CLIMATE CHANGE IN RURAL ZIMBABWE: AN ASSESSMENT OF THE INFLUENCES OF GENDER IN SMALLHOLDING AND ITS CONTRIBUTION TOWARDS ADAPTATION TO CLIMATE CHANGE IN RURAL ZIMBABWE

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CLIMATE CHANGE IN RURAL ZIMBABWE: AN ASSESSMENT OF THE INFLUENCES OF GENDER IN SMALLHOLDING AND ITS CONTRIBUTION TOWARDS ADAPTATION TO CLIMATE CHANGE IN RURAL ZIMBABWE

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Declaration

I declare that this is original work. I duly acknowledge materials from third parties. I declare that I have observed all rules of scientific conduct.

Kumbirai Musiyiwa

Abstract

Multiple stressors that include climatic and non-climatic constraints negatively impact rain-fed smallholder productivity and livelihoods in sub-Saharan Africa (SSA). Global circulation models predict temperature increases of about 3°C by the middle of the century. Impacts of warmer climates on rain-fed smallholder production are projected to be mainly negative.

Female-headed households (FHHs) constitute between 30% and 40% of households in smallholder areas of Zimbabwe. Access to resources and capital assets required for agricultural production often varies between male-headed households (MHHs) and FHHs. Differences in resource levels and roles of men and women imply different vulnerabilities and adaptation requirements to climate change for MHHs and FHHs. Mainstreaming gender in climate change planning is thus imperative for successful adaptation by MHHs and FHHs. There is, however, limited information on gendered differences in smallholder practices and outcomes arising from differently managed households in Zimbabwe, which is required for climate change planning. This study therefore sought to assess how the gender of household head affects smallholdings and adaptation to climate change in rural Zimbabwe using climate analogue analysis.

The analogue pair sites selected had similar annual rainfall totals but differed by 2-4°C in mean annual temperature. The sites were Kadoma (722mm, 21.8°C) expected to represent Mazowe/Goromonzi (842.9mm, 18.2°C) for sub-humid areas and Chiredzi (541mm, 21.3°C) hypothesized to represent Matobo (567mm, 18.4°C) for semi-arid areas following the effects of global warming by the 2050s. Household surveys, participatory evaluations and focus group discussions were conducted during the 2010/2011 and 2012/2013 rain seasons. Household demographic and socio-economic characteristics, farmer perceived stressors to production, and management strategies in MHHs and FHHs were assessed at each study site.

Resources that included financial capital and adult male labour were fewer, and education levels lower in FHHs than MHHs at the study sites. Crop production was the main source of income in FHHs at all the study sites. Meanwhile, in Kadoma, Mazowe/Goromonzi and Matobo districts, MHHs had more diverse sources of income. At each study site, crop choices, soil fertility, and soil and water management strategies in MHHs and FHHs were similar. However, quantities of inputs including fertilizer rates and share of area allocated to crops differed. Consequently, in Mazowe/Goromonzi and Matobo districts, crop yields were lower in FHHs compared to MHHs. Additionally, in Mazowe/Goromonzi, Kadoma, and Matobo districts, more FHHs than MHHs were food insecure.

Climatic stressors to agricultural production of analogue pair sites differed. At the sub-humid analogue pair sites, maize was the main crop grown. However, management practices differed. At the semi-arid sites, more farmers in Chiredzi compared to Matobo grew small grains. Maize yields were lower at the warmer analogue sites compared to the reference sites.

This study demonstrates that resource levels and resource-based forms of management differ by gender of household head, and MHHs and FHHs have different requirements for adaptation to current and future climates.

Key words: gender, smallholder agriculture, climate change, climate-induced risks, adaptation, temperature analogues

Preface

Multiple stressors that include climatic and non-climatic constraints negatively influence rain-fed smallholder productivity and livelihoods in SSA. The FHHs often have fewer resources required for agricultural production compared to male-managed households. In addition, males and females have different gendered roles i.e. domestic, productive and reproductive roles with females having a larger burden. Therefore, FHHs and MHHs require different resources for adaptation to climate change. Mainstreaming gender in climate change planning is imperative given that warming climates may reduce yield potential of crops such as maize and further increase vulnerability of the smallholder sector.

This study was conducted in the context 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). The study aimed to address 'agricultural adaptation to progressive climate change with special emphasis on predicted increases in temperature to enable farmers to adapt their farming practice to these new climate risks as they evolve'. Study sites included two analogue pair sites in sub-humid and semi-arid smallholder areas of Zimbabwe. Selection was based on 30 years meteorological rainfall and temperature data. Climates of current analogue study sites were assumed to represent future climates of reference study sites.

The study was composed of two components. The first component consisted of on station agronomic evaluation of crops and varieties, as well as soil and water management strategies and use of the weather-driven Agricultural Production Systems Simulator (APSIM). Crops tested include maize, sorghum, groundnut, pigeon pea and cowpea. The second component consisted of participatory research with farming communities at the analogue pairs. The two pairs of analogue locations were characterized with regard to crops, soils, climate, current farming practices, roles of male and female farmers, crop diversity, livestock management, farmers' perceptions of current climate induced risk and climate change (including gender perspective), and possible adaptation strategies. The main objective of this study was to assess the influence of gender of household head on rural Zimbabwe and its adaptation to climate change through climate analogue analysis. The methodology included household surveys, focus group discussions, key informant interviews (KIIs), and case studies.

This thesis has eight main chapters. The first chapter reviews literature on factors influencing smallholder production and climate change and its impacts on agriculture in SSA. Chapter 2 describes the background to the study, i.e. climate change adaptation and gender. Chapter 3 describes the research context of the study including the objectives and research questions of the study. Chapter 4 describes the methodology. Chapters 5, 6 and 7 describe results of the study. Chapter 5 describes how gendered patterns of resource ownership relating to the sex of household heads affect smallholder practices and their outcomes in rural Zimbabwe. Constraints to agricultural production, resource levels of households, yields, and food security of MHHs and FHHs were described. Chapter 6 assesses the effect climate change is likely to have on male-led and female-led smallholders in rural Zimbabwe in terms of resource-based forms of smallholder practices and outcomes. Constraints to production, resource levels of households, yields, food security and perceived impacts of climate of MHHs and FHHs at analogue pair sites were compared. Adaptation options of differently managed households for current and future climates are described in Chapter 7. A general summary of the study findings is given in Chapter 8.

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1.0 Smallholder farming and climate change

1.1 Introduction

The majority of the population in sub-Saharan Africa (SSA) lives in rural areas and largely depends on rain-fed agriculture for their livelihoods (Gollin, 2009). Notable is that about 90% of crops in Zimbabwe are grown under rain-fed conditions (Chetsanga, 2000). Smallholder local production is important for food security and as well as economic development (Funk and Brown, 2009). Biophysical stresses such as low and erratic rainfall and low human, physical and financial resources negatively impact smallholder production (e.g. Ncube et al., 2009). Reliance on mostly erratic and low rainfall and a low resource base makes the smallholder sector vulnerable to climate risks. Projected temperature increases and rainfall variability as a result of climate change (Hulme et al., 2001; Christensen et al., 2007) are likely to affect crop yields in many parts of SSA (Matarira et al., 1995; Christensen et al., 2007; Thornton et al., 2011). Male and female farmers often have different levels of resources required for managing biophysical stresses in smallholder systems. In addition, they have different domestic and productive roles in different farming systems that would require different adaptation strategies. Mainstreaming gender in progressive adaptation to climate change processes for smallholder farmers is thus imperative. It is against this background that this thesis seeks to make its contribution about the over-arching issues of climate change and variability and livelihoods sustainability.

According to the 2012 population census report, Zimbabwe has a population of 13 061 239 (ZimStat, 2012) of which 67% resides in rural areas. Nineteen percent to the country's Gross Domestic Product (GDP) is from agriculture (ZimStat, 2012). Smallholder farmers contribute significantly to the economy in Zimbabwe. Of the active labour force, 37% are communal farmers/workers. Meanwhile Brown et al. (2012) suggest that 70% of the population lives in rural areas and that about 66% of the labour force is in the agricultural sector. Agriculture practitioners are in the following categories: communal, A1, A2, old resettled (OR), small-scale commercial farmers

(SSCF) and large-scale commercial farmers (LSCF) and more recently peri-urban. As of 2007, communal areas, old resettlement and newly acquired A1 farms, which together compose the smallholder sector, constituted at least 75.60% of total agricultural land in Zimbabwe (Ministry of Agriculture, 2007). Smallholders constitute approximately 99% of farmers, 81% being communal farmers (Brown et al., 2012). Expansion of the sector illustrates its increasing contribution to the economy of the country. Smallholder farmers, for example produced the largest proportion of maize grain compared to other agricultural sectors in the 2010/2011 and 2011/2012 season i.e. communal areas produced about 40% and 43% of the national maize crop and the A1 sector contributed 23% and 24% respectively (Ministry of Agriculture, 2012). Optimizing productivity under rain-fed smallholder conditions is therefore necessary to increase food security for smallholder farmers and improve the economy of the country.

1.1.1 Gender and smallholder agriculture

Farming systems and/or farming enterprises in smallholder areas may be female-managed, male-managed or jointly managed by a male and female, with respect to main decision-making on production and use of the outputs (Meinzen-Dick et al., 2012). According to Meinzen-Dick et al. (2012), the male-managed farming systems i.e. male-headed households (MHHs) and enterprises dominate agriculture in SSA. Female-managed farming systems or households are a results of the female head of a household being widowed, divorced, or unmarried (Safilios-Rothschild, 1988). In some cases the husband may be engaged in a non-farm occupation or living away from the home. Single, widowed, divorced, or separated women manage *de-jure* female-headed households (FHHs). D*e-facto* FHHs are households where the husband is not physically present.

The percentage of households headed by women in developing countries (based on 1995-2003 data) in Africa is 23.8% (37 countries available data), in northern Africa 12.9% (based on 2 countries), in southern Africa 42.2% (3 countries). In the rest of SSA, about 23.5% of households are female headed (cited in Chant 2012; from Varley, 2008). Meanwhile the most recent census shows that females head approximately 35% of private households in Zimbabwe, the proportions varying by age groups and districts (ZimStat, 2012). Proportions range from 30% to 43% depending on household size category. Increases in the number of female-headed households (FHHs) result from several factors that include deaths of male heads of households, family conflicts and disruption, male migration for work, women deciding not to marry, changes in women's roles, and increased empowerment of rural women (Kassie et al., 2014).

The discourse of gender in smallholders can be at two different levels i.e. of female and male members within a household and of male- headed households (MHHs) and female-headed households (FHHs). In smallholder systems, males and females have domestic, reproductive and productive roles. In MHHs, men are typically involved in land preparation, application of pesticides and trading of produce. Upkeep of livestock that provide cash such as cattle is also the domain of men. Women usually contribute significantly to all the three roles i.e. child bearing, provision of food, water and energy for domestic consumption as well as productive duties. Women do the bulk of the domestic work. Domestic activities for women include caregiving, provision of food, water and energy for household consumption and generating the income needed to provide these necessities. Productive duties vary depending on agro-ecological and cultural settings. However, women are typically involved in every stage of the crop production process except for ploughing. The predominant agricultural activities of women include weeding, harvesting and fertilizer application. Kassie et al. (2014) showed that in Kenya, labour contributions of males and females to maize crop production differed by activity. Males contributed 51.1% and females 48.9% to land preparation and planting whereas 39.9% of weeding was done by males and 60.1% by females. Females provided 52% of harvesting labour as well as 52.8% of threshing labour. Women's contributions to selling of agricultural produce is low, particularly those in male-managed households. Females mainly sell female-managed crops and livestock. Women contribute high proportions of agricultural labour force. The World Bank, FAO and IFAD (2009) noted that in the year 1997 the proportion of women and men employed in the agricultural sector in SSA was 74.8% and 70% respectively and 67.9% and 62.4% respectively in 2007. In Zimbabwe, around 70% of women are smallholder farmers (Madzwamuse, 2010).

1.2 Factors affecting smallholder production

1.2.1 Resource ownership in smallholder settings

Smallholder farmers rely mostly on family labour and hand held tools for their production. Resources that influence management practices and productivity include family labour, agricultural tools such as ploughs as well as availability of draft power. Cattle and donkeys primarily provide draft power for land preparation. Many smallholder farmers are poor and have limited access to resources required for optimizing production. Resource constraints frequently associated with SSA smallholder production include labour constraints (e.g. Mudimu, 2003), draft power, inputs such as fertilizer and appropriate seed as well as transport and access to input and output markets in addition to knowledge. In Zimbabwean smallholdings labour units per households averaged about 2.5 adult equivalents (Mudimu, 2003). In comparison household had requirements of at least 3 adult equivalent units for 3 ha of crop and 5 for critical labour periods (Mudimu, 2003). Farmers also have inadequate access to draft power (Gambiza and Nyama, 2000; Mudimu, 2003; Ncube et al., 2009).

Low resource endowments in smallholder areas limit the capacity of farmers to use management strategies that increase productivity. Ncube et al. (2009) carried out a study over three seasons stretching from 2002 to 2005 in Tsholotsho district that lies to the south west of the country. They showed that better resourced farmers produced adequate grain for basic household consumption from 2002 to 2005, except in the drought year (2002/2003) while poorly resourced did not produce adequate grain. Zingore et al. (2007) also show linkages between resource ownership, nutrient management strategies, variability of soil fertility, and productivity.

1.2.2 Biophysical characteristics

There are five agro-ecological regions (AER) in Zimbabwe (AER I to V). Characterization of these regions was based on soil type, rainfall, temperature and other climatic factors (Vincent and Thomas, 1960). The national mean annual rainfall is 655 mm. In the low-lying Limpopo Valley (AER V) to the south of the country, the mean annual rainfall is 300 mm. Meanwhile, the mean is greater than 1000 mm per annum in some AER I regions like the Eastern highlands. Mean annual temperature varies from less than 15-18°C and can rise up to 30°C in the AER I around October, and in AER V ranges from 23-25°C but can rise to over 40°C in summer (Chagutah, 2010; Gambiza and Nyama, 2006). Agro-ecological region I mainly has fertile red soils. Meanwhile AER II, III and IV soils are mainly are associated with acidity, low cation exchange capacity and poor water holding capacity (Vincent and Thomas, 1960). AER V soils are variable and include vertisols, brown loam soils, sands, and sandy loams. Most smallholder farms are located in areas with sandy and generally infertile soils that are deficient in N, P and S and with low cation exchange capacity (Grant, 1967a,b; Nyamapfene, 1991). Approximately 74% of communal land and 43% of old resettlement land are in AER IV and V (Mehretu and Mutambirwa, 2006; Chimhowu et al., 2009) which has the least agricultural potential (Vincent and Thomas, 1960) and is more vulnerable to climate-induced risks.

Agricultural potential and crop production of the smallholder sector decreases from AER I to AER V mainly due to differences in mean annual rainfall and reliability, soil differences (Vincent and Thomas, 1960). Maize yields in high rainfall areas are often greater than 1 000 kg ha^{-1} and can be below 1000 kg ha^{-1} in low rainfall smallholder areas (e.g. Eilerts and Vhurumuku, 1997; Ministry of Agriculture, 2007; FAO/WFP, 2010). Crops mainly grown in smallholder areas of Zimbabwe include maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench), pearl millet (*Pennisetum glaucum* L.), oilseeds (e.g. sunflower [*Helianthus annuus* L.]), cotton (*Gossypium hirsutum* L), groundnut (*Arachis hypogaea* L.), cowpea (*Vigna unguiculata* (L.) Walp), Bambara groundnut (*Vigna subterranea* (L.) Verdc). Crop choices also vary by agro-ecological region. The proportion of maize total area in the smallholder sector, for example, decreases from AER I to AER IV (ZIMVAC, 2012; FAO/WFP, 2010). Meanwhile the proportion of area allocated to sorghum and other small grains such as pearl millet is highest in the drier AERs.

Land degradation in smallholder areas that includes soil erosion and soil degradation i.e. *in-situ* decline of the soil quality contribute to declining productivity. Increases in human population that lead to land use change (e.g. Hamandawana et al., 2005) and soil losses (Whitlow, 1988) contribute to land degradation. Prince et al. (2009) found that 16% of Zimbabwe was at its potential production and that human land use caused most degradation in the country. Increased acidification and decline in nutrient status of communal area soils also contribute to low productivity (Nyamangara et al., 2000). Low fertilizer use in communal soils (Bhondayi, 2004; Funk and Brown, 2009) contributes to decline in nutrient status. Poor management practices, in addition to the inherently low fertility of most soils, contribute to declining soil fertility and land degradation. Land degradation due to land use change and poor management practices, and current climate constraints that include low and unpredictable rainfall affect the biophysical environment for smallholder production. Climate changes further impose stresses to the biophysical environments of smallholders.

1.2.3 Climate change

Scientists mainly agree that anthropogenic activities that lead to greenhouse gas emissions are increasing global surface temperatures and affecting the earth's climate (McCathy 2001; IPCC,2007b; 2013a). The main anthropogenic activities that contribute to greenhouse gas emission include the provision of energy, transport, and agriculture (IPCC, 2013b). The main gases include CO_2, methane, fluorinated gases and nitrous oxide. The atmospheric concentrations of the greenhouse gases such as CO_2, CH_4 and N_2O, have grown significantly since pre-industrial times (about 1750 A.D.). Concentrations of CO_2, one of the main greenhouse gases, rose from about 296.2 ppm in 1900 to about 388.4 ppm in 2010 and 390.5 ± 0.3 in 2011 (IPCC, 2013b).

1.2.3.1 Trends in temperature

Climate records show regional variations in temperature changes over the past century. Global mean surface temperature has increased by between 0.3 and 0.6°C since the late 19th century (IPCC, 1995), with the most rapid warming occurring in the 1970s, 1980s and 1990s. Frequencies of warm spells over southern and western Africa increased between 1961 and 2000 (New et al., 2006). Meanwhile temperature increased by an average of 0.4˚C (per decade) over the past 100 years in southern African. In Zimbabwe mean annual temperatures have increased by an average of about 0.4˚C per decade since 1900 (Unganai, 1996; Tsiko, 2009) and daytime temperatures have risen by up to +0.8˚C from 1933 to 1993 (Unganai, 1996). Overall temperature has increased by approximately 2.6˚C in daily minimum temperatures and 2˚C in daily maximum temperatures over the last century. Additionally, Zimbabwe has in general had more hot days and fewer cold days since the 1950s, with the greatest warming occurring during the dry season (Climate Change in Zimbabwe, 2002). In wetter seasons, daytime temperatures have warmed more than night time temperatures. The 1990s were on record as the warmest and driest decade of the century (GoZ/UNDP, 2007) having experienced the six warmest years on record since 1987.

Irrespective of human interventions to reduce greenhouse gas (GHG) emmissions, increased concentrations of greenhouse gases will affect the earth's surface for the next coming decades (IPCC, 2007b). The climate change 2007 synthesis reports noted that even if GHG emissions were kept at the year 2000 level warming would still be expected (IPPC, 2007). Global circulation models (GCMs) of changes in global mean temperatures for the next two to three decades largely agree (IPCC, 2007b). Global mean surface temperature may increase by a range of 0.5˚C - 2.0˚C to the 2050s, relative to the 1986−2005 baseline (Kirtman et al., 2013). Global warming of about 0.2˚C per decade is projected for the next two decades, and higher increases are expected in Africa particularly in the drier subtropical regions by the middle of the century (IPCC, 2007). Temperature increases of between 0.2˚C and 0.5˚C per decade over Africa are suggested (Hulme et al., 2001; IPCC, 2001; Malhi and Wright, 2004) with the greatest warming in interior regions. By 2050, average temperatures in Africa are predicted to increase by 1.5˚C to 3˚C. Overall temperatures in southern Africa are expected to increase by between 3-7˚C. By 2100, the temperature increase may be as much as 7˚C in summer and 4ºC in winter (Ruosteenoja et al., 2003). Increases by as much as 9˚C for North Africa between June and August, and 7˚C for southern Africa from September to November are estimated. Large temperature changes are projected for North Africa and the Sahara (Mendelsohn et al., 2000).

