted during the 2009/10 and 2010/11 seasons in 15 districts across different Natural Regions of Zimbabwe also showed that under the conventional tillage system, most smallholder farmers weed their fields twice, irrespective of Natural Region (Nyamangara et al., 2013). Field experiments, for example by Kumwenda and Kabambe (1995) in Malawi and Mabasa and Nyahunzi (1995) in both low and high rainfall areas of Zimbabwe suggest that weeding twice has yield benefits. However, from field experiments conducted during the 1995/96 to 1998/99 at the University of Zimbabwe farm located in northern Zimbabwe under Natural Region II, Mashingaidze (2004) established that there was no grain yield benefit from increasing the frequency of hand hoe weeding from once to twice or thrice during the 1998/99 season and no significant difference in grain yield between a maize crop weeded once and one weeded twice during the 1997/1998. Results from simulation modeling also show that, in risky environments such as Lupane, only the first weeding is critical and that a second weeding does not have detectable benefits (Dimes et al., 2002). As suggested by Mashingaidze (2004) and IIRR and ACT

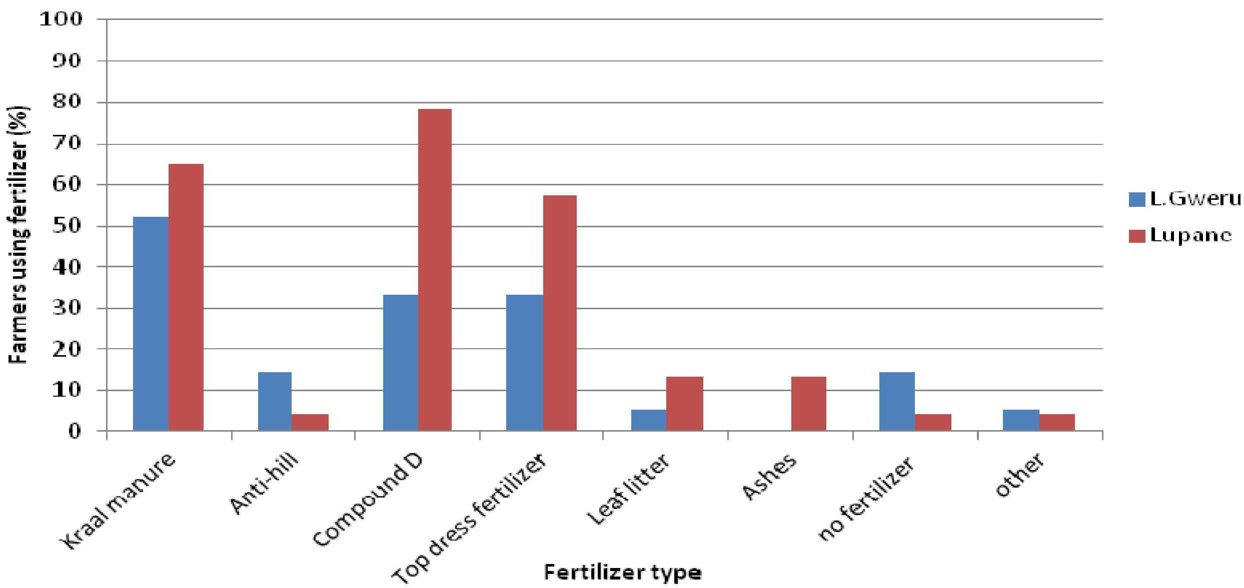

Figure 3. Fertilizer types used by farmers in Lower Gweru and Lupane communal areas during 2008/09 cropping season.

(2005), smallholder farmers, particularly those who entirely hand hoeing to control weeds, can reduce the need to weed more frequently by embarking on cultural practices such as intercropping with good cover crops, reducing inter-row spacing and early planting to control weeds. It was apparent that, in the majority of cases, farmers who use planting basins, also have fields where they practise conventional tillage. They weed three times on the basin plots, but only twice and rarely once on conventionally tilled fields. The high frequency in weeding on planting basins is consistent with Nyamangara et al. (2013)'s findings that farmers in different Natural Regions of Zimbabwe, who use planting basins, weed at least three times. Thus, the frequency of weeding varies according to tillage practice used. The method and frequency of weeding also depends on the availability of equipment and draft power. Weeding three times on planting basin plots is consistent with the observation that weed infestations tend to be high under minimum tillage (Mabasa et al. 1999; Twomlow et al., 2008). Thus, farmers who use planting basins need more labour during the season as well as during land preparation. However, with planting basins, weed pressure gets less in subsequent years (Twomlow et al., 2008).