1.2.3.2 Trends in precipitation

Global annual mean precipitation for land surfaces showed a small, but uncertain, upward trend of approximately 1.1mm per decade characterized by large inter-decadal variability over the 20th century (IPCC, 2007b). Trends in rainfall varied across Africa with large inter-annual rainfall variability as well as spatial and temporal variability in rainfall distribution over most of the continent (Hulme et al., 2005; IPCC, 2007;). Declines in rainfall were noted mostly in West Africa (Nicholson et al., 2000; Dai et al., 2004), in the tropical rain-forest zone (Malhi and Wright, 2004) and in annual rainfall along the Guinean coast (Nicholson et al., 2000). However, there have been no long-term precipitation trends noted in southern Africa. Decreases in rainfall amount slightly in southern and western Africa during the 20th century (New et al., 2006; Giannini et al., 2008) were not statistically significant. In parts of Zimbabwe, a general decrease in annual rainfall totals (Hulme, 1996; Hulme et al, 1996) and the amount of precipitation recorded from 1910 has deviated from the mean more frequently (Climate Change in Zimbabwe, 2002). Mazvimavi (2010) noted inter-annual variability in several parts of the country from 1920 to the year 2000 that included Harare to the north central part of the country, Mutare in the Eastern highlands, Bulawayo to the west, and Beitbridge to the southern most part of the country. Precipitation declined by an average of about 10% from 1900 to 1993 (Hulme, 1992; Unganai, 1996;) with declines of about 10% during the October to April season from 1900 to 1994 (Unganai, 1996).

Uncertainty exists with respect to precipitation changes for the 2050s and beyond. The magnitude of projected rainfall changes by the middle of the 21st century is, however, small in most African areas (IPCC, 2001). Models predict median increases in rainfall of about 7% for eastern Africa and decreases of about 4% for southern Africa are estimated by the end of the 21stcentury (Christensen et al., 2007). Meanwhile some models mostly estimate that precipitation may decrease in semi-arid regions of Africa and precipitation increase only in Western Africa by 2100 (Mendelsohn et al., 2000). In the eastern parts of southern Africa early summer rainfall (October to December) is expected to decrease, and late summer rainfall (January to March) is expected to increase (Tadross et al., 2005). Four of the GCMs used by Hulme et al. (2001) suggest wetting while three suggest drying in Zimbabwe. Hulme et al. (2001) estimated changes in rainfall of ± 5% to 15%. Christensen et al. (2007) projected mean precipitation decreases of about 10% in Zimbabwe under the A1B emissions scenario.

1.2.3.3 Other climate events

In addition to changes in rainfall and temperature there have been increased frequencies of extreme weather (IPCC, 2001). Extreme events noted include increased frequencies of droughts and flooding. From 1970 to 2004 fourteen African countries that include Kenya, Mozambique and Zimbabwe experienced droughts more than 10 times including severe droughts in 1982-1983, 1986- 87 and 1991-92. These droughts were mainly linked to El Niño-Southern Oscillation (ENSO) events (Haile, 2005). ENSO events are frequently associated with drier than average conditions over much of southern Africa (Ropelewski and Halpert, 1987, 1989, Mason and Tyson, 2000). Variability of inter-annual onset of growing season, decadal variability and in many cases late onset of growing season associated with heavier rainfall has increased during the period from 1979– 2001 (Tadross et al., 2005; Tadross et al., 2007). Parts of Zimbabwe were characterized by significant inter-annual and decadal variability of the onset of the rains from 1979–2001 (Tadross et al., 2007) and increases in the frequency and intensity of mid-season dry-spells (Unganai, 2009). In Makoni and Hwedza districts of Zimbabwe, Rurinda et al. (2014) also noted variability in the date for the start of the growing season, a delay of a week was observed for the period 1990–2010 and increased occurrences of dry spells between the end of January and early February.

Current climate models also predict the lengthening of drought periods. The Mediterranean coast and southern Africa in particular will be at higher risk of drought (Boko et al., 2007). Huntingford et al. (2005) suggest the number of extremely dry and wet years in the Sahel region will increase. In Zimbabwe changes may include rainfall distribution variability and shortening of the length of growing season (Burke et al., 2009; Nyabako and Manzungu, 2012).

1.2.3.4 Climate change impacts on agriculture

Agriculture is one of the most vulnerable sectors to climate change (Gregory et al., 2005; Kurukulasuriya et al., 2006; Thornton et al., 2011). Current impacts of climate change and variability in the agriculture sector include reduced yields (Lobell and Field, 2007) and loss of livelihoods (Zvigadza et al., 2010). In a global analysis of crop responses to rising temperature from 1981 to 2002, wheat, maize and barley yields responses were negative (Lobell and Field, 2007). Meanwhile farmers in Goromonzi district of Zimbabwe reported that climate change and variability had reduced crop yields, caused livestock deaths, and loss of livelihoods, labour migration and disintegration of families (Zvigadza et al., 2010). Warmer climates by the middle of the 21st century may increase or decrease agricultural production. Warming in the high latitudes will likely be beneficial and warming in the low-latitudes will likely be harmful to production (Mendelsohn et al., 2000). Greater impacts are expected from temperature increases compared to impacts from rainfall changes in most of SSA. This is partly because growing season average temperatures may rise quickly (Burke et al., 2009). Kurukulasuriya and Mendelsohn (2008) showed that in Africa crop choices are more sensitive to temperature changes compared to precipitation changes.

Exploration studies on impacts of future climates show mostly negative effects of warmer climates. Agronomic models project mostly declines in crop yields due to climate change (Rosenzweig et al., 1993; Thornton et al., 2011). The projected magnitudes of changes depend on baseline conditions and models used in analysis. Thornton et al. (2011) estimated 16% decreases in maize yields from the 2000s to the 2090s in a 5°C+ warmer southern Africa. In Zimbabwe, empirical agronomic studies show mostly negative effects of warmer climates on crop yields (Muchena 1994; Magadza, 1994; Matarira et al., 1995. Makadho, 1996). Muchena (1994) and Magadza (1994) showed that a 2°C rise in ambient temperature lowered yields. Makadho (1996) showed that due to effects of warmer 2050s climates, both irrigated and non-irrigated maize production may decrease by approximately 11–17% in Karoi, Gweru, Masvingo, and Beitbridge districts of Zimbabwe that represent Natural Regions II, III, IV, and V respectively. Jones and Thornton (2003) estimated using global circulation model (GCM) declines of about 17% in maize yields by the year 2055 for Zimbabwe.

Projected increases in marginal land (Fischer et al., 2005) and land use change may likely affect the landscape of food production in sub-Saharan Africa. There may be increases of arid and semi-arid land in Africa by the 2080s (Boko et al., 2007). Fischer et al. (2005) suggested increases in land with moisture stress and expansion of land with severe climate, soil or terrain constraints from 1990–2080 in sub-Saharan Africa. There might be more temperature extremes in sorghum and pearl millet regions in sub-Saharan Africa by the 2050s while precipitation changes may be considerably smaller (Burke et al., 2009). According to Downing (1992), wet zones of Zimbabwe may decrease by about 9% to about 2.5% and drier zones may double in area with a temperature increase of 2°C. Some southern areas of the country may become unsuitable for cereal production (Fischer et al., 2005). Climate change may also reduce the length of the growing season (Nyabako and Manzungu, 2012). Subsequently food production may be reduced. Christensen et al. (2007) estimates decreases of 12%, with great regional variations, in production of rain-fed cereals such as wheat and maize. In contrast, Funk and Brown (2009), estimated 4% increases in annual per capita cereal production in Southern Africa from 2008 up to 2030. Their findings were based on 1960-2007 production and harvested area trends.

Ricardian analyses of impacts of warming climates in Africa show mostly declines in net revenue from crops (Kurukulasuriya et al., 2006; IPCC 2007b; Kurukulasuriya and Mendelsohn, 2008). Meanwhile net revenue from African livestock may increase in some regions (e.g. Seo and Mendelsohn, 2008). Seo et al., (2009) estimated that farm net revenue i.e. combined crop and livestock net revenue, in 11 African countries (minus Zimbabwe) may differ across agro-ecological regions in Africa by 2100. Results from these studies suggest that mixed crop-livestock systems are more resilient to climate change. Meanwhile Nhemachena et al. (2010) projected generally negative effects of warmer and drier climates on net farm revenues in 11 African countries in east, west, north and southern Africa that included Zimbabwe. Mano and Nhemachena (2007) estimated mostly negative effects of high temperatures in summer on net farm revenues in Zimbabwe. Mendelsohn et al. (2000) estimated losses of 0.13% to 2% of GDP (from agriculture) in African by 2100 due to climate change and agricultural losses of between 0.4% to 1.3% in Southern Africa.

Changes in farm productivity and reduction in arable land and biodiversity may negatively affect smallholder livelihoods in SSA and reduce food security. In response to environmental stresses, male family members often migrate in search of alternative livelihood sources (Bryceson et al., 2000; Davis, 2003; Morton, 2007). Male labour migration increase workloads for rural women. Increase workload for women may also arise due to increase in time spent searching for water and energy sources for domestic consumption. Further, increased labour demands arising from cropping changes may be different for males and females depending on types of adapted crops.

Changes in crop and livestock production landscapes and resources may affect males and females differently with respect to income sources (Nelson and Stathers, 2009). Females often depend heavily on natural resources such as forests (Djoudi and Brockhaus, 2011). These natural resources may be impacted by climate change. Effects of warmer climates on MHHs and FHHs may differ. A review of impacts showed that gender-differentiated impacts of climate change are not always 'rigid, straightforward, or predictable' (Goh, 2012).

1.3 Institutional support in smallholder agricultural adaptation to climate change

Changes in landscapes of smallholder agriculture require dynamic institutional support. Various initiatives led to the formation of global level and local level institutions that aim to tackle climate change challenges. The Intergovernmental Panel on Climate Change (IPCC) provides information on human-induced climate change risks, observed and projected impacts, and options for adaptation and mitigation. The United Nations Framework Convention on Climate Change (UNFCCC) aims to contribute to stabilization of GHG concentration in the atmosphere to sustainable levels. The UNFCCC requires the world's 49 least developed countries (LDCs) to undertake National Adaptation Programmes of Action (NAPAs; Stringer et al., 2009). In an effort to reduce GHG emissions, the Kyoto Protocol sets binding GHG emission targets for 37 industrialized countries or countries in economic transition. In Africa, the New Partnership for Africa's Development (NEPAD) addresses climate change at policy level through its Environment Action Plan, as well as its Sub-Regional Environment Action Plan. The Common Market for Eastern and Southern Africa (COMESA) also has initiatives for climate change in Southern Africa.

Zimbabwe is not amongst the list of developed countries. The country, however, ratified the UNFCCC in 1992 and the Kyoto Protocol in 2009.The Zimbabwe Medium Term Plan (MTP) covering 2012-2015 has amongst its objectives a policy objective to promote climate change mitigation and adaptation strategies in social and economic development at national and sectorial level. The Climate Change Office within the Ministry of Environment and Natural Resources Management Zimbabwe developed and submitted its Initial National Communication to the UNFCCC in 1998 which detailed climate impacts and adaptation options in agriculture, forestry, water resources and human health sectors (Chagutah, 2010). A Second National Communication (SNC) report 'The National Climate Change Strategy; a Climate Change Policy and a National Action Plan for Adaptation and Mitigation' has since been developed. Meanwhile 'The national gender policy (2013-2017)' being developed by the Ministry of Women Affairs, Gender and Community Development has several objectives, one of which is to increase gender responsiveness to the environment and natural resources management strategies and climate change adaptation and mitigation initiatives.

1.4 Conclusion

Progressive adaptation to climate change requires that the nature of climate-induced risks be understood, as well as the range of adaptation options for different farmers. Holistic approaches are required to handle challenges to smallholder production and reduce food insecurity.

2.0 Gender and climate change adaptation

2.1 Introduction

Smallholder farming, in addition to being a source of subsistence for households, contributes to economic growth. Agriculture's contribution to GDP averages 21% in Africa and ranges from about 10% to 70% for most African countries (Mendelsohn et al., 2000). About 19% of Zimbabwe's GDP is from agriculture (ZimStat, 2012). Climate change may reduce agriculture's share of GDP for most African countries (e.g. Mendelsohn et al., 2000). The extent of losses will vary by region. Smallholder farmers are in general vulnerable to the effects of climate change. Adaptation is one of the strategies to reduce impacts of climate change in the smallholder sector. Adaptation is defined as the 'adjustments in ecological, social, and economic systems in response to actual or expected climatic stimuli and their effects or impacts, which moderates harm or exploits beneficial opportunities' (Smit et al., 1999; IPCC 2007a). Irrigation is an option for management of moisture–related stresses, but costs associated with irrigation are high. Irrigation may be associated with potential problems like salinization, acidification, and water mining that need appropriate management. Rain-fed agriculture will therefore remain important for smallholder livelihoods in the absence of large investments in irrigation technologies. Exploration of adaptation pathways and requirements of different smallholder farmers can assist in planning for change.

Climate change adaptation requirements of smallholders depend on types of climate-induced risks, biophysical characteristics of farms and households' socio-economic characteristics among other factors. Differences exist in domestic, reproductive and productive roles of male and female farmers in smallholder farming systems. In addition resource ownership of MHHs and FHHs in different agro-ecological regions often differ. Implications of these differences are that MHHs and FHHs have different levels of vulnerabilities and adaptation requirements. Warmer climates by the middle of the century will require that the nature of climate-induced risks and adaptation requirements for differently managed households be explored for effective climate change adaptation. This chapter outlines the nature of climate-induced risks, gender differences in resource ownership and some of the adaptation strategies used in different regions of Africa.

2.2 Definition of terms

For the purposes of this study, gender refers to:

> Differences in socially constructed roles and opportunities associated with being a man or a woman and the interactions and social relations between men and women (UN, 2009).

The UN (no date) defines gender equality as:

> The equal rights, responsibilities and opportunities of women and men and girls and boys. Equality does not mean that women and men will become the same but that women's and men's rights, responsibilities and opportunities will not depend on whether they are born male or female. Gender equality implies that the interests, needs and priorities of both women and men are taken into consideration, recognizing the diversity of different groups of women and men. Gender equality is not a women's issue but should concern and fully engage men as well as women. Equality between women and men is seen both as a human rights issue and as a precondition for, and indicator of, sustainable people-centered development.
>
> Gender mainstreaming is the process of assessing the implications for women and men of any planned action, including legislation, policies and programmes, in all areas and at all levels, and as a strategy for making women's as well as men's concerns and experiences an integral dimension of the design, implementation, monitoring and evaluation of policies and programmes in all political, economic and social spheres so that women and men benefit equally

and inequality is not perpetuated. The ultimate goal is to achieve gender equality' (ECOSOC, 1997/2).

Many definitions of vulnerability exist (e.g. Füssel and Klein, 2006; IPCC, 2007). The IPCC (2007) defines vulnerability as:

> The degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change, including climate variability and extremes'

Füssel and Klein (2006) define vulnerability to climate change as:

> The degree to which geophysical, biological and socio-economic systems are susceptible to and unable to cope with, adverse impacts of climate change'.

Ahmad et al. (2001) defines vulnerability as:

> A function of exposure to risks, i.e. the character, magnitude, and rate of climate variation to which a system is exposed; and sensitivity.

The 2007 Human Development Report of the UN Development Programme (UNDP) described 'vulnerability' in the context of climate change as 'an inability to manage risk without being forced to make choices that compromise human well-being over time.' Indicators of vulnerability to climate change and variability depend on the type of risks the farmers are exposed to and the forms of strategies that are required to reduce the impacts. Exposure, sensitivity and adaptive capacity i.e. the elements of vulnerability and their determinants are dynamic. They also vary from place to place. Smallholder farmers are particularly vulnerable to climate change and variability due to high dependence on rain-fed agriculture, limited land and resources. These farmers experience a variety of climatic and non-climatic stresses that include weather-related shocks, climate change, pest and diseases, economic shocks, environmental stresses such as land degradation and soil erosion.

Coping refers to short-term strategies that farmers implement. The coping range of climate is described in the TAR as the '…capacity of systems to accommodate variations in climatic conditions' (Smith et al., 2001).

Adaptive capacity is:

> The ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences' (IPCC, 2001).

The IPCC (2007) also describe adaptive capacity as:

> The ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies.

Determinants of adaptive capacity are the factors that influence the ability of the system to adapt (Adger, 2003). Indicators of adaptive capacity may include factors such as education, income and health.

2.3 Gender and ownership of agricultural resources

Smallholder farmers rely on different resources for their livelihoods. Resource limitations coupled with household characteristics limit the ability of most farmers to adopt strategies to improve agricultural production. Resource ownership in smallholder areas varies over time. Females often have lower accesses to agricultural resources compared to males (Quisumbing, 1995; Peterman et al., 2011; Croppenstedt et al., 2013). According to the Sustainable Livelihood Framework (SLF; DFID, Chambers, 1989; Scoones, 1998), resources required for sustainable livelihoods include human, natural, financial, physical and social assets. Human capital include active labour force, health, knowledge and skills while natural (and agricultural) capital includes access to common property resources, land and produce, water and aquatic resources and biodiversity. Financial capital includes income, credit, remittances and insurance and physical capital includes infrastructure such as housing and road networks, transport, energy, communications, tools and technology such as tools and equipment for production, seed, fertiliser, pesticides and traditional technology. Social (and political) capital includes social status, discrimination against women and social links. The World Bank refers to social capital as 'the institutions, relationships, and norms that shape the quality and quantity of a society's social interactions' (The World Bank, 2011).

Smallholders often have limited access to financial capital and credit (Maddison, 2007; Deressa et al., 2009, Nhemachena and Hassan, 2007). Access to financial capital and access to credit enable farmers to buy inputs such as feed, seed, fertilizers as well as farm equipment and other assets. Women often have limited access to cash and credit (Doss, 2001). Reasons for lower accesses to financial capital by females compared to males include low participation in cash crop production (Mackenzie, 1998), low productivity and lack of collateral to access credit. In Kenya, Mackenzie (1998) noted that females tend to focus on producing food rather than cash crops.

Physical capital asset constraints often encountered in smallholder areas include lack of appropriate equipment (Nhemachena et al., 2010). Agricultural equipment ownership often differs between men and women in male-managed households and between MHHs and FHHs. In seven districts in Manicaland and Mashonaland East Provinces of Zimbabwe FHHs were more disadvantaged than MHHs with respect to control of agricultural resources (Nyikahadzoi et al., 2012). Lower incomes of FHHs compared to MHHs, and legal and social traditions can contribute to low levels of resources in FHHs. After the death of the head of household females may receive fewer resources in favour of male relatives. Cultural and social traditions may make women reluctant to press for their rights (e.g. Kameri-Mbote, 2006). Females can sell some of their productive assets due to financial distress after death of spouse. Further low income of FHHs may also limit the buying power required to purchase agricultural equipment.

Livestock ownership is most often an indicator of wealth in African smallholdings. Livestock are also important sources of draft power and a source of animal manure for soil amendments. In southern Africa, large livestock is traditionally owned by males and small livestock by females. Njuki and Mburu (2003) showed that in Kenya, Tanzania and Mozambique, women are more likely to own small livestock such as poultry, sheep, and goats than large livestock such as cattle and buffaloes. In poor rural Indonesia, Peru, and in Kenya men were largely responsible for ruminants particularly if the livestock were for market purposes, for example cattle (Valdivia, 2001). Meanwhile women's roles in the management of small ruminants differed. In Kenya, males had control over decisions to sell for women-owned livestock (Njuki and Mburu, 2003). Males usually inherit large livestock. Therefore, females often own less livestock compared to males e.g. in Botswana males were shown to own and use significantly more draft power compared to females (Oladele and Monkhei, 2008).

Natural capital constraints often include availability of resources such as land, (Maddison, 2007; Deressa et al., 2009). Land is an important natural asset with respect to ownership (type), land size as well as quality of land owned. In Zimbabwe, males typically have larger land-holdings compared to females (FAO, 1997). Inheritance/social norms in many African communities can result in females losing part or most of the land after death of the spouse. Females in several countries in South America own land mostly through inheritance and males own land through markets and inheritance (Deere and Leon, 2003). Arguments are that lower land areas of FHHs are proportional to smaller families and fewer resources such as labour that these households have. Government policies in some African countries have improved women's access to land. Short-term impacts of a pilot land regularization program in Rwanda, for example included improved land access for legally married women (Ali et al., 2013).

Human capital constraints of smallholder farmers often include low education levels (Maddison, 2007; Deressa et al., 2009). Higher education levels are often associated with increased access to credit, and technology adoption. Since households in many

African countries prefer to educate males than females, male household heads are often more educated compared to female household heads (Meinzen-Dick et al., 2010; Quisumbing, 2003). Advocacy for equal opportunities for girls and boys has, however, contributed to increased education of females. In addition to education and knowledge constraints, African smallholdings often have labour constraints (Nhemachena et al., 2010). Available family labour influences adoption of technologies and farm management practices. Female-headed households, in particular *de facto* FHHs often have less male adult labour due to the absence of the 'male'. Based on survey data of 300 households in Zimbabwe Horrell and Krishnan (2007) showed significant differences in available family labour (primarily for maize production) between MHHs and *de facto* FHHs only (MHHs - 4.14, *de jure* - 3.97, and *de facto* - 3.12). Other human capital constraints in smallholdings include availability of extension advice (Valdivia et al*.,* 2001), lack of knowledge on farming strategies (Maddison, 2007; Nhemachena and Hassan, 2007, Nhemachena et al., 2010) and low experience (Below et al., 2010).

Farmer formal and informal organisations and farmer-oriented institutions are a source of social capital. Farmers' roles and integration in these groups measure social capital. Functions of farmer groups include collective action in farm production. Collective action often increases resource management and agricultural production (Quisumbing, 2003, Meinzen-Dick et al., 2002). Resources that can be mobilized by internal social capital include agricultural equipment such as draft power, access to financial capital through credit, and even transport to markets. Membership to rural institutions or farmers' groups increased food security of *de jure* FHHs (Kassie et al., 2014). Social capital facilitated participation in collective action initiatives and influenced individual soil conservation efforts in rural Kenya (Willy et al., 2013). Men are more likely to belong to productive as well as social associations, which enhance their adaptive capacity. Meanwhile women's levels of participation may be lower due to social and cultural barriers. Social barriers can reduce adaptive capacity and limit adaptation (Hulme et al., 2007; Adger et al., 2009).

Mobility in smallholder areas increases access to markets and access to meetings that facilitate or increases social networks of farmers. Depending on location, women often have limited market access due to low mobility. Men for example can use bicycles while few women are able to use bicycles (Kassie et al., 2014). Other non-climatic constraints that smallholder farmers often experience include market-related constraints, costs of inputs and low producer prices amongst other factors.

The Millennium Development Goal 3 reflects international effort to promote gender equality. Advocacy for primary education for all has improved levels of education of women (The World Bank, 1999). Other efforts include increased donor support for example in income generating programs. The water reform program implemented in 1995 (Utete, 2003) aimed to also increase access to water for women. Gaps in resource ownership and equality between males and females, however, still exist. Manase et al. (2003), for example, noted that despite efforts to increase access to water at government levels, clear gender policies lacked at the grassroots levels in Zimbabwe. The ZimStat (2012) also showed that in Zimbabwe females are still disadvantaged in accessing land. Societies are dynamic and have different social and cultural backgrounds. Therefore, resource ownership by MHHs and FHHs will not only be influenced by prevailing macro-economic and micro-economic conditions but will be community specific. There is therefore a need to map these gendered differences in resource ownership for effective rural development intervention strategies.

Empirical studies on determinants of adoption of technologies for improved yields often show variable effects of household resources on technology adoption. Adoption of technologies is often lower in FHHs compared to MHHs (Mazvimavi and Twomlow, 2009). Mazvimavi and Twomlow (2009) showed that women in Zimbabwean farming communities adopted fewer components of conservation agriculture. Ndiritu et al. (2014) found lower adoption of minimum tillage and animal manure in crop production by female managers compared to male mangers. In contrast, adoption levels of other technologies such as soil and water conservation measures, chemical fertilizers, and maize-legume rotations did not differ between males and females (Ndiritu et al., 2014).

Women tend to adopt new farming practices less frequently and are more prone to abandon them even after adoption (Marenya and Barrett, 2007).

Resource levels influence management practices that subsequently have a bearing on productivity. Female-headed households compared to MHHs often obtain lower yields, and higher food insecurity and higher poverty. Crop yields of FHHs are often lower compared to yields in MHHs (e.g. Tiruneh et al., 2001). Mutsvangwa (2010) showed that quantity of cereal produced was related to factors such gender of head of household and household income among other factors. However, not all women or FHHs are poorer or obtain lower yields than males or MHHs respectively. Using binary logistic regression for multivariate analysis, Oginni et al. (2013) noted that in Nigeria FHHs less likely to be poor than MHHs. Household survey data set for 10 developing countries, showed that poverty levels were not different among FHHs (compared to MHHs) in two-thirds of the study countries (Quisumbing et al., 2001). However, *de facto* FHHs were shown to be better off than de jure FHHs in most aspects. Lessons from successful FHHs can be important in climate change studies. There may be need to estimate total productivity that compares inputs and outputs to explain the productivity differences. This is because MHHs and FHHs production patterns may vary e.g. crop production profiles.

In addition to poverty, there are also other components of vulnerability of women. It is widely acknowledged that socially constructed roles such as gendered divisions of labour and inequalities and poverty make women in smallholders more vulnerable to the impacts of climate change than men (Lambrou and Piana, 2005; Aguilar et al., 2007; Brody et al., 2008; WEDO, 2008; Aguilar, 2009). Men and women have different domestic roles and activities. They therefore depend on different natural resources. Women for example depend on natural resources such as forest for firewood, which is the main source of energy for household activities. Women also provide water for household consumption. The availability of these resources may be affected by climate change and variability. Female household heads have extra responsibilities associated with being the decision maker and provider for the family.

2.4 Climatic stressors to production - farmer perceptions

Farmers experience different climatic and non-climatic stressors to production. Climatic stressors include droughts, low rainfall and high temperature. Farmers often experience climate variability that causes them to adopt coping strategies. Farmer perceptions of climate-induced risks are important in their decision making process (Grothmann and Patt, 2005; Maddison, 2007; Thomas et al., 2007; Adger et al., 2009). Maddison (2007) demonstrated that farmers' awareness of changes in climate attributes such as temperature and precipitation is important for adaptation. Nyanga et al. (2011) observed that Zambian smallholder farmers' perceptions related to floods and droughts were significantly associated with adoption of conservation agriculture. Participatory involvement of farmers also helps in identification of community specific needs with respect to development. Farmers' perceptions on stressors they encounter aid in polices for rural development and improved productivity.

Indicators of climate change reported by some farmers in various African countries include increased temperature, drier conditions and changes in timing of rains and increased frequency of droughts (Nhemachena and Hassan, 2007; Thomas et al., 2007; Adger et al., 2009). Farmers in different agro-ecological regions often perceive different forms of climate change and variability. In wetter agro-ecological regions of Zimbabwe, changes reported by farmers include decreases in rainfall and changes in distribution of rainfall, changes in onset of rains and cessation of rains (Nhemachena and Hassan, 2007; Zvigadza et al., 2010). Other climate change indicators reported include frequent occurrences of droughts and mid-season droughts (Progressio Zimbabwe 2009; Mutsvangwa, 2010). Zvigadza et al. (2010) assessed farmer perceptions of climate change in Munyawiri ward (Domboshawa district) using focus group discussions (FGDs), interviews and semi-structured questionnaires and field observations in village clusters. Changes reported by these farmers included late onset and early cessation of rains and increased frequencies of mid-season dry spells. Community perceptions on climate change included absence of off-season rainfall events like winter rain (*Mavhurachando*), August rain (*Gukurahundi)* and September rain (*Bumharutsva*) last experienced in the 1980s.

In drier agro-ecological regions, drought and increase in temperature, low and erratic rainfall were some of the most common changes mentioned by farmers. Perceptions of climate change and adaptation were analysed in Mazvihwa smallholder farming area in Zvishavane District (AER IV; Mutekwa (2009). Of the smallholder farmers interviewed in Zvishavane district (AER IV; Murowa Ward) 28% reported decreases in length of rain season, 25% reported increased temperature, and 41% reported increased frequency of droughts and increasing temperature. In contrast, many farmers in Lupane (AER IV) and Lower Gweru (AER IV) mentioned excessive rains in addition to unpredictability of the start of the rain season from around the mid-1990s, extending of winters, increased frequencies of droughts and increased temperature (Mutsvangwa, 2010). Masvingo District farmer-reported changes in climate include erratic rainfall patterns, decreased rainfall and temperature increases, leading to crop productivity decline and increased livestock morbidity and mortality over the past decade or two stretching from before 2009 (Moyo et al., 2012). Chiredzi district (AER V) respondents revealed that drought was considered the most important climatic hazard affecting livelihoods in ward 7 (Unganai and Murwira, 2010) with five drought types identified which were early season, mid-season, terminal, seasonal and extreme drought.

Farmers frequently mention shortening of the rain season and late onset of rains e.g. in Masvingo (Moyo et al., 2012), Zvishavane (Mutekwa, 2009), Lupane and Lower Gweru as indicators of climate change (Mutsvangwa, 2010). Farmers mentioned that rains that would normally start in October are now starting in November. In Masvingo District, farmers also mentioned shifts in the onset of the rainy season from around the third dekad in October to end of November and early December (Moyo et al., 2012) and early cessation of rainfall in both Hwange and Masvingo i.e. ended as early as beginning of March. Meanwhile in Zvishavane farmers mainly mentioned that the rain season used to begin in late October or early November and end as late as mid-May, but in the late 1990s onwards it could start as late as mid-December and end as early as mid-March.

Farmer perceptions often correspond with climatic data (Thomas et al., 2007; Rurinda et al., 2014). A survey of 8000 households in 11 African countries showed that farmers recalled major events such as droughts, mid-season drought and floods (Hassan and Nhemachena, 2008). In Zimbabwe, Makoni and Hwedza farmers' recall of weather and climate closely matched climatic records i.e. no change in total seasonal rainfall, and increased variability in the rainfall distribution within seasons (Rurinda et al., 2014). Lower Gweru and Lupane farmers recalled periods of droughts and excessive rains, their perceptions tallied with available rainfall data (Mubaya et al., 2010). Similarly, Masvingo farmers' perceptions were in agreement with climatology data that showed an increase in both minimum and maximum temperatures between 1960 and 1993 (Moyo et al., 2012). Often farmer perceptions regarding climate change do not correspond with climate data (Maddison, 2007; Rao et al., 2011). Climatology data showed no shifts in onset and cessation dates of the rainy seasons as reported by farmers in Masvingo and (Hwange; Moyo et al., 2012). Rao et al. (2011) also showed that in Kenya farmers' perceptions of changing rainfall patterns corroborated well with perceptions of other farmers across the African continent but observed trends in rainfall data did not support their perceptions. They also showed that farmers gave greater weight to negative effects that led to higher risk perception by farmers. Climate induced risks are often over-estimated (Coe and Stern, 2011; Rao et al., 2011) and according to Rao et al. (2011) farmers may then fail to utilize opportunities presented by climate. Farmer perceptions of climate change and consequently accuracy may be related to age and farming experience. Maddison (2007) showed that experienced farmers were more likely to notice climate changes in a study of 11 African countries. Farmers may also fail to interpret the effects of climate-induced risks due to compounding interactions between climate and non-climatic factors e.g. soil fertility (Rao et al., 2011).

Differences in climate risk concerns often exist between males and females. Gustafson (1998) noted different levels of concern about risk of droughts or floods as well as variations in importance and meanings of same risks between men and women. He attributed these differences to men and women's different roles and activities. In some South African communities, more females than males recognized heavy rains as a distinctive risk. Meanwhile more males than females reported drought as a distinctive risk, suggesting differences in perceived risks (Thomas et al., 2007). The authors suggested that differences in livelihood activities might have contributed to differences in perceived risks. Gendered livelihood patterns differed i.e. women were more involved in crop production and men in livestock production whose sensitivities to climate change differ (Thomas et al., 2007). There is, however, limited information on male and female farmers' perceptions of climate-induced risks. The assessment of perceptions of climate-induced risks of male and female farmers can help to identify climatic factors important for their livelihoods. Analysis of perceived risks by males and females warrants further research, thus ensuring that climate adaptation policies take into consideration both women's and men's priorities (Terry, 2009).

2.5 Impacts of climatic stressors on smallholdings

Smallholder farmers in SSA are some of the most vulnerable to environmental stresses. Imapacts of climate change (and variability) on smallholder livelihoods can either be positive or negative. Empirical studies mostly show reduced cereal yields in smallholdings due to climate change and variability. Climate change and variability can shift agricultural crop and livestock production patterns and affect women and men's well-being, asset base such as livestock ownership, and financial and social capital. Climate change may also result in loss of physical assets and natural resources. The loss of resources may bring about varied impacts for women and men in terms of their human, physical, financial capital and social capital.

At household level, low yields and productivity can affect men and women differently. In Niger women's control over livestock increased because men had to sell their livestock for household food security because of cultural norms that require males to care for the family (Kristjanson et al., 2010). Nelson and Stathers (2009) found that in Tanzania changes in crops grown affected men and women's access and control of income, as well as workloads.

Lower productivity may increase dependency of households on other livelihood sources such as off-farm work that can in turn result in increased labour migration. Males and females have different capacities with respect to migration due to societal and culturally expected norms/values with males often being more mobile (Agwu and Okhimambe 2009; Nelson and Stathers, 2009). Male labour migration increases *de facto* FHHs with workloads of these families increased due to absence of the 'male' in the household. In addition, because females and males have different domestic and reproductive roles and depend on different natural resources they are affected by climate change in different ways. Thus depletion of water resources, for example, may increase labour hours of women and jeopardize women's livelihoods and social connections as happened in Sonora, Mexico (Buechler, 2009). In Uganda, floods had positive effects on husbands land accumulation and negative effects on wives' non-land asset holdings (Quisumbing et al., 2011).

The IPCC's Fourth Assessment Report (IPCC, 2007) recognizes that 'gender roles and relations shape vulnerability and people's capacity to adapt to climate change'. They noted that women assumed traditional male responsibilities, in addition to their own without the same access to resources that males had. This increased labour may be additional to the increased times spent in subsistence activities such as fetching water and firewood. These increased workloads of women may in turn affect their health and well-being. In FHHs, the increased labour on domestic roles and reduced male labour may influence their agricultural management and coping strategies. Although smallholder households may benefit from males who migrate in search of livelihoods through increased income, not all households may realise benefits from male labour migration. Thus climate change and variability can therefore affect food security as well as the social wellbeing of farmers.

2.6 Adaptation strategies

Farmers are known to implement both coping and adaptation options in response to climate change and variability. Adaptation strategies can reduce impacts of climate change on the well-being of farmers. The interaction between climatic factors, the biophysical environment that include soil types, resource availability, socio-cultural backgrounds, farmer perceptions regarding climate change, and benefits of implementing strategies contribute to choice of strategies. Even marginalised households can adapt to changing climates. In the Makoni and Hwedza districts of Zimbabwe, for example, households that were perceived marginalized were able to cope and adapt to changing climates and variability (Rurinda et al., 2014). They adapted through strategies that included diversifying crops and cultivars and staggering planting dates. Adaptation forms that reduce the impact of climate-induced risks for different environments include autonomous or planned, and reactive or anticipatory adaptation (Fankhauser et al., 1999; Smit et al., 2000; IPCC TAR, 2001). Forms of adaptation in smallholder systems include use of different technologies, financial management, and diversification of livelihoods and networks (Below et al*.,* 2010). Adapters include stakeholders in the value chain (Eele, 1996; Magadza, 1996; Downing et al., 1997).

Adaptation strategies are diverse across the African continent. Management strategies include use of water conservation techniques (Nhemachena and Hassan, 2007) and in-situ rain-water harvesting strategies (Nyagumbo, 1999; Twomlow and Bruneau, 2000; Rockström, 2003; Mutekwa et al., 2009, Biazin et al., 2012). In-situ rainwater harvesting technologies include infiltration pits, cross-tied graded contours, deepened contours and fanya juus (Hagmann, 1994). Water conservation techniques include mulching and different forms of conservation agriculture. Some farmers from 11 African countries mentioned adaptation strategies that include crop diversification, using different crop varieties, varying the planting and harvesting dates, increasing the use of irrigation, increasing the use of water and soil conservation techniques, shading and shelter, shortening the length of the growing season and diversifying from farming to non–farming activities (Hassan and Nhemachena, 2008).

The commonly used crop management strategies in sub-Saharan Africa include crop and variety choices, and crop diversification (e.g. Phillips et al., 2002; Kurukulasuriya and Mendelsohn, 2008). Based on data from a cross-sectional survey (of farmer practices and perceptions) of over 8000 farms from 11 African countries, specialized crop cultivation (mono-cropping) was shown to be the most vulnerable agricultural practice to climate change in Africa (Hassan and Nhemachena, 2008). Based on cross-sectional household survey data collected from 1000 households during the 2004/2005 production season, adaptation strategies of farmers in the Nile basin of Ethiopia included planting trees, soil conservation, use of different crop varieties (most common), changing planting dates and irrigation (least practiced; Deressa et al., 2009). Smallholders also integrate livestock into crop farming systems (Mortimore and Adams, 2001). Adaptation in field based livestock systems include use of supplementary feeds and concentrates, and mixed livestock/crop systems including using adapted forage crops amongst others. Others diversify income sources e.g. some farmers in Zvishavane district of Zimbabwe (Murowa Ward; AER IV) (Mutekwa et al., 2009). Climatic conditions contribute significantly to farmers' choices of adaptation strategies. Planting different varieties of the same crop and changing dates of planting, for example, were some of the strategies reported important for adaptation in many African countries (Maddison, 2007).

Temperature often influences farmers' choices of adaptation strategies. Adaptation strategies that were common in some warmer climates of 11 African countries included irrigation, multiple cropping and integration of livestock (Hassan and Nhemachena, 2008). According to Maddison (2007), adaptation strategies of some farmers in Africa include growing different varieties, shading and sheltering trees, shortening growing season, increased use of soil and water conservation techniques and soil conservation techniques. Meanwhile maize-beans and sorghum were the main crops in cooler regions of Africa and in hot regions farmers preferred cowpea and millet

(Kurukulasuriya and Mendelsohn, 2008). According to Maddison (2007), adaptation strategies of farmers in cooler regions included changing from farming to non-farming activities, use of insurance or weather derivatives, use of irrigation/groundwater/watering, differing varieties an differing planning dates. Some farmers mentioned adaptation strategies to increases in temperature that include shortening the growing season, shading and planting trees, changing from farming to non-farming activities, increased use of water conservation techniques, differing planting dates and growing different crop varieties.

Precipitation also influences smallholder practices. Under dry-land, the most common practices by farmers include multiple cropping mixed with livestock rearing conditions (Hassan and Nhemachena, 2008). Strategies used by farmers in dry climates include differing varieties, shading and sheltering/planting trees, shortening growing season, increased use of soil and water conservation, soil conservation techniques, changing from farming to non-farming activities, differing planting dates and those in wet climates mainly used differing varieties followed by differing crops (Maddison, 2007). Meanwhile adaptation strategies to decrease in precipitation mentioned by farmers include different varieties, shortening the growing season, increased use of soil and water conservation techniques, soil conservation techniques, shading and sheltering/tree planting and differing in planting dates in descending order.

Adaptation and coping strategies commonly used by farmers in Zimbabwe include dry and early planting, growing drought resistant crops, changing planting dates, and using irrigation (Mano and Nhemachena, 2007). Mano and Nhemachena (2007) showed dry and early planting to be the most commonly used strategy (about 21%). Other adaptation strategies used by farmers include winter ploughing, planting short season varieties, irrigating, and growing drought resistant crops, planting short season and drought resistant crop varieties and practice multiple cropping that includes changing crop mixes. Some farming practices in Zimbabwe differ by agro-ecological region. There are five agro-ecological regions with different agricultural potential due to differences in rainfall patterns, and other biophysical differences such as temperature and soil types. In wetter agro-ecological regions, for example in Munyawiri (Goromonzi District II) that lies in a wetter region (AER II) of the country, Zvigadza et al. (2010) noted that in addition to crop production, horticulture was important for economic livelihoods particularly for the better-off households. The farmers also had a number of other livelihood strategies. Some adaptation options to increased rainfall variability in some Zimbabwean smallholder areas include diversifying crops and cultivars and staggering planting dates (Rurinda et al., 2014).

In drier agro-ecological regions of Zimbabwe, small grain production and extensive livestock production are important strategies for farmers. The most common adaptation strategy mentioned by farmers in Gweru and Lupane Districts of the country, for example, was the use of drought tolerant crops (Mutsvangwa, 2010). In Zvishavane district (AER IV), farmers reported changes in climate that included increased frequencies of drought, excessive precipitation, and changes in timing and pattern of seasons (Mutekwa, 2009). Farmer-suggested adaptation options to these changes included strengthening and improving indigenous land and water management practices, use of decision support tools, such as seasonal weather forecast data, growing drought resistant crops, improving indigenous animal breeds, and development of irrigation infrastructure (Mutekwa, 2009).