Fertilizer use

Farmers in the study areas apply little fertilizer to their fields mostly because the fertilizers are expensive and / or unavailable. They also use less fertilizer because of limitations in soil water in these areas. The main soil ameliorants used are cattle manure and inorganic fertilizers (compound D, with N:P:K =7:14:8 and Ammonium nitrate, N =34.5% or urea, N = 46%), while leaf litter, anti-hill and ash are used to a lesser extent (Figure 3).

Although about 15 and 60% of the farmers in Lower Gweru and Lupane respectively, own donkeys, they do not use donkey manure and their reason is that, this manure burns crops, due to high nutrient content presumably high N. Manure and inorganic fertilizer rates used are quite diverse and most farmers use amounts that are below the recommended rates. The majority of farmers who use inorganic fertilizers regularly use 100 kg ha^{-1} of compound D and a top dress of 50-100 kg ha^{-1} of Ammonium Nitrate or 50 kg ha^{-1} of urea on maize in both natural regions III and IV. Blanket fertilizer recommendations given by extension officers are 200-300 and 150-200 kg ha^{-1} compound D (basal) for natural region III and IV respectively, while corresponding top dressing fertilizer rates are 150-200 and 100-150 kg ha^{-1} Ammonium Nitrate respectively. The general recommendation for cattle manure is 20-30 t ha^{-1}, but due to limited supplies farmers often apply limited amounts. The use of planting basins allows precision application of the limited fertilizers and as a result of this and other benefits associated with use of these basins, it was found that more farmers in Lower Gweru and Lupane are adopting the practice.

Farmers and agricultural extension officers pointed out that some farmers use inorganic fertilizers only when they get them from government or NGO drought relief programmes. This is in agreement with Ahmed et al. (1997), who drew the same conclusion regarding some farmers in South-western Zimbabwe, including Lupane district. Ellis-Jones and Mudhara (1995) establish that nearly all communal area farmers in Zimbabwe used fertilizers over the period 1992-1994 when fertilizer was provided at no costs, under the government drought relief and recovery programmes. Agricultural extension staff in the study areas confirmed that there was a decline in fertilizer use in these areas from the late1990s to the early 2000s, following the phasing out of drought relief programmes. With the launch of new government input schemes such as "*Maguta*", "Champion Farmer" and the SADC input scheme (Mare, 2010, personal communication), inorganic fertilizer use is likely to increase, but probably only temporarily, in the targeted communal areas which include both Lupane and Lower Gweru. Some farmers in Lupane are sceptical about using inorganic fertilizers as they believe that these fertilizers "kill" the soil. This observation is consistent with Ahmed et al. (1997)'s findings regarding perceptions of some farmers in Western Zimbabwe, on fertilizer use. Of the commonly used inorganic fertilizers, compound D and Ammonium Nitrate, it is the former that they believe to be more detrimental to the soil especially when one does not use it continuously (every season) in a particular field - "the problem is worse if one does not apply the fertilizer every season". A similar perception by some smallholder farmers in Western Kenya is highlighted by Misiko et al. (2009) where the farmers believe that fertilizers "spoil" the soil in that "the soil gets addicted to the fertilizer" so much that if it (the soil) is not fertilized, crop (maize) yields drop drastically. The perception that fertilizer "kills" the soil probably arises as a result of increased soil acidity due to use of inorganic fertilizers, particularly nitrogenous fertilizers which leads to reduced or non-availability of nutrient elements to the crop.

Cropping systems and patterns

The "true" rotations that farmers practise are basically cereal - legume rotations and these are practised by about a third of the farmers in each of the communal areas. Maize-groundnut-maize rotation is the most common rotation in Lower Gweru while in Lupane maize, sorghum or pearl millet is rotated with cowpeas. In Lower Gweru, maize-bambara nut rotation is popular with women. Other crop sequences include maize-pearl millet-maize, maize-sorghum-maize, sorghum-groundnuts-sorghum and fallow-bambara nuts (that is, bambara nuts grown on a newly opened field). Some farmers in the study areas, allocate certain fields / soils to particular crops, for example, in Lupane some farmers plant maize, continuously on the more fertile and high soil water holding capacity "*isidaka"* soils. This practice is a limitation to the implementation of rotations. In Lupane, farmers believe that pearl millet revives the soil because of its high tillering ability (more roots are developed) and for this reason, they alternate it with maize, so that maize benefits from the improved organic matter content of the soil.