Strategies to manage stress from warmer climates and climate variability by the middle of the 21st century and beyond can include use of short season crop varieties and changing crop choices, as well as shifts in livelihoods strategies. Agronomic modelling by Matarira et al. (1995) using GCM adjusted climates and the Ceres-maize model, projected reduction in maize yields in future climates primarily due to temperature increases that shorten the crop growth period, particularly the grain-filling period. Adaptation options suggested from the study included switching to stress tolerant small grains and short season maize varieties. Nyabako and Manzungu (2012) also suggested most of the country may become more suitable for short-season maize varieties (e.g. current AER II and III) and the current drier agro-ecological regions may become unsuitable for maize production and become more suitable for stress tolerant small grains such as sorghum and millets. The area of AER I and II may decrease in size by 14%, AER III by 26%, while AER IV and V may increase by 40% (Nyabako and Manzungu, 2012). According to their models, most agro-ecological regions will become unsuitable for long season varieties of maize crop. However, there is need for more studies on adaptation to future climates. Current information is mostly for country-level adaptation strategies, generalising for different communities.

2.7 Gender and adaptation to climate change

Empirical adoption literature shows that farm assets and wealth factors, and household size have mixed impacts on farmers' adoption of agricultural technologies. At community level, households with larger asset bases and institutional support may be better able to adopt improved technologies and improve management practices, change farming practices, and diversify in response to climate change and variability. According to Ethiopian farmer perceptions, lack of information, lack of money, shortage of labour, shortage of land, and poor potential for irrigation contributed to lack of adaptation to climate change (Deressa et al., 2009). Hassan and Nhemachena (2008), for example, noted that multiple cropping was mainly practiced by large families and mono-cropping by smaller families under both dry-land and irrigation. In some sub-Saharan African countries (South Africa, Zambia and Zimbabwe), farmers with access to credit and extension, and with more farming experience were more likely to take up adaptation options (Nhemachena and Hassan, 2007). In addition, the numbers of adaptation measures adopted per household are often related to more sources of income (Coe and Stern, 2011). In contrast to findings that show positive effects of resources on adaptation, increasing household size did not significantly increase the probability of adaptation using soil conservation methods, crop varieties, planting dates, planting trees and irrigation in the Nile basin of Ethiopia (Deressa et al., 2009). In general, resources influence uptake of different adaptation strategies.

Differences in resource levels, social-cultural norms and roles of males and females imply different management pathways for MHHs and FHHs. Female farmers in drought-affected Tanzania and Kenya smallholder communities, for example, had fewer sources of livelihoods compared to male farmers within the same household (Eriksen et al., 2005). The fewer sources of livelihoods for females were attributed to lack of access to financial capital, gender norms that excluded women from the more profitable activities such as bee keeping, and heavy reproductive work burdens. In contrast, FHHs used more adaptation options compared to MHHs in some southern African countries (Nhemachena and Hassan, 2007). Meanwhile, in the Nile Basin of Ethiopia MHHs adapted more readily to climate change compared to FHHs i.e. MHHs were 9% more likely to conserve soil, 11.6% more likely to change crop varieties and 10% more likely to plant trees (Deressa et al., 2009). Furthermore, male and female farmers have different interests. They face different situations that oblige them to acquire different capacities and knowledge. Resource ownership and command, and household strategies, relate to key gender divisions such as occupational segregation, domestic divisions of labour, power inequalities and gender practices (Bradley, 1996). Different resource levels by MHHs and FHHs, as well as social and cultural norms, for instance gendered divisions of labour, physical mobility usually influence their vulnerability and adaptive capacity and management strategies.

According to Terry (2009), there is a gap in consideration of gender issues in international policy discourse. Therefore, there is need for gender-specific policies for climate change management. Information gaps exist within the current literature concerning the coping and adaptation strategies of differently managed households in Zimbabwean smallholder farming systems. Requirements for mainstreaming gender in climate change adaptation include information on practices and preferences of MHHs and FHHs in different climates. Based on gender differences with respect to domestic divisions, power inequality and gender practices and on resources ownership and command, and household strategies, this study proposed that gender processes affect resource availability in rural smallholdings and this in turn affects smallholding practices and adaptive capacity, thereby creating gender differentiated responses to climate change.

2.8 Assessment of climate change impacts

Approaches to understand impact of climate change include historical climate impacts, climate analogues, and contemporary climate impacts i.e. studies of the impact of present day climate and climate variability (Feenstra et al., 1998; Wilby et al., 2009). Formulating and improving adaptation options for future climates and policies for smallholder farmers entails that stakeholders understand the nature of climate-induced risks and vulnerabilities of smallholder in different settings, range of adaptation options required for different farmers. Due to the complex nature of smallholdings and the compounding effects of climatic and non-climatic stressors to agriculture robust approaches that combine different methods are required to understand climate impacts on smallholders.

2.8.1 Analogue analysis concept in climate change studies

Analogue analysis is an approach that can give useful insights about climate change impacts. Analogue locations are locations that have today the climatic characteristics that are expected tomorrow for a given site (Diffenbaugh et al., 2008, Williams et al., 2007). Analogue scenarios include temporal analogue scenarios in which past warm climates offer scenarios for future warm climates, and spatial analogue scenarios in which the current climate in another usually warmer area is hypothesized to represent the future climate of the study area (Feenstra et al., 1998). Climate-analogue analyses methods work by identifying geographic areas with the closest contemporary climatic analogues for the future projected climates at the reference location (Burke et al., 2009).

Spatial analogues use cross-section evidence to make statistical estimations of how changes in climate would affect agricultural production across different climatic zones (Mendelsohn and Dinar, 2003). Spatial analogue yields of the same crops at different latitudes or during different periods of the year can be used to derive possible crops reactions to changing climatic conditions (Schimmelpfennig et al., 1996). The Ricardian cross-sectional approach is an example of a spatial analogue approach. The performances of households are measured across spatial scales with different climates.

The Ricardian model compares the net returns on land in locations which have already adapted i.e. takes it account the adaptation strategies implemented (e.g. Mendelsohn and Dinar 1999). However, there is need to control for many variables in addition to climate. The carbon dioxide fertilization effect is also not taken into account. Cross-sectional models also (often) fail to take into account water supply (Darwin, 1999; Kurukulasuriya and Mendelsohn, 2006).

Spatial analogue models (Adams et al., 1998, Williams and Jackson, 2007, Diffenbaugh et al., 2008, Burke et al., 2009) can be platforms to better understand possible impacts of climate change under different settings of smallholder farmers. The assumption is that crop, farmer responses to climate are already present, and that biophysical and economic adjustments imposed by climate change have been made. By looking at the choices, strategies and technologies being adopted by farmers in current climates, it is possible to infer how farmers may respond to a changing climate when it takes analogue site characteristics. Climate analogues enable description of climate scenario and associated impacts in far greater temporal and spatial detail, they are easy to apply and reveals multi-sector impacts/vulnerability to past climate conditions or extreme events (Wilby et al., 2009). The biological communities such as dominant crop types can be compared between the target location and its closest analogue as a first indication of the potential ecological and economic consequences of climate change.

Spatial analogue approaches have other applications. Mendelsohn et al. (1994) used analogues to analyse cross-sectional data on land values and estimate the effects of climate shifts on producers' net income, and Chen and McCarl (2001) to estimate pesticide treatment costs and to estimate crop variability. Spatial analogue approaches have also been used to identify adaptation strategies for urban planners (Hallegatte et al., 2007; Hayhoe et al., 2010), examine the economic effects of climate change on agriculture (Parry and Carter, 1988), distinguish climate change hotspots (Diffenbaugh et al., 2008), and locate areas at risk of novel or disappearing environmental conditions (Williams et al., 2007).

Climate analogues within and across countries can be explored for climate risks analysis. In southern Africa, temperature may increase by between 3°C to 4°C by the middle of the 21st century (e.g. Hulme et al., 2001; IPCC, 2007b). Temperature analogue sites can therefore have mean annual temperatures that are higher by about 2-3°C compared to the reference sites. Spatial temperature analogue analysis can be used to explore impacts of warmer climates and adaptation requirements for smallholder farmers. Spatial temperature analogue models assume that cooler regions will have the patterns observed in other regions currently with warmer climates if subjected to a climate-induced shift (Adams et al., 1998). Good 'within country' temperature analogue locations representing the 2050s climates exist in Africa (Burke et al., 2009). Burke et al. (2009) argued that, with some exceptions, good temperature analogues also tend to be good precipitation analogues. Based on observations by Burke et al. (2009), the assumption of this study was that climate analogues existed for the sub-humid and for the semi-arid smallholder areas of Zimbabwe. Therefore, this study was based on climate analogue analysis.

Limitations of analogue approaches include the fact that recommendations for future climates are based on prevailing conditions i.e. macro-economic and micro-economic conditions. The strategies and options suggested are not applicable for all smallholder farmers in Zimbabwe. They are applicable to study sites and other smallholder areas with similar rainfall and temperature characteristics and biophysical environments. Carbon dioxide effects are not taken into consideration. The information obtained from studies of spatial analogues needs to be interpreted carefully as other geographical and other differences are likely to impact climate (and other responses; Carter et al., 1994). Extensive data is also required to identify analogue pairs (Feenstra et al., 1998).

2.8.2 Assessment of vulnerability and adaptation options

The three elements of vulnerability of a system include exposure to a hazard, sensitivity to that hazard, and the capacity of the system to cope, adapt or recover from the effects of those conditions (Smit and Wandel, 2006). Farmers sometimes identify vulnerability indicators that are specific to their communities. Comparative evaluation or rating of vulnerabilities and adaptive capacities are based on criteria, indices and variables typically selected by the researcher (Brooks et al., 2005). Net or residual impacts (initial impact costs minus net adaptation savings) are sometimes used to assess vulnerability. Meanwhile adaptive capacity is also analysed by thresholds and "coping ranges", defined by the conditions that a system can deal with, accommodate, adapt to, and recover from (Smit et al., 2000). Frameworks for analysing or conceptualising adaptive capacity largely focus on capital asset indicators (Brooks et al., 2005; Dulal et al., 2010). Jones et al. (2010) proposed a framework that identifies five yet distinctively inter-related characteristics that support adaptive capacity. These include asset base, institutions and entitlements, knowledge and information, innovation, and flexible forward-looking decision-making.

Approaches to assessment of effects of climate change on agriculture may include agro-economic models, agro-ecological zone models and Ricardian cross-sectional models (Mendelsohn and Dinar, 1999). Agronomic models measure impacts of climate change and variability on crop growth. In agro-economic models costs associated with changes in crops grown in a given area are calculated per given land i.e. crops are allocated to particular ecological zones according to climatic suitability and changes in producer and consumer surplus are calculated.

Adaptation options can be assessed through modelling studies (e.g. Deressa et al., 2009) and comparing farmer practices in different climates (e.g. Kurukulasuriya and Mendelsohn, 2008). Deressa et al. (2009), for example assessed determinants of adaptation options through analysis of farmer practices and perceptions and multinomial logit (regression) analysis. Adaptation choices of smallholder farmers are influenced by multiple factors that include climate, resources, and farmer preferences. Information of benefits, costs, implementability, effectiveness, efficiency of adaptations to climate change stimuli (Fankhauser et al., 1999; Feenstra et al., 1998) is also important in the adaptation process. Multi-criteria analysis is another tool often used to analyse agricultural decision-making processes (Janssen and Van Herwijnen, 2006; de Bruin, 2011). In this method, criteria selected used to make a decision are weighted depending on their value.

Reed et al. (2013) suggested an integrated analytical framework to assess vulnerability to climate change, and to identify and compare adaptation options. The integrated framework combines the use of the Sustainable Livelihood Framework (SLF), the ecosystems services, diffusion of innovations, social learning, transitions management and adaptive management analytical frameworks. Füssel and Klein (2006) proposed a conceptual framework for vulnerability assessment that combined climate impact assessments, first generation and second-generation vulnerability assessment, and adaptation assessments. This study followed the SLF in assessing and comparing the resources that farmers have that can enhance management and adoption of strategies to reduce vulnerability to climate shocks and adaptation to current and progressive climate change.

2.9 Climate change studies in Zimbabwe

Climate change studies done in Zimbabwe include risk assessments mainly based on farmer perceptions. Assessments of climatic and non-climatic constraints to smallholder livelihoods, for example, were carried out in several districts of Zimbabwe including Makoni and Hwedza districts in eastern Zimbabwe (Rurinda et al., 2014), and in Masvingo and Hwange Districts (Moyo et al., 2012). Farmer perceptions of climatic constraints were compared to information from climate data. However, farmer perceptions were often not matched with climate data, for example in Zvishavane district (Mutekwa, 2009). Vulnerabilities and adaptive capacity of smallholder communities in Lower Gweru and Lupane districts of Zimbabwe were assessed based on the Sustainable Livelihood Framework (Mubaya et al., 2012). Meanwhile, Mutsvangwa (2010) used the Chaudhuri approach (Chaudhuri et al., 2002) to assess vulnerabilities of smallholder communities to food insecurity at the two districts.

Impacts of warmer climates on crop production, with particular reference to maize, the main food security crop, were assessed using various models (Matarira et al., 1995; Makadho, 1996; Rurinda et al., 2014). In addition, economic impacts of climate change on some Zimbabwean communities were assessed using Ricardian analyses (e.g. Mano and Nhemachena, 2007). Other studies include those on seasonal forecasts for climate risk management (Phillips et al., 2001; Unganai and Mason, 2002; Manatsa et al., 2012; Moyo et al., 2012). Development projects to enhance the capacity of smallholdings include a UNDP–funded project in some Chiredzi District wards that focused on enhancing agricultural and pastoral systems in Zimbabwe to adapt to climate variability (UNDP, 2012).

Smallholder socio-economic environment and cultural factors influence climate change adaptation. Integration of methods is therefore important for climate change studies. Rurinda et al. (2014), for example, assessed vulnerability and adaptation to climate variability and change in Makoni and Hwedza districts in eastern Zimbabwe through field observations and surveys, systems analysis and field experimentation, and simulation modelling (the Agricultural Production Systems Simulator (APSIM). Knowledge gaps on climate change impacts and agricultural adaptation with a gender perspective in SSA and specifically in Zimbabwe, however, still exist.

2.10 Conclusion

Smallholders farm across different agro-ecological regions, have different cultures and socio-economic backgrounds. Many information gaps remain in smallholder climate change adaptation in Zimbabwean smallholder areas. Information on vulnerability, adaptive capacity and adaptation strategies is limited to a few smallholder areas and in not exhaustive. Evidence from literature suggest that levels of resources often differ between MHHs and FHHs. Information on current gendered differences in resource levels of MHHs and FHHs in different climates and outcomes of management practices is limited. Further, climate induced risks differ in smallholder areas of sub-Saharan Africa. Climate change affects the biophysical and socio-economic environment of farmers differently. To date there have been few studies that assess climate-induced risks and adaptation options with a gender perspective in smallholder areas of Zimbabwe. Further information on possible transitions, adaptation pathways for warmer climates and requirements of MHHs and FHHs in limited.

The study was based on the theory that women and men have different accesses to resources and that these gendered differences result in different management strategies for differently managed households. Analysis of resources levels, farmer perceptions and farmer practices could give insights into climate-reduced risks, management strategies and requirements for differently managed households.

Assumptions of the study were that climate analogues for semi-arid and sub-humid smallholder areas (which are the predominant agricultural lands for smallholder farmers in Zimbabwe) existed within the country. Burke et al. (2009) showed the existence of climate analogues for the 2050s (and beyond) within and between African countries, and therefore support the assumption of this study. Climate projections are for temperature increases ranging from about 2-3 °by the middle of this century. Climate analogue pairs consist of the reference site, and its analogue site. These have similar rainfall patterns, but the analogue would be warmer by about 3°C to represent the effects of global warming. Comparisons of analogue pairs i.e. the reference site and analogue site can help identify opportunities and risks as well as management options. Assumptions in climate analogue analysis are that farmers at analogue sites i.e. those sites representing future climates have adjusted their practices to suite the warmer climates. Farmers at the reference sites may shift some of their practices to resemble those at the analogue sites. Therefore, climate analogues present insights through which researchers and smallholder farmers can learn for progressive adaptation to climate change.

3.0 The study context

3.1 Introduction

Climate change by the middle of this century may negatively influence smallholder agricultural production in sub-Saharan Africa (SSA). The fifth report of the IPCC notes that the risks of reduced crop productivity and household food in security will require technological adaptation and strengthened institutions as well as new gender-oriented policies (IPCC, 2014). Given the projected effects of climate change on human livelihoods, and the fact that it is cheaper to adapt rather than handle the effects of not adapting, it is imperative that a holistic approach be taken in climate change adaptation research. Existing studies cover only a small fraction of Africa. Information available is often segmented. Vulnerability studies often fail to consider differences in farming systems and agro-ecological conditions within a country or region. Few studies in Africa include data on actual farmer behaviour, particularly from a gender perspective. This is despite the fact that gendered differences exist in resource levels, as well as in roles. There is also increased 'feminisation' of agriculture in some parts of Africa as men seek alternative sources of livelihoods elsewhere. Identifying adaptation options through better understanding of risks and opportunities, and mainstreaming gender issues in adaptation, are important for climate change planning. Managing current climate-induced risks through integrated strategies is important for adaptation to future climates.

This study was conducted in the context 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), implemented by ICRISAT. The CALESA project sought to test potential agricultural adaptation strategies for rain-fed agriculture in the semi-arid and dry sub-humid tropics (i.e. in Zimbabwe and in Kenya) through climate analogue analysis. The CALESA project sought to develop promising smallholder adaptation strategies for current and future climates through on-station trials and participatory methods involving farmers.

The first component of the CALESA project involved iterative on-station field research that evaluated 'potential crop, soil, and water management and crop genotype adaptation' options. In Zimbabwe, the Zimbabwe Meteorological Services Department (ZMSD) assisted in the identification of sites for on-station trials. Crops evaluated included two cereals (maize and sorghum) and two legumes (groundnut and cowpea). Evaluations for each crop included an assessment of the agronomic performance of three varieties: short season, medium season, and long season. Impacts of climate change on yields were analysed using the Ceres-crop model. Evaluations also included soil and water management, fertilizer rates, and the effects of planting dates on different crops.

The second component of the study characterised the analogue locations with regard to crops, soils, climate, current farming practices, documented stakeholder perceptions about climate variability and change and their impacts on crop management, and production and other livelihood activities at the study sites. This component, based on participatory approaches, sought to complement on-station trials and modelling data for the CALESA project and involved characterisation of smallholders close to the on-station trial sites. The purpose of this study component was to explore climate-induced risks through temperature analogue analysis and propose gender-sensitive adaptation requirements for progressive climate change adaptation through participatory research with smallholder farmers. The study mainly focused on crop production. Crop production and livestock production are some of the main subsistence activities of many smallholder farmers. This was therefore an exploratory study of the adaptation options and requirements of MHHs and FHHs for warmer 2050s climates.

3.2 Problem statement

Females often own fewer resources compared to males. These differences are in part due to inequalities arising from socio-cultural norms. Women and men have different gendered roles (i.e. domestic, reproductive, and productive roles) as well as different cultural and societal influences. These differences between males and females influence the management practices of MHHs and FHHs. Adoption of technologies in differently managed households often varies. However, adoption levels in FHHs are often lower than in MHHs (e.g. Mazvimavi and Twomlow, 2009). Consequently female-headed households often have lower yields compared to MHHs. Climate change by the middle of the century is likely to negatively affect smallholder production and livelihoods. Climate change may further increase the vulnerabilities of FHHs. Mainstreaming gender in response strategies and climate planning is therefore necessary for improved adaptation and food security among smallholders. However, few studies show how differently resourced households, with particular reference to MHHs and FHHs, manage their resources for improved livelihoods. Responding to shifts in food production patterns and livelihoods because of climate change and environmental variability requires holistic approaches that involve various stakeholders.

3.3 Main objective

The main objective of the study was to determine how the gender of household heads affects smallholding and adaptation to climate change in smallholder areas of Zimbabwe.

3.3.1 Specific objectives

The specific objectives of the study were:

i. To assess how gendered patterns of resource ownership by household heads affect smallholder practices and their outcomes in rural Zimbabwe.
ii. To assess the effect climate change is likely to have on male-led and female-led smallholdings in rural Zimbabwe in terms of resource-based forms of smallholder practices and outcomes.
iii. To assess the adaptation options and requirements of differently managed households for current and future climates.

3.4 Research questions

The study pursued the following research questions in meeting its objectives:

i. How do gendered patterns of resource ownership relating to the sex of household heads affect smallholder practices and their outcomes in rural Zimbabwe?
ii. What effect is climate change likely to have on male-led and female-led smallholders in rural Zimbabwe in terms of resource-based forms of smallholder practices and outcomes?
iii. Overall, how will gender affect adaption to climate change and outcomes for smallholders in rural Zimbabwe?

The overall research question was: Are there gendered differences in climate change adaptation and requirements for adaptation?

3.5 Significance of the study

The goal of this research was to investigate how to improve the ability of MHHs and FHHs in semi-arid and sub-humid sub-Saharan Africa to adapt to progressive climate change and to recommend appropriate gender-sensitive management strategies for farmers. The farming systems in sub-humid and semi-arid areas experience different climate-induced risks. The largest population of rain-fed smallholders and the main agricultural land is in semi-arid and sub-humid areas; hence, sites were selected from semi-arid and sub-humid agro-ecological regions of Zimbabwe occupied by the majority of the smallholder population. Female-headed households represent 30% to 40% of households in smallholder areas of sub-Saharan Africa. Women in general depend on natural resources for their livelihoods. Climate change affects natural resources. Women are therefore vulnerable due to their weak resource bases and their dependence on natural resources. Strategies employed by successful female-headed households can provide insights into successful adaptation to different climates.

4.0 Research methods

4.1 Introduction

This study was conducted in the context of the research project 'Adapting agriculture to climate change: Developing promising strategies using analogue locations in Eastern and Southern Africa'. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) implemented the CALESA project (Climate Analogue Locations in Eastern and Southern Africa). The study involved two research methods that ensured multidisciplinary approaches in formulating adaptation options for SSA sub-humid and semi-arid smallholder areas. The methods included on-station evaluations and participatory approaches that involved household surveys, FGDs, and participatory evaluations of on-station trials by smallholder farmers. The participatory approach followed in this study sought to document smallholder farmer perceptions of climate-induced risks at the sites, and to identify and quantify production risks for current and future climates (climate change) through comparisons of farming systems between analogue pairs. This study also sought to identify climate-induced risks through farmer perceptions and possible adaptation options with a gender perspective for both current and future climates. Criteria for selection of smallholder sites included proximity to the sites of the on-station trials.

4.2 Description of the study sites

The study was carried out in Zimbabwe, a landlocked country in the southern African region, which lies between 15°33' and 22°24' south latitude and 25°12' and 33°03' east longitude. Relief regions include the high-veld that lies between 1200 m and 2000 m above sea level, the middle-veld that lies between 900 m and 1200m above sea level, and the low-veld that lies below 900 meters above sea level. The country is divided into five main agro-ecological regions (AER I, II, III, IV, and V) according to differences in effective rainfall (Vincent and Thomas, 1960). Rainfall and crop productivity progressively decline from Region I to V. Zimbabwe's climate typically consists of one crop growing season, mediated by the ENSO and the Inter-Tropical Convergence Zone (ITCZ), which stretches from November to March.

Selected analogue pairs represented semi-arid and sub-humid agricultural areas of Zimbabwe. Mean annual rainfall and temperatures were calculated from meteorological stations with at least 30 years of climate data, with the assistance of the Zimbabwe Meteorological Services Department (ZMSD). Analogue pair study sites were then selected based on climate projections. Climate projections estimate an average temperature increase of about 3°C in mean annual temperature for the 2050s climates in most of sub-Saharan Africa (Hulme et al., 2001). There are uncertainties in the direction of precipitation changes. However, models project changes in precipitation of ± 5–15% (Hulme et al., 2001). Therefore, selected analogue pairs had similar annual rainfall and a difference in average annual temperature ranging from 2°C to 4°C. The sites selected covered four agro-ecological regions of the country and five districts (Figure 4.1; Table 4.1).

The pair representing the wetter sites consisted of Henderson Research Station and Kadoma Research Station (Figure 4.1; Table 4.1). Henderson Research Station is in Mazowe District, which is about 30 km north of Harare and lies in AER IIb of Zimbabwe. The geographical coordinates of the station are longitude 17°35′S and latitude 30°58′E and its altitude is approximately 1272 m above sea level. Kadoma Research Station is situated at 29°53′E and 18°19′S at an altitude of 1156 m above sea level. These have a mean temperature difference of 3.6°C. Kadoma district (722 mm, 21.8°C) was expected to represent the Mazowe/Goromonzi district (842.9 mm, 18.2°C) following the effects of global warming by the middle of the century. Figure 4:2 summarizes the temperature trends at the study districts. Soils in the Kadoma and Mazowe/Goromonzi district study sites mainly consisted of sands and sandy loams. The soils in Kadoma district are well-drained and reddish brown, and belong to the fersiallitic group (Nyamapfene, 1991).

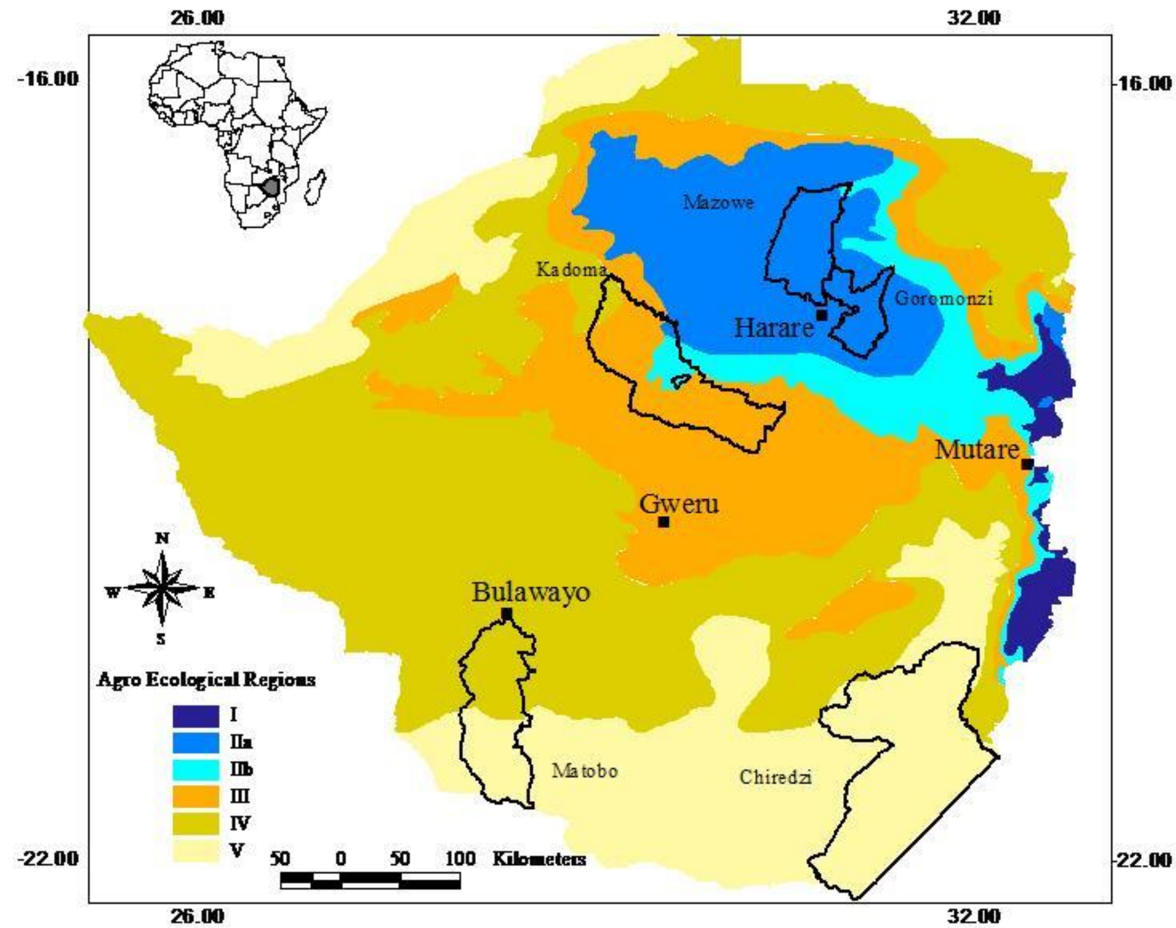

Figure 4:1 Locations of study districts in Zimbabwe

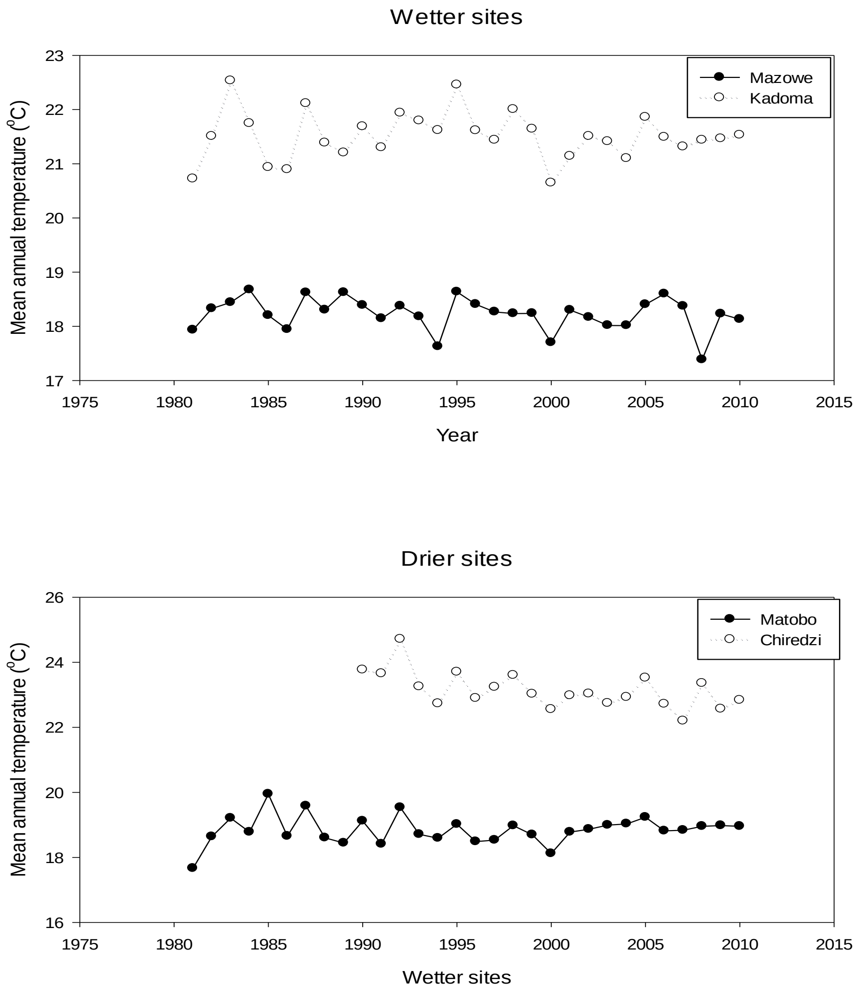

Figure 4:2 Temperature trends at the study districts (source of data ZMSD)

Table 4.1 Characteristics of selected sites and sample sizes

	Wetter analogue Pair			***Drier Analogue Pair***		
			Difference			*Difference*
Station	Henderson Research Station	Kadoma Research Station		Matobo Research Station	Chiredzi Research Station	
Characteristics	Cool/wet (reference)	Hot/wet (analogue)		Cool/dry (reference)	Hot/dry (analogue)	
Smallholder Sites	Mazowe/ Goromonzi districts	Kadoma district		Matobo district	Chiredzi district	
Mean Annual T°C	18.2	21.8	*3.6*	18.4	21.3	*2.9*
Mean Annual Rainfall (mm)	842.9	721.7	*-121.2*	567.1	541.2	*-25.9*
Soil types	Greyish brown sands and sandy loams	Greyish brown sands and sandy loams		Greyish brown sands	Heavy clays, vertisols, sands, sandy loams	
1st survey (n)	153	149		159	163	
FGDs (n)	4	4		4	4	
2nd survey (n)	61	59		55	61	
Farmer assisted evaluations (n)	2	4		2	4	

The sites representing drier areas were Matopos Research Station and Chiredzi Research Station. The Chiredzi district climate (average annual rainfall of 541 mm, average annual temperature of 21.3°C) was hypothesized to represent Matobo district climate (average annual rainfall of 567 mm, average annual temperature of 18°C) by the middle of the century. Figure 4.2b shows the mean annual temperature differences between the two sites. Matopos Research Station lies in AER IV and V, in the south of the country, 28 km south of Bulawayo at 20°23'S and 28°31'E and at an altitude of 1430 m above sea level. Its reference site, Chiredzi Research Station, lies in the southeast of the country (21°33'S and 31°30'E , elevation 429 m). The district is in AER V and is characterised by low mean annual rainfall, and unreliable rainfall (Vincent and Thomas, 1960). Rainfall distribution is very poor and mid-season droughts are a common feature, as are frequent short seasons (e.g. Unganai and Murwira, 2010).

Most soils in Chiredzi district are heavy clays, while some soils, e.g. the soils at Chiredzi Research Station, are dark-reddish brown clays derived from basic gneiss.

On-station trials were conducted at the four research stations. Smallholder communities selected for the participatory research resided close to the research stations.

4.3 Data collection methods

Methods of data collection included household interviews, key informant interviews (KIIs), FGDs, and participatory evaluations. A total of two household surveys, 16 FGDs, and 12 participatory evaluations were done. Triangulation of data involved within-method and across-method strategies to check and compare the results for reliability. KIIs were conducted to triangulate data and confirm statistics given by farmers. Triangulation is necessary in the social sciences because of the inherent 'softness' of most of the data that is collected (Riley and Felding, 2001). The participatory approach integrated farmers in the process of climate change planning. Surveys and focus groups facilitated collection of both qualitative and quantitative data for 'generalization for a population' (Banda, 2003). Table 4.1 contains summaries of the site characteristics and respondent statistics.

4.4 Household surveys

A cross-sectional household survey to characterize farming systems of the 2010/2011 cropping season, was conducted from July 2011 until September 2011. In each district, at least three wards were selected close to each of the research stations. The smallholder farmers close to Henderson Research Station that were selected included those from two districts, namely Mazowe district in Chiweshe and Goromonzi district. Hereafter the site is referred to as the Mazowe/Goromonzi district. Selection purposefully included those with smallholder areas and old resettlement areas. 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. This enabled disaggregation of the data by gender. Structured questionnaires were the main instruments for household survey data collection. Data collected included demographic and socio-economic characteristics, agricultural practices, constraints, soil, water, and fertility management practices, and sources of information. Information provided by farmers, with particular reference to farm sizes and harvests, was corroborated through KIIs with the Agricultural Technical and Extension Services (AGRITEX) officers. Triangulation of data was within and between methods. There were 727 questionnaires with usable data from the four study sites, after data cleaning (Table 4.1).

A second survey was conducted from September to November 2013 in two wards at each site. Pre-surveys with test questionnaires were used to evaluate flow and feasibility. Farmer perceptions of climate change and variability, gender roles, and farmer groups that were operational were assessed. Two hundred and thirty six farmers were interviewed, 61 from Mazowe/Goromonzi, 59 from Kadoma, 55 from Matobo, and 61 from Chiredzi. Once more, at least 30% of the respondents at each site were from FHHs.

4.5 Focus group discussions

The FGDs were conducted from January 2013 to February 2013. The purpose was firstly to triangulate survey data, and then to enable an in-depth analysis of farming systems and climate-induced risks, gendered differences, and preferred adaptation options.

4.5.1 Sampling

Discussions were conducted in two wards at each site. In each ward, two group discussions were held. One group consisted of male farmers and the other of female farmers. Each focus group consisted of a maximum of 12 farmers whose socio-economic backgrounds varied. These farmers also represented married and single farmers, and younger (less than 35 years) and older farmers (above 35 years). Two note takers assisted in data collection.

4.6 Farmer-assisted evaluations of on-station trials

4.6.1 Experimental design

On-station trials were conducted during the 2012/2013 cropping season under rain-fed conditions. Sites for the trials were Henderson Research Station (Mazowe), Kadoma Research Station, Matopos Research Station, and Chiredzi Research Station. The experimental design consisted of a 4 × 3 × 3 randomized block design with four crops, three varieties of each crop, and three replications. Crops were selected based on farmer preferences and included two cereals (maize and sorghum) and two legumes (groundnut and cowpea) (Table 4.2). Farmer FGDs evaluated crop varieties qualitatively at the four research stations.

Table 4.2 Crops and varieties evaluated

	Variety		
Crop	Early maturing	Medium maturing	Late maturing
Maize	SC403	SC513	SC727
Sorghum	Macia	SDSL89473	Pato
Groundnut	Nyanda	Natal Common	Makhulu Red
Cowpea	CBC1	CBC2	Landrace

4.6.2 Data collection

Groups of six to 10 farmers compared the performance of the crops and varieties 103 to 126 days after planting (DAP). One group composed of male farmers and one group composed of female farmers evaluated crops at the reference study sites in Matobo district (semi-arid) and Mazowe district (sub-humid). Analogue site trials in Chiredzi district (semi-arid) and Kadoma district (sub-humid) were each evaluated by four focus groups. They consisted of one group of male farmers and one group of female farmers from the respective districts, and one group of male farmers and one group of female farmers from the reference site.

Crops were evaluated at physiological maturity; evaluations were conducted from April to May in 2013. Farmers compared the performance of crops and noted their preferences by direct observation of plant traits at maturity. Farmers recorded their observations on paper scrips. Two experienced note-takers recorded their comments and selection criteria. Data analysis for participatory evaluations comprised complementary qualitative and quantitative techniques. Data were analysed using the Statistical Package for the Social Sciences (SPSS) version 21.

4.7 Summary of data collected and data analysis

Table 4.3 summarises the data collected through the surveys in response to each of the three research questions.

Table 4.3 Summary of data collection methods and data collected

	Research question	Data collection methods	Data collected
1	How do gendered patterns of resource ownership relating to the sex of household heads affect smallholder practices and their outcomes in rural Zimbabwe?	Household survey Resource maps	Demographic characteristics of respondents and heads of households – education levels, family sizes, farming experience, human capital-family labour Physical assets – arable land sizes, agriculture assets, household assets, types of households Crop grown, Livestock kept, Livelihood options Calendar of activities, Resource maps
		FGDs	Main crops grown in order of importance Livelihood options –ranked in order of importance Gender roles in management of different crops and livestock e.g. planting, weeding, harvesting, soil and water management strategies
2	What effect is climate change likely to have on male-led and female-led smallholders in rural Zimbabwe in terms of resource-based forms of smallholder practices and outcomes?	Household Survey	Crops grown, crop area in 2010/2011 season Crop harvests Perceived crop production constraints Perceived livestock production constraint Social groups
		FGDs	Production constraints in crop production, livestock production and livelihoods
3	Overall, how will gender affect adaptions to climate change in smallholder practices and outcomes in rural Zimbabwe?	Household Survey	Perceived climate changes Crop production constraints Livestock production constraints
		FGDs	Perceived climate changes in recent years
		Participatory evaluations	

4.8 Challenges encountered in implementing the study

Access to farmers in the rainy season was limited due to poor road networks, particularly in Chiredzi district. The Runde River was flooded, and the bridge en-route to Chiredzi ward 7, which had partially collapsed, was impassable. Households sampled in the first and second surveys were in some cases different due to labour migration, deaths of household heads, and travel by members of households. At times, the sampling was not random, but targeted to fulfil the quota of FHHs.

4.9 Summary of data analysis

Data analysis was composed of qualitative content analysis (QCA) and quantitative data analysis. Quantitative household survey data were coded manually to identify themes/categories of responses. The codes were transcribed into SPSS. Qualitative and quantitative data were selected to reflect the production risks, vulnerabilities, resource levels, and adaptation options of differently managed households at each site. Comparisons of MHHs and FHHs at each site (Chapter 5) assessed gendered differences. Comparisons of MHHs and of FHHs at reference sites and analogue sites (Chapter 6) assessed some likely effects of different climates.