Although most farmers are aware of the benefits of a good crop rotation, they do not practise effective rotations and the rotations they use do not have a consistent pattern. These findings are consistent with Mudhara (1995), who concludes that in the third year, farmers in Chivi communal area (southern Zimbabwe) rotate only 40% of the area planted to maize in the previous year with other crops such as pearl millet, finger millet, groundnuts and sunflower. Chuma et al. (2001) also highlight the point that smallholder farmers in Zimbabwe do not practise effective rotations. One reason for ineffective and / or inconsistent rotations is their decision to allocate more land to grain cereals in an attempt to achieve household food security each year. This is in line with Ahmed et al. (1997)'s findings that most smallholder farmers in south-western Zimbabwe allocate most of their cropping area to cereals, namely maize, pearl millet and sorghum. So, where cropping land is limited, priority is given to these staple crops. Seed shortages and labour constraints lead to a reduction in area planted to grain legumes, groundnuts in particular, and this contributes to ineffective and inconsistent crop rotations in these communal areas. Shumba (1983) highlights the shortage of groundnut seed as a major constraint to groundnut production in communal areas of Zimbabwe while labour shortage is another important constraint, especially for the resource poor farmers (Shumba, 1983; Waddington and Karigwindi, 2001; Zingore et al*.,* 2009).

Farmers in Lower Gweru and Lupane predominantly practise sole cropping, although pumpkins, sweet reeds and melons are often sparsely intercropped with the main cereal crops. A few farmers grow or strip intercrop groundnuts, cowpeas or bambara with cereal grain crops, especially maize. In Lupane, some farmers are forced to intercrop due to shortage of planting seed, since they will not have adequate seed of one crop to plant all the intended cropping area. Others intercrop sorghum with maize due to shortage of land, but they do not intercrop pearl millet with maize as they believe that the two crops are "not compatible". In fact, the farmers ascertain that maize dies when intercropped with pearl millet. Extension officers in Lupane verified that the common practice was to mix sorghum and maize and not pearl-millet and maize, but they were not sure why this was the case. Although pearl millet has been found to have allelopathic effects on germination and growth of certain weeds, for example as was established by Narwal et al. (1998), in weed suppression experiments, the possibility of direct allelopathic effects of pearl millet on maize germination and growth may be ruled out in this case since farmers who practise sole cropping indicated that they usually grow maize after pearl-millet and get a good maize crop. The ability of pearl millet to regenerate growth following drought conditions and to tiller heavily under fertile and adequately wet soil conditions probably makes the crop a better competitor than maize, under these conditions. This may explain farmers' views on the performance of maize and pearl millet when the two are grown together.

Water management practices

Inadequate soil water is a limiting factor to crop productivity in both Lower Gweru and Lupane, although flooding and waterlogging are occasionally experienced. Water management, particularly as it relates to soil water conservation and water harvesting goes a long way in improving water availability in these water stress environments.

Less than 50% of farmers use any form of water conservation measures in either communal area. However, more farmers in Lupane than in Lower Gweru use some of the techniques. This scenario is expected since rain water is more scarce in Lupane than in Lower Gweru. Contour ridges followed by winter ploughing are the main conservation techniques used by farmers in both areas. About 48% of farmers in Lupane and 24% in Lower Gweru use contour ridges while winter ploughing is practised by 16 and 35% of farmers in Lupane and Lower Gweru respectively. It was pleasing to note that most of the farmers who used contour ridges had moved away from the traditional graded contour ridges to the zero gradient contour ridges which are more suitable for retaining water in the field. Use of planting basins, conserves soil water as the water is concentrated in the basins. Farmers who use this method also apply mulch to the basins when it is available, hence the use of mulch by 30% of farmers in Lupane where basins are more commonly used. Pot-holing and tied ridging are used by a few farmers (less than 10%), while ridging is practised by about 13% of farmers in Lupane. Low adoption rates for water conservation techniques such as use of tied ridges, is not unique to Lower Gweru and Lupane, as the adoption of these technologies by smallholder farmers elsewhere in Zimbabwe and Africa are also slow and low (Chuma et al*.,* 2001; Mutetwa and Kusangaya, 2006; Chiputwa et al., 2011; Marongwe et al., 2012; Nyamadzawo et al., 2013). Reasons for low adoption rates include shortage of draft power and labour, lack of suitable implements, inadequate institutional support and lack of capital to purchase inputs (Chuma et al*.,* 2001; ; Mazvimavi and Twomlow, 2009; Nyagumbo et al., 2009; Nyamadzawo et al., 2013). Nyamadzawo et al. (2013) also attribute low adoption rates for soil and water conservation technologies to blanket recommendations and yet according to Nyagumbo et al., 2009 and Places and Deewes, cited in Chiputwa et al., 2011, biophysical requirements for effective implementation of the different technologies are known. Although some technologies conserve water during low rainfall seasons, they result in waterlogging during high rainfall seasons and this discourages farmers from adopting them (Mutekwa and Kusangaya, 2006).