4.10 The analytical framework

Figure 4.1 outlines the analytical framework of the study. Two pairs of analogue sites representing sub-humid and semi-arid sites were selected. Climate-induced risks and farming systems of differently managed households were compared using climate analogue analysis. In this study, the influence of the gender of the head of household on smallholding was analysed by comparing MHHs and FHHs at each site. The influence of climate and other non-climatic factors on differently managed households was analysed by comparing FHHs at reference sites with FHHs at analogue sites, and by comparing MHHs at reference sites with MHHs at reference sites. Comparing MHHs at each analogue pair and FHHs at each analogue pair enabled comparisons and estimations of some likely impacts of warmer 2050s climates on smallholder production. Adaptation options were obtained from analysis of management practices and farmer preferences.

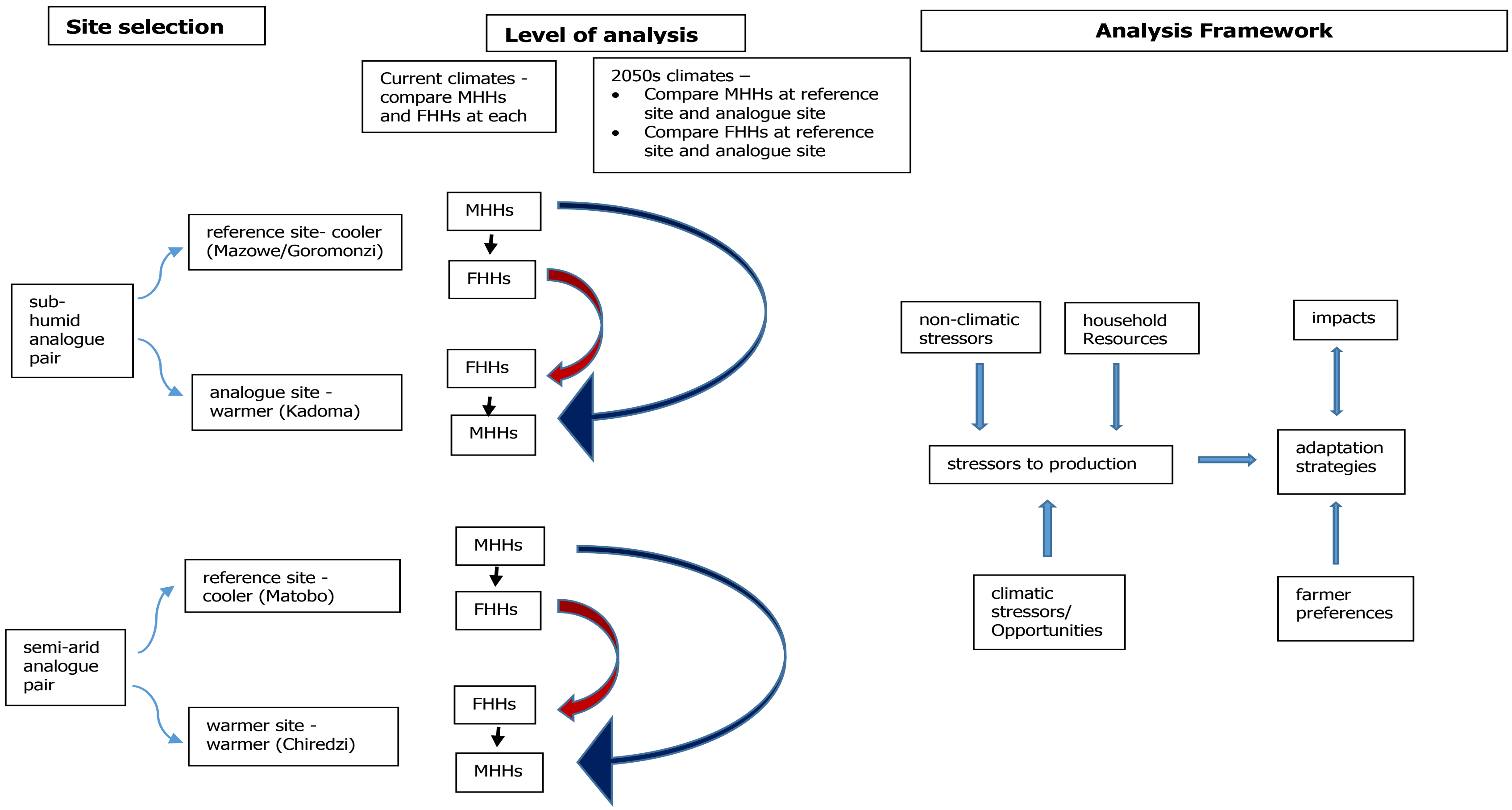

Figure 4.1 Analytical framework of the study

5.0 An assessment of the influences of the gender of the head of household on smallholdings in Zimbabwe

5.1 Introduction

Climatic and non-climatic stressors such as socio-economic constraints negatively affect farming systems in smallholder areas of SSA (Morton, 2007). Male-managed and female-managed households in smallholder areas often have variable access to resources required for production (e.g. Quisumbing, 1995; Doss, 2001; Odame et al., 2002). Lower resource levels sometimes results in lower yields in FHHs compared to MHHs (e.g. Tiruneh et al., 2001). Socially constructed roles of males and females also differ and influence farming choices. Differences between MHHs and FHHs suggest different vulnerabilities and management pathways for climatic and non-climatic stressors. Information on differences between differently managed households in smallholder areas representing the major production regions of Zimbabwe can assist in mainstreaming gender issues in policies for rural development and climate change. There is, however, inadequate information on how the gender of householders affects farming and adaptation with respect to production constraints, their adaptive capacity, and the impacts of climates on production and livelihoods.

According to Scoones (1998), resources required for sustainable livelihoods are categorised as human, financial, natural, physical, and social capital. Resources that are often lower for female-headed households compared to male-headed households in SSA include labour, livestock, farm size, and education levels. Lower levels of resource ownership of FHHs compared to MHHs are usually due to socially and culturally constructed roles and inequalities. Resource differences often influence crop management decisions as well as yields (e.g. Tiruneh et al., 2001; Horrell and Krishnan, 2007; Ncube et al., 2009).

In an effort to increase knowledge of farming systems and vulnerability to climate factors, this study explored the nature of the differences between MHHs and FHHs in terms of resource ownership at the study sites, stressors to production, and outcomes in production and food security. This study sought to find out how gendered patterns of resource ownership relating to the sex of household heads affected smallholder practices and their outcomes in rural Zimbabwe. The research question of this study was: How do gendered patterns of resource ownership relating to the sex of household heads affect smallholder practices and their outcomes in rural Zimbabwe?

5.2 Analytical framework and data analysis

Four study sites were selected. The sites included sub-humid localities in Mazowe/Goromonzi district (cooler) and in Kadoma district (warmer), and semi-arid sites in Matobo district (cooler) and Chiredzi district (warmer). Data on resource ownership, management practices, and production outcomes of FHHs and MHHs were collected at each study site through household surveys, FGDs, and KIIs (Chapter 4).

5.2.1 Resource ownership

Assets owned by farmers are important indicators of their capacity to adapt to climate change. Demographic and socio-economic characteristics were described in the context of a sustainable livelihoods framework (Scoones, 1998). They were categorised into human capital, physical capital, natural capital, and financial capital. Human capital assets included household characteristics such as age, education, farming experience of head of household, and household size (Table 5.1). Income received for the 2010/2011 season represented financial capital. Measurements of physical assets included livestock ownership (with particular reference to cattle) and Tropical Livestock Units (TLUs; Njuki et al., 2010). TLUs per household were calculated based on a method described by Njuki et al. (2010). In their method, one Tropical Livestock Unit (TLU) is equivalent to one cow with a body weight of 250 kg. To calculate TLUs, one cow was equated to 0.70 TLU, sheep and goats = 0.10, donkeys = 0.5, pigs = 0.20, and poultry and rabbits = 0.01. Farm size represented natural capital.

Table 5.1 Types of capital assets assessed

Characteristics	Capital assets following Scoones (1998)
Age	Human capital
Schooling years	Human capital
Farming experience	Human capital
Full-time farming	Human capital
Household size	Human capital
Family labour	Human capital
Ownership of agricultural equipment (e.g. ox-drawn ploughs)	Physical capital
Ownership of owning cattle/draft power and other livestock	Physical capital
Farm size	Natural capital
Mean income in the 2010/2011 season	Financial Capital
Membership to local farmer groups	Social capital

The influences of capital assets on smallholdings are variable. Experience and age of the household head has variable effects on adoption and adaptation. Age of the household head, for example, positively influenced uptake of soil conservation, crop varieties, and planting dates for climate change adaptation in the Nile basin of Ethiopia (Deressa et al., 2009). Perceptions of climate change may also differ depending on age. Access to technologies and credit is often associated with higher education levels as well as increased adaptation to climate change and higher productivity. Household size has implications on family labour available. Management decisions such as adoption of soil and water management may depend on family labour available. These technologies are usually associated with high labour demands. Financial capital contributes to increased access to inputs and access to resources required for timely operations. Farmers' access to draft power and to agricultural equipment such as ploughs influences land preparation management decisions, e.g. time of planting and land preparation methods. Livestock ownership represents wealth.

Levels of capital assets of MHHs and FHHs were compared at each site. Categorical data such as the proportion of farmers owning agricultural assets were compared using Pearson's chi-square test. Numerical data were compared using the independent t-test, either parametric or non-parametric, after testing for normality of the data (Field, 2005; 2013). The sources of assets such as income, agricultural equipment, and cattle were analysed using descriptive statistics and the results were tabulated.

5.2.2 Sources of capital assets

Sources of income and agricultural assets that included ox-drawn ploughs and livestock were categorised and analysed using descriptive statistics and the results were tabulated.

5.2.3 Crop production stressors

Stressors to crop production were assessed through household surveys and FGDs. Household survey results of farmer-perceived stressors to production were coded and analysed using descriptive statistics. Farmer-perceived constraints to production were compared between FHHs and MHHs at each site using Pearson's chi-square test, an analysis tool for categorical data. The data were triangulated by comparing them with responses from FGDs. Responses from FGDs were categorised and transcribed.

5.2.4 Management practices

Maize-cropped area for the 2010/2011 season, the proportions of households that applied fertilizer, labour input, and sources of labour were assessed. Mean maize area for the 2010/2011 season was calculated based on farmers' estimates. Labour input was calculated based on estimates of the time spent by farm workers in production, from land preparation to harvesting. The total number of hours for all individuals was aggregated and then divided by eight to obtain man-days. The man-days were then divided by area to obtain man-days per hectare. MHH and FHH means of these characteristics were compared at each site.

5.2.5 Smallholder production outcomes

Outcomes of smallholder practices were determined by estimating maize yields and food security at the household level. Maize yields for the 2010/2011 season were quantified using household-level data. Mean household yields for each crop were calculated with SPSS version 21 by dividing total harvest by crop area. Mean yields of MHHs and FHHs for the main crops grown at each site were compared. Calculations of yields were based on farmers' stated land area and the harvest obtained.

According to the 1996 World Food Summit:

> Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Food insecurity exists when people do not have adequate physical, social, or economic access to food as defined above (FAO, 1996).

Food security at the household level is often assessed by analysis of consumption (converted into calories) or expenditure data. Other assessments include self-reported poverty (e.g. Deaton, 2010) and people's subjective perceptions of their economic welfare (e.g. Ravallion and Lokshin, 2002, in Russia). Food security can also be estimated by assessing per capita production in households. Food security is also often measured using a household's own perception of food security (Kassie et al., 2014). In this study, household food security was assessed through subjective farmer perceptions. Farmers were asked if there was any time of the year that households did not have enough food. Differences in the proportions of MHHs and FHHs who were food insecure were compared for each site.

5.3 Results

5.3.1 Household resources

The capital asset levels of smallholder farmers selected for this study are given in Table 5.2. Demographic and head of household characteristics representing human, natural, physical, and financial assets differed by gender of head of household at each study site (Table 5.2).

The average farm size of MHHs was higher than that of FHHs in Mazowe/Goromonzi and Kadoma districts (Table 5.2). There were no differences ($P<0.001$) in farm size of MHHs and FHHs in Matobo district or in Chiredzi district. Proportions of households who rented-in or rented-out cultivated and/or fallow lands were less than 10% at all the study sites.

Human capital assets of farmers included age, education level, farming experience and employment status of head of household, household size, and mean family labour (Table 5.2). A higher proportion of female household heads than male household heads were full-time farmers and had more farming experience at the Mazowe/Goromonzi, Kadoma, and Matobo district study sites. Male heads of households had more years of schooling compared to female heads of households. Average family labour (calculated as adult units per household) was approximately three at all four sites, except among Chiredzi MHHs where it was 3.6. Family labour per hectare was greater ($P<0.001$) in FHHs compared to MHH at both Mazowe/Goromonzi and Kadoma sites.

At the drier sites (Matobo and Chiredzi districts), female heads of households had lower education levels compared to male heads of households (Table 5.2). In Chiredzi district, male heads of households had significantly higher farming experience, schooling years, and family size compared to female heads of households.

Physical capital assets assessed included agricultural equipment such as ox-drawn ploughs, cultivators, and livestock owned. There were no differences in asset ownership between Mazowe/Goromonzi district MHHs and FHHs. Fewer Kadoma district FHHs owned cultivators (18%) compared to MHHs (41%). At the drier sites, fewer Matobo FHHs owned agricultural equipment such as ploughs, scotch-carts, and cultivators compared to MHHs (Table 5.2). Fewer Chiredzi FHHs (37%) compared to MHHs (68%) owned ploughs. More MHHs in Chiredzi owned goats compared to FHHs.

Based on estimated household incomes over a period of about 12 months, MHH incomes were significantly higher ($P<0.01$) compared to FHH incomes at both sub-humid sites in Mazowe/Goromonzi and Kadoma districts and in semi-arid Matobo district (Table 5.2).

5.3.1.1 Sources of income

About 90% of Mazowe/Goromonzi district MHHs received income from crop production (including horticulture for Goromonzi district farmers) compared to 79% of FHHs. Meanwhile, more than 20% of MHHs also received income from each of the following sources: livestock sales, casual employment, and remittances (Table 5.3). Eighty-four percent of Kadoma district MHHs received income from crop sales compared to 68% of FHHs. The other main sources of income in MHHs were livestock sales, casual employment, individual businesses and remittances (Table 5.3). Livestock sales and remittances were the other main sources of income for Kadoma district FHHs.

Table 5.2 Capital asset levels of male-led and female-led households at the study sites

	Districts											
	Mazowe/ Goromonzi (wetter/cooler)			Kadoma (wetter/warmer)			Matobo (drier/cooler)			Chiredzi (drier/warmer)		
Assets	MHH[1]	FHH[2]	[a]T-value/ χ^2	MHH	FHH	T-value/ χ^2	MHH	FHH	T-value/ χ^2	MHH	FHH	T-value / χ^2
N	87	66	N/A	111	39	N/A	105	54	N/A	102	63	N/A
Proportion of de–juri FHH (%)	N/A	97	N/A	N/A	97.4	N/A	N/A	92.6	N/A	N/A	82.5	N/A
Farm size (ha)	2.1	1.6	2.348**	3.8	2.5	4.400**	1.4	1.2	1.640	2.5	1.8	0.832
Mean age of HHH[3]	3.91	4.77	-4.177***	3.96	4.72	-2.865**	4.41	4,87	-2.266**	3.82	3.22	2.183**
HHH with no basic education (%)	3.4	22.7	13.437***	2.7	5.1	0.527	10.5	11.1	0.015	28.4	33.3	0.443
HHH mean school years	8.9	5.5	6.161**	8	5.5	3.613**	6.6	5.4	2.056**	5.1	4.6	4.229**
HHH mean farming experience (years)	19	30.3	-4.856**	17.9	23.3	-2.452**	22.6	28.3	-2.162**	22.1	19.4	14.029**
% HHH Full time Farmer	80.5	98.5	11.746***	76.6	97.4	8.508**	61	81.5	6.898**	81.4	92.1	3.581
Household size (n)	6.1	5.8	0.653	6.5	6.1	0.899	6.7	5.8	2.058**	7.2	5.9	3.083**
[4]Adult units ha^{-1}	2.1	3.3	-2.670**	1.5	3	-3.737**	4.2	4.1	0.246	2.6	2.2	1.082
Family labour (n)	3.3	2.9	1.367	3.3	3.1	0.691	2.9	2.6	1.396	3.6	2.7	2.130**
Adult male labour (n)	1.51	1.02	3.216**	1.57	1.03	3.407***	1.4	0.85	3.639***	1.66	0.79	5.460***
% Owning cattle	59.8	45.5	3.092	64	61.5	0.073	65.7	46.3	5.563*	68.6	46	8.285**
% Owning goats	46	36.4	1.425	44.1	48.7	0.244	42.9	37	0.5	70.6	50.8	6.549*
TLU[5]	2.8	1.7	2.417**	3	2.5	0.922	3.3	1.8	2.884**	3.7	2.1	4.12667**
% Owning Ox - drawn plough	60.9	56.1	0.366	74.8	74.4	0.003	72.4	46.3	10.471***	67.6	36.5	15.308***
% Owning Scotch-cart	41.4	40.9	0.003	56.8	46.2	1.306	38.1	7.4	16.779***	35.3	22.2	3.151
% Owning Cultivator	39.1	39.4	0.002	41.4	17.9	6.971	28.6	7.4	9.501**	6.9	3.2	1.027
Mean Income 2010/2011 (US$)	1557.1	990.3	2.388**	2429.5	1013.5	2.275**	831.4	280.4	3.785**	500.2	396.6	1.015
Per capita income	336.2	189	2.384*	333	212.5	1.411	159.3	122	-0.437	78.6	72.5	0.340

[a]T-value for continuous variables and Chi-square for categorical data- *Significant at the 10% level, **Significant at the 5% level, ***Significant at the 1% level

[1]MHH = Male headed households, [2]FHH = female headed household, [3]Age of head of household (1=18 - 25 years; 2= 26 - 35 years; 3= 36 - 45 years; 4= 46 - 55 years; 5= 56 - 64 years; 6= above 65 years);

[4]adults units per hectare (of total cultivated area for the 2010/2011 season), [5]Tropical Livestock Units

Table 5.3 Sources of income during the 2010/2011 season

Income source[1]	Wetter sites				Drier sites			
	Mazowe/ Goromonzi district (wetter/cooler)		Kadoma district (wetter/warmer)		Matobo district (drier/cooler)		Chiredzi district (drier/warmer)	
	MHHs[2]	FHHs[2]	MHHs	FHHs	MHHs	FHHs	MHHs	FHHs
Crops sales	89.7	78.8	84.7	66.7	41	42.6	33.3	31.7
Livestock sales	27.6	1.5	17.1	10.3	6.7	5.6	31.4	20.6
Petty trading	4.6	0	6.3	2.6	15.2	18.5	49	23.8
Regular employment	16.1	3	9.9	2.6	18.1	0	6.9	3.2
Casual employment	20.7	1.5	21.6	5.1	12.4	11.1	35.3	4.8
Individual businesses	6.9	1.5	10.8	0	19	5.6	1	0
Remittances	19.5	13.6	14.4	10.3	33.3	13	17.6	4.8
Pension	6.9	0	1.8	0	2.9	0	2	0
Gold panning	0	0	2.7	0	0	0	0	0
Fish sales	0	0	2.7	0	0	0	0	0
Rental	1.1	0	0.9	0	0	0	0	0
Craft	0	0	2.7	0	0	0	0	0

[1]proportions of households that obtained income from the source [2]male-headed households; [3]female-headed households, *Some farmers had multiple sources of income

At the semi-arid study sites in Matobo, the main sources of income for MHHs were crop sales (41% of households received income from this source), remittances (33% of households received income from this source), regular employment (18%), and individual businesses (19%). Crop sales and petty trading were the main sources of income for Matobo FHHs. In Chiredzi district, the main sources of income for MHHs included petty trading (49%), casual employment (35%), crop sales (33%), and livestock sales (31%). Sources of income for FHHs in Chiredzi included crop sales, livestock sales, and petty trading.

5.3.1.2 Sources of household physical assets

Most of the agricultural equipment was bought by households (Table 5.4)

Table 5.4 Sources of main agricultural equipment at study districts

Site	Type of households		Sources of agricultural assets			
			bought	gift	inheritance	other
			%	%	%	%
Mazowe	MHHs	Ox - drawn plough	92.5	1.9	5.7	0
Goromonzi		Scotch cart	94.4	0	5.6	0
district		Cultivator	88.2	0	11.8	0
(wetter/cooler)		Hoes	100	0	3.4	0
	FHHs	Ox - drawn plough	81.1	2.7	16.2	0
		Scotch cart	85.2	0	14.8	0
		Cultivator	88.5	0	11.5	0
		Hoes	96.9	1.5	6.2	1.5
Matobo	MHHs	Ox - drawn plough	97.4	2.6	0	1.3
district		Scotch cart	100	0	0	0
(drier/cooler)		Cultivator	100	0	0	0
		Hoes	98.1	1	1	0
	FHHs	Ox - drawn plough	96	4	0	0
		Scotch cart	100	0	0	0
		Cultivator	100	0	0	0
		Hoes	100	0	0	0
Chiredzi	MHHs	Ox - drawn plough	94.2	0	5.8	2.9
district		Scotch cart	97.2	0	5.6	0
(drier/warmer)		Cultivator	85.7	0	0	14.3
		Hoes	91	12	6	4
	FHHs	Ox - drawn plough	78.3	0	21.7	0
		Scotch cart	71.4	0	28.6	0
		Cultivator	0	0	50	50
		Hoes	80	16.7	10	5

*Kadoma farmers indicated that they bought most of the agricultural equipment, results excluded from table

Notable was the 20–28% of FHHs who inherited ox-drawn ploughs and scotch carts. Livestock was mostly either bred on farm or bought from neighbours (Table 5.5).

Table 5.5 Livestock sources at study sites

districts		Livestock type	Sources of livestock (%) Bred on farm	Bought from neighbour	Bought from market	Inheritance	Gift from friend / relative	Other
Mazowe	MHHs[1]	Cattle	56.2	27.4	6.8	6.8	1.4	1.4
Goromonzi		Sheep/goats	60.7	37.5	1.8	0	0	0
(wetter/cooler)	FHHs[2]	Cattle	76.3	21.1	0	2.6	0	0
		Sheep/goats	73.3	26.7	0	0	0	0
Kadoma	MHHs	Cattle	66.2	0	33.8	0	0	0
(wetter/warmer)		Sheep /goats	72.9	0	27.1	0	0	0
	FHHs	Local cattle	41.7	8.3	50.0	0	0	0
		Local sheep / goats	63.2	0	36.8	0	0	0
Matobo	MHHs	Cattle	40.7	30.9	27.2	1.2	0	0
(drier/cooler)		Sheep/goats	36	30	34	0	0	0
	FHHs	Cattle	53.1	28.1	9.4	3.1	0	6.2
		Sheep/goats	54.2	37.5	8.3	0.0	0	
Chiredzi	MHHs	Cattle	44.1	34.3	1.0	2.9	2.9	14.8
(drier/warmer)		Local sheep / goats	42.2	43.4	1.2	1.2	2.4	9.6
	FHHs	Cattle	62.5	20	0	2.5	5.0	10
		Sheep/goats	50	38.2	0	0	5.9	5.9

[1]Male headed households; [2]Female headed households

Notable also was the fact that the highest proportion of cattle were bred on farms at all the study sites.

5.3.2 Stressors to crop production

5.3.2.1 Farmer perceptions of crop production stressors

Crop production constraints mentioned by farmers included climatic and non-climatic factors (Table 5.6). The main constraints mentioned by both MHHs and FHHs from Mazowe/Goromonzi were non-climatic and included high costs of inputs, unavailability of inputs on the market, lack of equipment, lack of labour, and low prices for output, in descending order. The main climatic stressor mentioned was erratic rainfall. The most mentioned non-climatic stressor by Kadoma respondents was lack of access to inputs and the most mentioned climatic stressor was erratic rainfall. There were no significant differences between MHH and FHH perceptions of climatic and non-climatic stressors for crop production at the two sites (Table 5.6). At the drier site in Matobo, the most mentioned stressor was erratic rainfall (climatic), followed by access to inputs, lack of equipment, lack of labour, and high costs of inputs. In Chiredzi, the most important constraints were erratic rainfall and high temperatures. More FHH respondents mentioned draft power constraints compared to Chiredzi MHH respondents. Meanwhile, more respondents from MHH mentioned erratic rainfall constraints compared to respondents from FHH.

Table 5.6 Climatic and non-climatic stressors to crop production mentioned by farmers at study sites

	Sites											
	Mazowe/Goromonzi district (wetter/cooler)			Kadoma district (wetter/drier)			Matobo district (drier/cooler)			Chiredzi district (drier/warmer)		
Production constraints	MHHs[1]	FHHs[2]		MHHs	FHHs		MHHs	FHHs		MHHs	FHHs	
	%	%	χ^2	%	%	χ^2	%	%	χ^2	%	%	χ^2
Erratic rainfall	34.5	33.3	0.002	48.6	53.8	0.312	73.3	64.8	1.243	100	92.1	8.346**
High temperatures	14.9	21.2	1.015	24.3	15.4	1.344	8.6	14.8	1.456	66.7	50.8	4.110*
Pest and disease attacks	32.2	24.2	1.155	19.8	33.3	2.946	19	7.4	3.77	49	41.3	0.941
Wild animals	0	0	*N/A*	9	7.7	0.063	7.6	7.4	0.002	15.7	15.9	0.001
Low soil fertility	24.1	13.6	2.626	2.7	2.6	0.002	26.7	22.2	0.374	1	6.3	3.82
Poor access to inputs	44.8	36.4	0.833	54.1	53.8	0.001	57.1	53.7	0.171	30.4	41.3	2.038
Lack of labour	47.1	54.5	0.826	42.3	51.3	0.933	39	44.4	0.43	51	61.9	1.879
Lack of equipment	48.3	47	0.026	44.1	56.4	1.742	44.8	53.7	1.143	44.1	69.8	10.373***
High cost of inputs	71.3	81.8	2.28	18	17.9	0.004	30.5	25.9	0.359	51	50.8	0.001
Lack of draft power	19.5	22.7	0.23	3.6	0	1.444	1	1.9	0.232	1	0	*N/A*
Low prices for output	25.3	37.9	2.796	0.9	0	0.354	2.9	1.9	0.147	*0*	*0*	*N/A*
n	87	66	*N/A*	111	39	*N/A*	105	54	*N/A*	102	36	*N/A*

*Significant at the 10% level, **Significant at the 5% level, ***Significant at the 1% level [1]male headed households [2]female headed households

5.3.2.2 Farmers' views concerning production constraints

- Goromonzi District (wetter/cooler) - Ms. P. Moyo is a 58-year-old *de jure* female head of household. On changes noticed in agriculture, she mentioned shifts in cropping seasons. She also mentioned that in the past farmers used to harvest by December, but onset of rains was now late. The farmer also perceived quality of soils to have deteriorated, and required more water (*mvura yemushapa*) for sustainable crop production. To address labour challenges she hired and paid cash for people to cultivate her field. When asked on what households can do to increase productivity she mentioned that growing vegetables/horticulture could increase income and access to resources for farmers. However, she noted the need for functional irrigation facilities for supplementary water. She also highlighted female famers had horticulture market access constraints. Men were able to form groups and transport their produce, while fresh to markets. They were also more mobile compared to females. Therefore, few women competed well in horticulture production. She then mentioned that female farmers could increase sources of livelihoods by rearing chicken for marketingand engaging in other non-agricultural activities (Interviewed in October 2013).

- Mazowe district (wetter/cooler) - Ms. A. Muza a *de jure* head of household (widowed), aged 64 lived alone. Relatives who stayed in nearby villages assisted her with land preparation, cultivation and weeding. However, they often would delay in land preparation and weeding at her farm, since the male farmers would first attend to their fields. According to Ms. A. Muza women had lower levels than men and therefore encouraged farmers groups. She also reported inequalities in distribution of donated seed. Single women would often not receive seed through various government and non-governmental initiates. Male farmers would argue that it was not necessary for female household heads to receive seed since they did not own much land (Interviewed in October 2013).

- Sanyati, Kadoma district (wetter/cooler) - Ms. N. Dube, a female household head from Sanyati in Kadoma, had a family of six members. She reported that improved access to draft power and to fertilizer was required to improve agricultural productivity. She reported that in past years, farmers used to form farmer groups that combined resources. However, formation of farmer groups had declined,partly because some well-resourced farmers were not willing to participate in community initiatives. She therefore encouraged formation of active farmer groups. Constraints to agricultural production and livelihoods mentioned also included late access to seed and accessing water for domestic use. She also reported unequal sharing of income from agricultural output in MHHs in the district, with females not receiving any income (Interviewed in 2013).

- Matobo District (drier/cooler - Ms Moyo was interviewed in September 2013. She mentioned challenges in accessing water for domestic use. Females in the community had to walk long distances to fetch water. Further, females in the district were responsible for most agricultural activities. Therefore, females had more labour burdens than males. She noted that horticulture was one of the main income generating activity and farmer groups eased labour burdens.

- Chiredzi District (drier/warmer) - Ms. S Phiri, a 31 year old *de facto* female head of household was interviewed in October 2013. Her husband stayed and worked off farm, in a neighbouring country. She stayed with her two children, one 4 years old and the other 9 years old. She cultivated two and a quarter acres and planted finger millet, barley and maize in a distance field during the 2012/ 2013 season. No fertilizer was applied. The household owned only one plough and one cow and therefore had shortages of agricultural resources. She, nevertheless, was not a member of any farmer group that could assist with agricultural resources. However, she hired a few women to assist in agricultural activities, such as transporting harvest from distant fields. The produce of the season was kept for household consumption. Copying strategies included selling small livestock i.e. chicken, reducing the number of meals per day, reducing the amount of food consumed, borrowing cash, selling firewood, buying and selling fermented milk (*lacto*). The household also sought relief from social welfare. This case study demonstrated that *de facto* FHHs often encounter labour challenges, and limited access to agricultural resources and do not always benefit from income generated from male labour migration.

5.3.3 Maize production practices at analogue sites

Management of maize crops was assessed in the context of area, fertilizer use, and labour inputs (Table 5.7). In the Mazowe/Goromonzi district, FHHs had lower maize crop areas compared to MHHs ($P<0.001$) at the 95% level. The proportion of MHHs and FHHs that applied fertilizer, and the fertilization rates themselves, did not differ. The average amount of time spent in maize production was 82 man-days for MHHs and 70 man-days for FHHs. There were no statistically significant differences in labour input. Concerning labour, 42% of both MHHs and FHHs hired labour for maize production in Mazowe/Goromonzi district. In Kadoma district, land area allocated to maize was lower for FHHs (1.0 ha) compared to MHHs (1.2 ha). Male-headed households, however, allocated less fertilizer per hectare compared to FHHs. Seventeen percent of MHHs and 26% of FHHs hired labour for maize production.

Table 5.7 Maize production practices during the 2010/2011 cropping season

	sites	Gender HHH[1]	mean area ha	Fertilizer use % hhds	Fertilizer Rate (Nitrogen) Kg ha^{-1}	Labour input man-days[2]
	Mazowe/ Goromonzi	MHHs[3]	1.00	97.7	70.5	82.4
	district (cooler)	FHHs[4]	0.70	98.5	70.4	70.3
Wetter		[a]T-value/ χ^2	3.827***	0.120	-0.29	1.538
sites	Kadoma district	MHHs	1.20	68.2	30.1	100.4
	(warmer)	FHHs	0.70	71.8	49.2	84.8
		T-value/ χ^2	4.854 ***	0.176	-2.602***	1.304
	Matobo district	MHHs	0.7	68.6	28	78.8
	(cooler)	FHHs	0.7	61.1	23	70.6
Drier		T-value/ χ^2	0.136	0.885	1.349	0.827
sites	Chiredzi district	MHHs	0.8	0	N/A	39
	(warmer)	FHHs	0.7	0	N/A	37.4
		T-value/ χ^2	0.364	N/A	N/A	0.261

[1]Head of household, [2]Calculated as Total hours worked divided by 8 hours, [3]male headed households, [4]female-headed households

[a]T-value for continuous variables and Chi-square for categorical data- *Significant at the 10% level, **Significant at the 5% level, ***Significant at the 1% level

At the semi-arid study sites, mean maize area, fertilizer rates and labour inputs for the 2010/2011 season was similar Matobo district MHHs and FHHs. Meanwhile 10% of MHHs and 18% FHHs hired labour. Chiredzi district mean maize area was 0.8 and 0.7 ha per household for MHHs and FHHs respectively and was not significantly different. At the drier Chiredzi sites, farmers did not apply any fertilizer to their maize crop. Nine percent and 7% of MHHs and FHHs respectively hired labour.

5.3.4 Maize crop yields

Yields of the main crops grown during the 2010/2011 season gave partial estimates of farm productivity. Yield characteristics of the main crops grown varied between MHHs and FHHs at the study sites (Figure 5.1). There was no statistical difference between the maize yields of MHHs (2027 kg ha^{-1}) and FHHs (1985 kg ha^{-1}) in Mazowe/Goromonzi district. In Kadoma lower yields were realised by FHHs (900 kg ha^{-}

[1]) compared to MHHs yields (1298.4 kg ha^{-1}). Similarly, Matobo district FHHs had lower average maize yields compared to Matobo district MHHs (Figure 5.1). There were no yield differences between differently managed households in Chiredzi district.

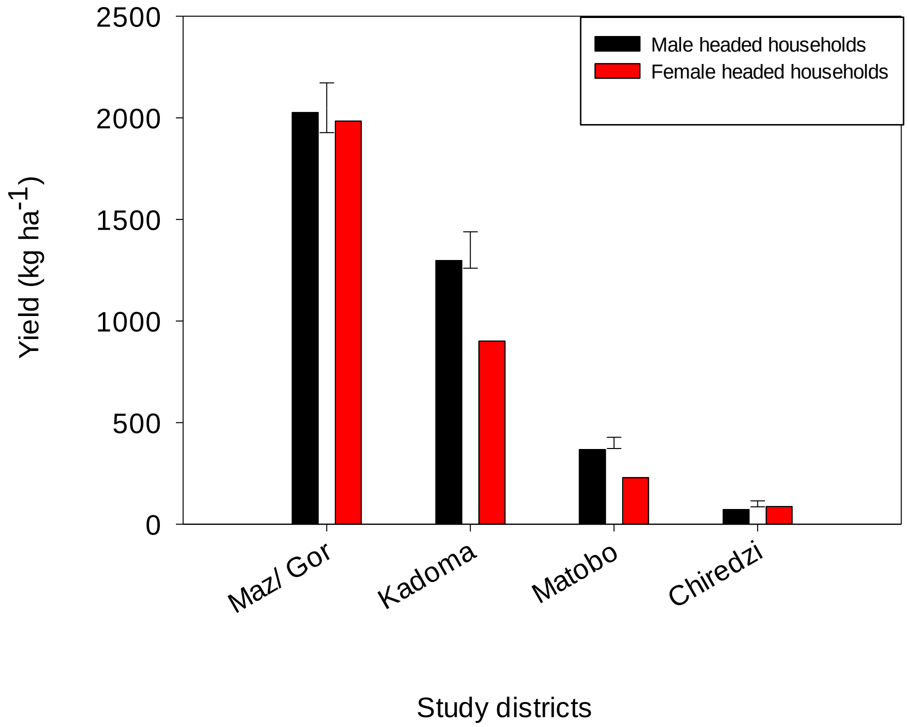

Figure 5.1 Crop yields at study sites in the 2010/2011 cropping season

5.3.5 Household food security

More FHHs compared to MHHs were food insecure in Mazowe/Goromonzi, Kadoma, and Matobo districts (Table 5.8). Approximately 73% of MHHs and 70% of FHHs were food insecure in Chiredzi district.

Table 5.8 Households food insecure at study sites during the 2010/2011 season

		Wet analogue set		Dry analogue set	
		Mazowe/ Goromonzi (cooler)	Kadoma (warmer)	Matobo (cooler)	Chiredzi (warmer)
		%[1]	%	%	%
MHHs		6.9	16.2	59	72.5
FHHs		19.7	30.8	79.6	69.8
	χ^2	5.654**	3.820*	6.736***	0.140
Total		12.4	20	66	71.5
	χ^2	3.212		1.132	

[1]Proportion of households that did not have enough food to meet family needs during at least one month of the year (2010/2011 season)

5.4 Discussion

The research question of this study was: How do gendered patterns of resource ownership relating to the sex of household heads affect smallholder practices and their outcomes in rural Zimbabwe? Results from this study showed lower levels of resource ownership among FHHs compared to MHHs, as well as different crop production management practices and outcomes.

Male-headed households and FHHs at each of the study sites differed in levels of resource ownership. At the sub-humid sites, female-headed households had, on average, smaller farms (natural capital) than MHHs. Lower farm sizes of FHHs could be due to cultural and social norms that favour inheritance of land by male members of a family. At the semi-arid study sites, the average farm size of MHHs and FHHs was similar. This observation shows that MHHs have larger farm sizes compared to FHHs in high potential areas.

At the sub-humid sites, FHHs had more family labour compared to MHHs. However, most of the labour was provided by women and children. More family labour in Chiredzi district MHHs compared to FHHs could be due to generally younger female heads of households and subsequently smaller families. Adults units were lower than 3.5 per hectare at all sites except Matobo. By contrast, Mudimu (2003) noted averages of about 2.5 adult-equivalents of family labour. According to Mudimu (2003), at least three adult-equivalent units are required for 3 hectares of crop, and five units during critical labour periods. Accordingly, farmers perceived lack of labour to be one of the main constraints to production. Farmer perceptions of labour constraints were confirmed by the demographic characteristics of generally low levels of family labour. The proportion of respondents who mentioned labour constraints ranged from 40% to 55% in Mazowe/Goromonzi, Kadoma, and Matobo districts. Fifty percent and 62% of Chiredzi MHHs and FHHs, respectively, mentioned labour constraints. Labour availability influences timing of operations and weed management practices among other variables. 'Absence' of the male head of household contributed to lower levels of male adult family labour in FHHs at all the study sites. Low levels of adult male family labour in FHHs compared to MHHs at most sites imply either outsourcing of labour or higher female involvement in and contributions to activities predominantly considered as 'male' tasks such as land preparation. Hiring labour may also be dependent on financial capital.

The generally higher literacy levels of men compared to women at all study sites were comparable to findings that show lower levels of education of females compared to males in other African countries (Quisumbing, 2003; Meinzen-Dick et al., 2010). Higher literacy levels of male farmers compared to female farmers may partly explain the higher participation of males in off-farm employment and increased livelihood sources. Low education levels are often mentioned as constraints on smallholder production (Maddison, 2007; Deressa et al., 2009). However, farmers at the study sites did not mention lack of knowledge as constraints to crop production during household surveys, although they did highlight knowledge constraints in FGDs, particularly with reference to management of livestock diseases.

Access to financial capital enables farmers to purchase agricultural equipment such as ploughs and cultivators, and to access draft power and inputs such as seed and fertilizer required for timely production. It also increases management options for farmers and can increase access to hired labour. Higher financial capital in MHHs compared to FHHs was also noted elsewhere in African agriculture (Doss, 2001). Males often grow more cash crops compared to females and thus have higher financial capital (Mackenzie, 1998). In this study, Mazowe/Goromonzi and Kadoma district MHHs grew more cash crops than FHHs. Cash crops such as maize and cotton usually require more inputs. Therefore, FHHs and women generally tend to grow fewer cash crops. Female-headed households at the sub-humid sites also owned smaller farms, which could also influence cropping decisions. Male-headed households at the study sites also had more alternative sources of income, such as off-farm employment, compared to FHHs. The FGDs also revealed that more male heads of households participated in non-farm activities (such as casual employment and regular employment) compared to female heads of households. In contrast, the highest share of income for FHHs came from crop production followed by remittances. Females also participated more in trading at wetter sites, and in income generating projects and labour sales at the drier sites. Matobo and Chiredzi district women were more active in labour sales compared to males. Sources of income therefore differed by gender of head of household. Asfaw et al. (2013) found, similarly, that forest income was also more important for FHHs (58.2%) than for MHHs (29%) in the eastern highlands of Ethiopia. In contrast to the findings from this study, Horrell and Krishnan (2007) noted that FHHs and MHHs both suffered from poverty. Policies and strategies are required that increase financial capital for women, e.g. increased financing. Market-oriented development could also be one of the mechanisms for increasing access to financial capital.