CONCLUSION AND RECOMMENDATIONS

The study established cropping systems and practices of smallhoder farmers in Lower Gweru and Lupane areas of Zimbabwe It was established that the majority of smallholder farmers in the study area use conventional tillage systems. Farmers should be encouraged to practise minimum tillage rather than conventional tillage since minimum tillage promotes sustainable agriculture as there is minimum disturbance of the soil. Minimum tillage also uses less energy and is ideal for resource poor farmers who do not have enough draft animals and implements. The minimum tillage technologies, that a few farmers in the study area are using, e.g. planting basins are rather labour intensive. Use of appropriate equipment rather than use of hand hoes to make basins may improve adoption of this technology. Tillage practices such as ripping and direct seeding equipment such as the jab planters can also be introduced to the farmers to ease and promote minimum tillage. A wide variety of crops are grown by the farmers. This study confirmed that maize is the main cereal crop in Lower Gweru, while pearl millet is the major cereal crop in Lupane. Groundnut is the major dryland legume crop in Lower Gweru, while in Lupane it is cowpeas.

It was noted that both hybrid varieties and OPVs of maize are grown by the farmers, with more farmers in Lupane using OPVs than those in Lower Gweru. It was disappointing to find that in both areas improved OPVs are used by fewer farmers than the traditional/local OPVs. Due to the biophysical and political-economic constraints faced by smallholder farmers in Lower Gweru and Lupane and Zimbabwe's semi-arid areas at large, OPVs have a place in these areas. It is encouraging to report that it appears more farmers are currently using improved varieties of small grain crops than in the past. However, the current political situation has resulted in a general seed shortage for most crops and farmers have coped by using seed retained and selected from previous harvests and the use of OPVs of maize has gone a long way in alleviating the maize hybrid seed shortage.

The study has shown that in most cases, farmers have reasons for what they do or do not do and it is important for researchers and extension agents to understand the underlying reasons, before they can propose any interventions. Although farmers are aware of the benefits of certain crop husbandry practices such as soil and water conservation and crop rotations, adoption of these practices is low and slow because of the biophysical and economic constraints that the farmers encounter.

It is apparent that research work is needed to understand some observations made by farmers, for example the detrimental effects that donkey manure has on crop growth and development. Suggestions could then be made on how the manure can be treated to render it useful to farmers. The negative interactions between maize and pearl millet that farmers have observed may also need investigation. Legume crop breeders should avail improved varieties as farmers are still growing the traditional low yielding varieties. Seed multiplication agencies should supply adequate seed of improved small grain crops, open pollinated maize varieties and sunflower.

There is room for improving smallholder productivity through recommendation of practices such as use of appropriate plant spacings for small grain crops as some of the farmers in the study area are using variable spacing which is at variance with the recommended spacing. Use of improved OPVs should be encouraged in these areas as they yield better than traditional OPVs. Due to farmers' sceptism about fertilizer use, fertilizer use may remain insignificant in areas such as Lupane. It is essential to educate farmers on how fertilizers work under different soil, crop and management conditions. Fertilizer use efficiency could be improved by employing techniques such as precision agriculture and micro-dosing, technologies which have been tested elsewhere in the country. Other sustainable technologies of improving soil fertility, for example, inclusion of nitrogen fixing species in cropping systems should be encouraged since inorganic fertilizers are expensive and organic sources often inadequate and of poor quality.

Given the marginal nature of their cropping environment and labour constraints, smallholder farmers in the study area (particularly those in Lupane) who use conventional tillage systems may not have to weed more than once. They can use cultural practices such as intercropping with good cover crops and early planting to minimize the frequency of weeding. Effective implementation of the agronomic improvements suggested in this paper can be achieved through collaborative on-farm demonstration trials, where farmers, extension agents and researchers from both the public and private sectors participate.

Conflict of Interest

The authors have not declared any conflict of interest.

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REFERENCES

Ahmed MM, Rohrbach DD, Gono, LT, Mazhangara EP, Mugwira L, Masendeke DD, Alibaba S (1997). Soil fertility management in communal areas of Zimbabwe: Current practices, constraints and opportunities for change: Results of a diagnostic survey. Southern and Eastern Africa Region Working Paper no. 6, Bulawayo, Zimbabwe: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Southern and Eastern Africa Region. P. 27 (Semi-formal publication).

Bless C, Higson-Smith C (2000). Fundamentals of social research methods: An African perspective. 3rd edition. Juta Edu. (Pvt) Ltd. P. 165.

Chambers R (1994). The Origins and Practice of Participatory Rural Appraisal World. Dev. 22(7):953-969.

Chatizwa I, Nazare RM (2000). Animal power for weed control: Experiences in Zimbabwe. In: P Starkey, P Kaumbutho (eds) Animal power for weed control. A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA) Harare, Zimbabwe: Intermediate Technology Publications, London.

Chiduza C, Waddington SR, Mariga KI (1994). Grain yield and economic performance of experimental OPVs and released hybrids of maize in a remote semi-arid area of Zimbabwe. Zimb. J. Agric. Res. 32(1):33-43.

Chiputwa B, Langyintuo AS, Wall P (2011). Adoption of Conservation Agriculture Technologies by Smallholder Farmers in the Shamva District of Zimbabwe: A Tobit application. Paper accepted for the 2011 meeting of the Southern Agricultural Economics Association (SAEA) in Texas, USA, Feb 5-8. Available on: http://ageconsearch.umn.edu/bitstream/98851/2/Chiputwa_etal_SAEA_Paper.pdf (Accessed 09/07/2013).

Chuma E, Mvumi B, Nyagumbo I (2001). A review of sorghum and pearl millet- based production systems in the semi-arid regions of Zimbabwe. SADC /ICRISAT Sorghum and Millet Improvement Program (SMIP), P.O Box 776, Bulawayo, Zimbabwe: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). P. 72.

Dimes J, Muza L, Malunga G, Snapp S (2002). Trade-offs between investments in nitrogen and weeding: On-farm experimentation. In: DK Friesen and AFE Palmer (eds) Integrated Approaches to Higher Maize Productivity in the New Millennium: Proceedings of the Seventh Eastern and Southern Africa Regional Maize Conference. pp. 452-456. Nairobi, Kenya. 11th -15th February, 2001.

Ellis-Jones J, Mudhara M (1995). Factors affecting adoption of soil and water conservation technologies in semi-arid Zimbabwe. In: S Twomlow, JE, Jones, J Hagman and LoosH (eds.) Soil and water conservation for smallholder farmers in semi-arid Zimbabwe: Transfers between Research and Extension. Proceedings of a national technical workshop, Masvingo, Zimbabwe. 3-7 April, 1995. pp. 106-117.

Flick U (2006). An Introduction to Qualitative Research. Third Edition. Sage Publications. London. Thousand Oaks, California. New Delhi. 448pp. Gill P, Stewart K, Treasure E, Chadwick, B (2008). Methods of data collection in qualitative research: interviews and focus groups. Brit. Dent. J. 204(6):291-295.

Grant PM (1981). The fertilization of sandy soils in peasant agriculture. Zimb. Agric. J. 78:169-175.

Hardaker JB, Anderson JR, Dillon JL (1984). Perspectives on assessing the impacts of improved agricultural technologies in developing countries. Aust. J. Agric. Econ. 28(2-3):87-108. http://dx.doi.org/10.1111/j.1467-8489.1984.tb00642.x

Harrell MC, Bradley MA (2009). Data collection methods: Semi-structured interviews and focus groups. Santa Monica, CA: RAND Corporation. Available on: http://www.rand.org/content/dam/rand/pubs/technical_reports/2009/RAND_TR718.pdf (Accessed 29/01/2013).

IIRR (International Institute of Rural Reconstruction) and ACT (African Conservation Tillage Network) (2005). Controlling weeds - Chapter 7. In: Conservation Agriculture: A manual for farmers and extension workers in Africa. International Institute of Rural Reconstruction, Nairobi; African Conservation Tillage Network, Harare. Available on: http://www.fao.org/ag/ca/africatrainingmanualcd/pdf%20files/07WEEDS.PDF (Accessed 02/01/2014).

Kumwenda JDT, Kabambe VH (1995). Critical period of weed interference in pure maize and maize- pigeon pea and maize-soyabean intercrops in Malawi. In: DC Jewell, SR Waddington, JK Ransom, KV Pixley (eds) Maize research for stress environments. Proceedings of the 4th Eastern and Southern Africa Regional Maize

Conference, Harare, Zimbabwe. 28 March – 1 April 1994: Mexico D.F. CIMMYT, pp. 234-237.

Mabasa S, Nyahunzi S (1995). Maize competition with natural weed infestation in communal areas in three agro-ecological zones of Zimbabwe. In: DC Jewell, SR Waddington, JK Ransom, KV Pixley (eds) Maize research for stress environments. Proceedings of the 4th Eastern and Southern Africa Regional Maize Conference, Harare, Zimbabwe, 28 March – 1 April 1994: Mexico D.F. CIMMYT, pp. 219-222.

Mabasa S, Shamudzarira Z, Makanganise A, Bwakaya F, Sithole T (1999). Weed management under different tillage systems in smallholder farming areas of Zimbabwe. In: Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) (eds) Maize production technology for the future: Challenges and opportunities. Proceedings of the Eastern and Southern Africa Regional Maize Conference 6, Addis Ababa, Ethiopia. 21-25 September, 1998, pp. 310-313.

Mashingaidze AB (2004). Improving weed management and crop productivity in maize systems in Zimbabwe. PhD Thesis. Department of Theoretical Production Ecology, Wageningen University. Wageningen. The Netherlands.

Mashiringwani NA (1983). The present nutrient status of the soil in the communal lands of Zimbabwe. Zimb. Agric. J. 80:73-75.

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

Misiko M, Tittonell P, Giller KE, Richards P (2009). Strengthening understanding and perceptions of mineral fertilizer use among smallholder farmers: evidence from collective trials in western Kenya. Agric. Hum. Values (published with open access at Springerlink.com).

Mpatane O, Kayombo B, Patrick C (2012). Preliminary assessment of socio-economic potential for rain water harvesting (RWH) in semi-arid Bobirwa Sub-district of eastern Botswana. 3rd RUFORUM Biennial Meeting 24 - 28 September 2012, Entebbe, Uganda. pp. 711-715. Available on: http://www.ruforum.org/system/files/Mpatane%20711.pdf (Accessed 05/01/2014).

Mudhara M (1995). Maize production in the face of unreliable rainfall. A case study of Chivi Communal Area: In: DC Jewell, SR Waddington, JK Ranson, KV Pixley (eds) Maize Research for Stress Environments. Proceedings of the Fourth Eastern and Southern Africa Regional maize Conference, Harare, Zimbabwe. 28 March – 1 April 1994: Mexico D.F. CIMMYT, pp. 285-290.

Mutekwa V, Kusangaya, S (2006). Contribution of rainwater harvesting technologies to rural livelihoods in Zimbabwe: The case of Ngundu ward in Chivi District. Water SA. 32(3):437-444.

Narwal SS, Sarmah MK, Tamak JC (1998). Allelopathic strategies weed management in the rice-wheat rotation in North-western India: In: Olofsdotter (ed) Proceedings of workshop on Allelopathy in rice, Manila, Phillipines. 25–27 November, 1996: IRRI. pp. 117-131.

Ncube B, Twomlow SJ, Dimes JP, van Wijk, MT, Giller KE (2009). Resource flows, crops and soil fertility management in smallholder farming systems in semi-arid Zimbabwe. Soil use manage. 25:78-90. http://dx.doi.org/10.1111/j.1475-2743.2009.00193.x

Norton A (1995). Soil and water conservation for smallholder farmers: Past, present and future. In: S Twomlow, JE Jones, J Hagman, H Loos (eds) Soil and Water Conservation for Smallholder Farmers in Semi-arid Zimbabwe: Transfer between Research and Extension. Proceedings of a Technical Workshop, Masvingo, Zimbabwe 3-7 April 1995, pp. 5-21.PMid:7843331.

Nyagumbo I, Munamati M, Chikwari E, Gumbo D (2009). In-situ water harvesting technologies in semi-arid southern Zimbabwe: Part I. The role of biophysical factors on performance in Gwanda district. Paper presented at the 10th WaterNet/WARFSA/GWP-SA Annual Symposium, Entebbe, Uganda, 2009. Amsterdam, Netherlands: WaterNet. Available on: http://www.waternetonline.ihe.nl/challengeprogram/p81%20nyagumbo%20water%20harvesting.pdf(Accessed 29/07/2013).

Nyamadzawo G, Wuta M, Nyamangara J, Gumbo D (2013). Opportunities for optimization of in-field water harvesting to cope with changing climate in semi-arid smallholder farming areas of Zimbabwe. Springer Plus 2013, 2(100):9pp. Available on: http://www.springerplus.com/content/pdf/2193-1801-2-100.pdf

Pixley K, Bänziger M (2001). Open-pollinated maize varieties: A backward step or valuable option for farmers. In: DK Friesen, AFE Palmer (eds) Seventh Eastern and Southern Africa Regional Maize Conference proceedings, 11th – 16th February, 2001, pp. 22-28.

Punch KF, (2005). Introduction to social research: Quantitative and qualitative approaches. 2nd edition. Sage Publications. London. Thousand Oaks, California. New Delhi. Singapore. 325pp.

Rockstrom J (1999). On–farm green water estimates as a tool for increased food production in water scarce regions. Phys. Chem. Earth Part B 24(4):375-383. http://dx.doi.org/10.1016/S1464-1909(99)00016-7

Rohrbach D (1989). The economics of smallholder maize production in Zimbabwe: Implications for food security. MSU International Development MSU International Development Papers. Department of Economics- Michigan State University. U.S.A. 11:8-17.

Scoones I (1996). Crop production in a variable environment: A case study from Southern Zimbabwe. Exp. Agric. 32:291-303. http://dx.doi.org/10.1017/S0014479700026235

Shumba E (1983). Factors contributing to a decline in groundnut production in the Mangwende–Murewa district and the need for a technical research input. Zimb. Agric. J. 80:251-254.

Shumba E (1989). Maize technology research in Mangwende, a high potential communal area environment in Zimbabwe. Part 2: The on-farm experimental program. Farming Syst. Bull, East. South. Afr. 1:1-13.

Sibanda S (2005). Evaluation of three animal powered weeding implements in cotton based systems of the Zambezi valley in Zimbabwe. Master of Philosophy Thesis, Department of Soil Science and Agricultural Engineering, Faculty of Agriculture. University of Zimbabwe. Harare, Zimbabwe.

Snapp SS, Blackie MJ, Donovan C (2003). Realigning research and extension to focus on farmers' constraints and opportunities. Food Policy 28:349-363.http://dx.doi.org/10.1016/j.foodpol.2003.08.002

Sutherland A (1998). Participatory research in natural resources.Socio-economic Methodologies. Best Practice Guidelines. Chatham, UK: Natural Resources Institute. [Available online at http://www.fao.org/docs/eims/upload/agrotech/1911/BPG03.pdf. Retrieved 17/06/11]

Thompson JG, Purves WD (1978). A guide to the soils of Rhodesia. Rhod. Agric. J. Tech. Bull. P. 3.

Vincent V, Thomas RG (1962). An agricultural survey of Southern Rhodesia: Part I Agro-ecological Survey: Harare, Government Printer P. 147.

Waddington SR, Karigwindi J (2001). Productivity and profitability of maize and groundnut rotations compared with continuous maize on smallholder farms in Zimbabwe. Explor. Agric. 37:83-99. http://dx.doi.org/10.1017/S001447970100103X

Waddington SR, Sakala WD, Mekuria M (2004). New directions for a diverse planet. Proceedings of the International Crop Science Congress. 26 Sep –10 Oct 2004. Brisbane, Australlia. Published on CD-ROM. Website www.cropscience.org.au

Zingore S, Gonzalez-Estrada E, Delve RJ, Herrero M, Dimes JP, Giller KE (2009). An integrated evaluation of strategies for enhancing productivity and profitability of resource-constrained smallholder farms in Zimbabwe. J. Agric. Syst. 101(1-2):57-68. http://dx.doi.org/10.1016/j.agsy.2009.03.003