Levels of agricultural asset ownership were mostly similar between MHHs and FHHs at the sub-humid sites. Horrell and Krishnan (2007) similarly observed that *de jure* FHHs usually have similar physical assets compared to MHHs, with the exception of livestock. Households at the study sites bought most agricultural assets such as ploughs. Notably, FHHs at Mazowe/Goromonzi and Chiredzi also inherited assets. Women also inherit movable assets such as agricultural equipment, and this could partly account for similarities in ownership of agricultural resources. In contrast to findings at the sub-humid sites, fewer FHHs in Matobo and in Chiredzi owned ox-drawn ploughs compared to MHHs (as well as scotch-carts, and cultivators in Matobo). Lower financial capital may affect Matobo FHHs' ability to acquire agricultural resources. In general, female heads of households in Chiredzi were younger compared to female farmers at other sites. This may partly account for their fewer resources, i.e. they had a shorter time to accumulate resources, in particular in the presence of their male spouses.

Cattle ownership is an indicator of wealth for smallholder farmers and influences access to cattle manure and early land preparation. Ownership of cattle also increases choices of strategies in management. Cattle ownership increases access to manure for soil fertility management thus increasing adaptation options for soil fertility management. Cattle also provide draft power required for land preparation and sometimes for cultivation for weed management. The proportion of households that owned cattle ranged from approximately 45% to 70% at the sites, indicating poverty and inadequate accesses to draft power for families that did not own livestock. In contrast to findings from this study, about 40% of households owned cattle in some smallholder areas of Zimbabwe (Gambiza and Nyama, 2000; Mudimu, 2003; Ncube et al., 2009). Livestock deaths due to adverse climates partly account for variations in livestock ownership in Zimbabwean smallholdings. While proportions of surveyed households that mentioned draft power constraints in crop production were few, FGDs revealed that lack of draft power was one of the major non-climatic constraints on crop production, particularly in Chiredzi district where droughts often result in livestock deaths.

There were gendered differences in livestock ownership at the study sites. Mazowe/Goromonzi FHHs owned fewer TLUs/cattle compared to MHHs. Meanwhile, the proportion of Mazowe/Goromonzi MHHs and FHHs that mentioned draft power constraints were similar, i.e. 20% and 22%, respectively. Fewer FHHs than MHHs in Matobo and Chiredzi districts owned cattle, suggesting lower access to draft power and lower wealth levels among FHHs. Lower TLUs in Mazowe/Goromonzi, Matobo, and Chiredzi districts for FHHs can be attributed to gendering processes leading to males mainly owning cattle. Males mainly own cattle while females own small livestock (Njuki and Mburu, 2003). In this study, male and female FGD results revealed that males were responsible for cattle and females were responsible for small livestock such as goats. Cultural norms favour inheritance of livestock by male family members. Thus, women may not favour keeping large numbers of livestock. Study results show that in Mazowe/Goromonzi livestock were mostly either bred on-farm or bought from neighbours. In Matobo district, livestock were either bred on-farm or bought from neighbours or markets, whereas in Kadoma district livestock was mainly bred on-farm or bought from markets.

Other non-climatic constraints mentioned by farmers, particularly in Mazowe/Goromonzi district, included market related constraints, i.e. low prices for outputs and high costs of inputs. Based on responses, the main non-climatic constraints mentioned at each site were mainly similar between male-managed and female-managed households at each of the study sites except in Chiredzi (drier/warmer). In Mazowe/Goromonzi (wetter/cooler) and Kadoma (wetter/warmer), production constraints included high costs of inputs such as seed and fertilizer, and lack of labour. Matobo district (drier/cooler) farmers' perceived non-climatic constraints included poor access to inputs, lack of equipment, lack of labour, and lack of draft power. Chiredzi FHHs' perceived non-climatic constraints to production included lack of equipment. Farmer perceptions of non-climatic constraints on production corroborate findings from other studies that show that smallholder farmers are generally poorly resourced (e.g. Ncube et al., 2009). While male and female farmers mentioned similar production constraints, their levels of resource ownership differed, indicating different capacities to adapt to climate change. Differences in resource ownership between MHHs and FHHs at each site imply that crop management strategies differ between MHHs and FHHs.

Assessments of maize production practices showed variation between MHHs and FHHs at the study sites. The first observation was that FHHs allocated less land to maize during the 2010/2011 season compared to MHHs at the sub-humid study sites. Smaller farm size as well as less financial capital may contribute smaller maize areas for FHHs compared to FHHs at the sub-humid sites. Mazowe/Goromonzi MHHs and FHHs, however, did not differ in labour and fertilizer input. In turn, Kadoma FHHs used higher fertilizer rates compared to MHHs and generally hired more labour than MHHs. These results indicate a preference for intensification in production by FHHs to increase yields on smaller areas. Seed used was either retained, bought from local and distant markets, or distributed by the government and NGOs. Fertilizer was similarly obtained from government input distribution programs and NGOs and bought from local and distant markets. In a review of 20 studies, Peterman et al. (2010) reported that in 16 out of 20 studies, men used more inputs than women did. In contrast, Gilbert et al. (2002) noted higher input use by males with respect to fertilizer, as well as more cash crop area and total field area among males. Moock (1976) found that females used less purchased inputs than males in Kenya.

Mean maize area, fertilizer rates, and labour inputs for the 2010/2011 season were similar for Matobo MHHs and FHHs and for Chiredzi MHHs and FHHs. However, Matobo FHHs had less financial capital than MHHs. Chiredzi FHH farms were, in general, smaller than MHH farms; FHHs also had lower levels of labour as well as agricultural resources. Other studies show that females allocate less land to crops with high capital requirements (Gilbert et al., 2002).

This study was not exhaustive in management practices that farmers employed. Other practices that could have varied include time of planting, and other soil fertility management practices such as application of manure and compost and methods of land preparation. Lower male adult labour in FHHs can affect the timing of planting.

Case studies demonstrated that smallholder farmers have different constraints to production, including financial constraints, labour constraints that affect timing of operations, and land preparation methods amongst other strategies.

Yield and food security outcomes of FHHs and MHHs at each study site varied. Yield differences could be due to spatial variation in biophysical characteristics and management practices that are largely determined by resource availability. Male-headed households had higher maize yields compared to FHHs in Kadoma and in Matobo. Similar to the findings of this study, Tiruneh et al. (2001) also observed lower wheat productivity in FHHs compared to MHHs in some Ethiopian communities. They attributed these lower yields to factors such as family labour and fertilizer use. Females in MHHs may also obtain lower yields compared to their male counterparts for similar crops (Udry et al., 1995; Udry, 1996; Goldstein and Udry, 2008) due to resources and management practices. In contrast, there were no differences in maize yields of MHHs and FHHs in Mazowe/Goromonzi district and in Chiredzi district.

Based on reports of households that did have enough food for at least one month during the 2010/2011 season, more FHHs experience food insecurity in Mazowe/Goromonzi, Kadoma, and Matobo districts. Lower yields and/or smaller cultivated areas could account for the observed differences in household food security. In addition, other factors such as income that enables households to purchase extra food also contribute to low food security. Meanwhile, in Chiredzi district more than 65% of MHHs and FHHs experienced food shortages indicating vulnerability to climatic stressors. In addition to yields, vulnerabilities/impacts on food availability showed that many households at the drier sites did not harvest enough to meet family requirements for the 2010/2011 season.

Understanding resource ownership levels of MHHs and FHHs in different climates and their implications for management practices, yield, and food security are necessary steps for mainstreaming gender issues in agriculture, and increasing yields. The information can also inform stakeholders such as governmental and non-governmental organisations about the developmental requirements for different smallholder areas.

5.5 Conclusion and recommendations

Mainstreaming gender in climate planning is imperative for progressive smallholder adaptation to climate change processes. It is against this background that this study explored the gendered patterns of resource ownership relating to the sex of household heads, as well as smallholder practices and their outcomes in rural Zimbabwe.

Conclusions from the results of this study are that levels of resource ownership differ between MHHs and FHHs at each study site and that management practices and outcomes differ as well in terms of yields and food security. Female heads of households at all sites have lower levels of education and adult male labour compared to MHHs. Mazowe/Goromonzi, Kadoma, and Matobo district female heads of households, however, have more farming experience compared to male heads of households. Both MHHs and FHHs mentioned labour constraints on production. Strategies with low labour requirements and financial capital that can enhance the ability of FHHs to hire labour may be necessary to improve technology adoption and farm management by FHHs. Improvement of human capital could include skills training for females. Advocacy of education for all that can increase education levels of women may be necessary.

There was less financial capital in FHHs compared to MHHs, and fewer physical assets. Ownership of agricultural resources, e.g. movable assets such as ox-drawn ploughs, is lower for FHHs compared to MHHs in Matobo and Chiredzi districts, and TLUs are lower for FHHs in Mazowe/Goromonzi, Matobo, and Chiredzi districts. Access to agricultural resources could be increased by access to financial capital. This can be achieved through various strategies such as income generating projects and making credit available to farmers. Strengthening farmer groups could also increase access to resources.

The average farm size of FHHs is smaller compared to that of MHHs in Mazowe/Goromonzi and Kadoma, and similar to MHHs in Matobo and Chiredzi. In addition to this, male-headed households grow maize on larger areas compared to FHHs in Mazowe/Goromonzi and in Kadoma. Access to land for females could be improved by policies that advocate equality in land ownership between males and females. These include addressing cultural issues of inheritance that favour males in inheriting land, and policies and advocacy for equal opportunities for males and females to own land. In order to improve the resilience of FHHs there may be a need to mainstream climate financing in order to increase their resource bases.

Male and female farmers at the sub-humid study sites in Mazowe/Goromonzi and Kadoma districts and the semi-arid Matobo district have similar levels of climate risk perceptions. These include erratic rainfall and non-climatic factors such as poor access to inputs, labour, and high costs of inputs.The FHHs also experienced constraints on markets access. At the drier sites, perceived climatic constraints and climatic constraints of MHHs and FHHs differ.

Kadoma and Matobo maize yields are lower in FHHs compared to those in MHHs. Female-headed households are more food insecure compared to MHHs in Mazowe/Goromonzi, Kadoma, and Matobo districts. Management with respect to fertilizer application and labour input is not different between MHHs and FHHs except in Kadoma district.

Strategies need to be improved and policies strengthened that increase access to resources for agricultural production for women, and these can be implemented at different levels (government, community, and household). There is also a need for interventions in other socio-economic constraints such as market access. Further research using panel data can also assist in assessing the effects of inter-seasonal variability in climatic factors and heterogeneity in socio-cultural effects.

5.6 Summary

Different resources and capital assets are required for adaptation to climate change. According to the sustainable livelihood framework (Scoones, 1998), capital assets required for sustainable livelihoods include human, physical, social, and natural assets. Gendered differences in resource ownership often exist in smallholder farming systems and are in part due to gendering processes that result in inequalities and inequity. Understanding the nature of smallholdings as affected by gender of heads of households can assist in identifying the resource requirements of MHHs and FHHs for sustainable agricultural production. This study was therefore carried out to assess how gendered patterns of resource ownership relating to the sex of household heads affect smallholder practices and their outcomes in rural Zimbabwe.

The sites selected included sub-humid sites in Mazowe/Goromonzi district (cooler) and Kadoma district (warmer), and semi-arid sites in Matobo district (cooler) and Chiredzi district (warmer). Data were collected through household surveys, FGDs, and KIIs. Levels of household resources and stressors to crop production management practices for production of maize, the main food security crop, were compared between FHHs and MHHs at each site.

Resource ownership differs between MHHs and FHHs at each site. Female-headed households at all sites have lower levels of capital assets/productive assets compared to MHHs. Female-headed households have lower levels of draft power (cattle in Matobo and Chiredzi districts, TLU in Mazowe/Goromonzi, Matobo, and Chiredzi districts), agricultural equipment (Kadoma, Matobo and Chiredzi), financial capital at all sites, and land farm size (Mazowe/Goromonzi and Kadoma districts). Women-headed households in Matobo, Chiredzi, and Kadoma districts have lower access to financial capital and resources required for agricultural activities. There are gender differences and site differences in access to labour. Women-headed households at the drier sites have less access to adult male family labour, while those at the wetter sites have higher adult units per hectare compared to their male-headed counterparts. However, male adult labour is lower in FHHs compared to MHHs.

Management with respect to fertilizer application and labour input is not different between MHHs and FHHs. Yields of FHHs are often lower compared to those of MHHs, for example in Kadoma and Matobo districts. There were more food shortages in FHHs than in MHHs in Mazowe/Goromonzi, Kadoma, and Matobo districts, while the results show vulnerability of both MHHs and FHHs in Chiredzi. Female-headed households are more vulnerable to food insecurity compared MHHs.

There needs to be a development of strategies and a strengthening of policies that increase access to resources for agricultural production for women (FHHs) and these can be at different levels (government, community, and household).

In order to improve their resilience there is need for mainstreaming women in climate financing in order to increase their resource bases. At the drier sites, where there was high adult male labour migration and low access to labour, there is need to develop technologies that are not labour intensive, as well as to create incentives that make agricultural production more attractive. This can be achieved through forming effective labour groups, mechanisation, and the adoption of policies that make agriculture more profitable and thus retain labour within the sector.

There also need for interventions in other socio-economic areas such as market access. Further research using panel data can also assist in assessing the effects of inter-seasonal variability in climatic factors and heterogeneity in socio-cultural effects.

6.0 A comparative analysis of male-managed households and female-managed households at temperature-analogue pairs

6.1 Introduction

Simulation models suggest declines in cereal crop yields as well as overall reduction in crop production in some parts of sub-Saharan Africa by the middle of the century (Christensen et al., 2007; Schlenker and Lobell, 2010; Zinyengere et al., 2014). Agro-economic models suggest mostly losses in net farm revenue for sub-Saharan Africa (Kurukulasuriya et al., 2006; Kurukulasuriya and Mendelsohn, 2008), with the extent of the losses depending on climatic conditions (Mendelsohn et al., 2000). Impacts of climate change on different smallholdings are likely to differ. Accesses to resources required for production and for livelihoods are often lower for FHHs than for MHHs (Peterman et al., 2011; Croppenstedt et al., 2013), as are yields (Horrell and Krishnan, 2007). Therefore, MHHs and FHHs may be affected by climate change in different ways. Climate analogues represent windows through which the impacts of climate change can be analysed (Williams et al., 2007; Diffenbaugh et al., 2008; Wilby et al., 2009). Information about the possible impacts of climate change on differently managed households in different smallholder areas of Zimbabwe may inform different stakeholders in smallholder agriculture about the nature of required intervention strategies for community development.

Reduction of cereal yields in smallholdings due to a combination of climate change and management practices can reduce household food security and affect the socio-economic environment of smallholder farmers. Household income from crop production, for example, can decrease, which in turn reduces the financial capital available for farm operations. Losses in net farm revenue due to climate change (Kurukulasuriya et al., 2006; Kurukulasuriya and Mendelsohn, 2008) can result in shifts from farming to non-farming activities and labour migration.

Vulnerabilities in different smallholder areas include climate risks such as low rainfall and high temperature, and non-climatic factors such as accesses to resources (Morton, 2007). Among other factors, perceived risks influence the decision to adapt and to implement adaptation strategies (Grothmann and Patt, 2005; Maddison, 2007; Thomas et al., 2007; Adger et al., 2009). Farmer perceptions of climate-induced risks often align with climatic data (Thomas et al., 2007; Mubaya et al., 2010; Moyo et al., 2012), while other studies often show that farmers overestimate the risks associated with climatic factors (Maddison et al., 2007; Rao et al., 2011). Analysis of farmer perceptions on stressors to production for differently managed households, together with climatic data, are therefore important tools in understanding the nature of the stressors that smallholder farmers have to deal with, and for participatory development of technologies relevant to different climates and farming systems (Rao et al., 2011).

Analysis of possible MHHs and FHHs practices and outcomes using climate analogue analysis (e.g. Adams et al., 1998; Williams and Jackson, 2007) can provide information necessary for understanding how different climates affect male-headed and female-headed households. This study therefore sought to explore some of the likely effects of warmer climates on MHHs and FHHs in terms of resource-based forms of smallholder practices and outcomes by the middle of the 21st century through climate analogue analysis. The research question of the study was: What effect is climate change likely to have on male-led and female-led smallholders in rural Zimbabwe in terms of resource-based forms of smallholder practices and outcomes?

6.2 Analytical framework and data analysis

The two pairs of analogue study sites selected were a sub-humid pair from Mazowe/Goromonzi district (reference site) and Kadoma district (analogue site representing the Mazowe/Goromonzi 2050s climate), and a semi-arid pair from Matobo district (reference) and Chiredzi district (analogue site representing Matobo 2050s climate). Data were collected through household surveys using structured questionnaires and FGDs. Farmer perceptions regarding sources of vulnerabilities, risks to production, and climate change and variability, as well as resource ownership and crop management practices were compared between FHHs at the reference site and FHHs at the analogue site, as well as between MHHs at each pair. The differences in smallholder practices, yields, and livelihood outcomes were also assessed.

6.2.1 Stressors to crop production in different climates

Perceived crop production constraints were categorised, and the proportion of households that mentioned each constraint was obtained using SPSS version 21. Differences in climatic and non-climatic production constraints between analogue pair sites were assessed at two levels. The proportion of responses for each constraint was compared between MHHs at the reference site and MHHs at the warmer site for each pair of analogue sites. The proportion of FHHs was also compared using the Pearson's chi-square test.

In addition to stressors to production, farmer perceptions of climate change and variability were assessed. Farmers with at least five years of farming experience were asked if they had observed any changes in climate and variability. Those who mentioned that they had observed changes then stated the nature of the observed changes. Responses to questions on farmer perceptions were coded as binary variables. The codes were then entered into SPSS and the frequencies of responses were obtained and then categorized. Broad categories consisted of changes in temperature, changes in rainfall, changes in seasons, and changes in wind patterns. Data were analysed using descriptive statistics and tabulated. Farmer perceptions of the impacts of climate change and variability were categorised and coded, and frequencies obtained.

6.2.2 Resource levels of farmers in different climates

Levels of assets owned by FHHs at the cooler references sites were compared to those owned by FHHs at the warmer analogue study sites. The assets included physical assets such as tropical livestock units, livestock ownership (with particular reference to cattle), and farm size. The resources were also compared between MHHs at the cooler reference sites and those at the warmer analogue sites for each analogue pair. Tropical livestock units (TLU) per household were calculated based on the method described by Njuki et al. (2010; Chapter 5). Categorical data such as the proportion of farmers owning agricultural assets were compared using the Pearson chi-square test. Numerical data were compared using the independent t-test (Field, 2005; 2013).

6.2.3 Maize production practices at analogue pair sites

The proportions of households that applied fertilizer, the labour input, and the sources of labour for maize production were assessed as described in section 5.3.4. These represented some of the production practises of smallholders. Production characteristics of MHHs and FHHs at analogue pair sites were compared using the t-test.

6.2.4 Production outcomes and impacts of climate change and variability

Production characteristics of MHHs and FHHs at reference sites and at analogue sites were compared using non-parametric tests and the parametric independent t-test (Field, 2009). Mean household yields for maize were calculated by dividing total harvest by crop area. In addition, food security was assessed through subjective farmer perceptions. Farmers were asked if there had been any time of the year that their households did not have enough. Differences in the proportion of farmers who did not have enough for at least one month of the year were compared between MHHs and FHHs at each analogue pair.

The proportion of farmers who perceived changes in climate were compared at the analogue pair sites. Respondents who mentioned changes in climate identified impacts on crop production, livestock production, and livelihoods. Frequencies of responses were categorised and presented in tables to give an overview of farmer-perceived impacts at different sites.

6.3 Results

6.3.1 Sources of vulnerabilities in different climates

Sources of vulnerabilities to smallholder production in different climates were identified through analysis of farmer perceptions of crop production constraints and farmer perceptions of climate change and variability.

6.3.1.1 Crop production stressors – farmer perceptions

Climatic and non-climatic stressors to production mentioned by farmers at the study sites are summarised in Table 6.1. The main constraints mentioned by Mazowe/Goromonzi farmers were, in descending order, high costs of inputs, unavailability of inputs on the market, lack of equipment and lack of labour, erratic rainfall, and low prices for output. In comparison, Kadoma district farmers' main production constraints included lack of access to inputs and erratic rainfall. Twenty four percent of Kadoma MHHs compared to 15% of Mazowe/Goromonzi MHHs mentioned high temperature constraints. Higher proportions of Kadoma district MHHs compared to Mazowe/Goromonzi district MHHs perceived erratic rainfall constraints (Pearson chi-square test, 95% level). Concerning soil fertility, the number of Mazowe/Goromonzi district respondents from MHHs who mentioned low soil fertility constraints (24%; Table 6.1) was higher than the number from Kadoma (3%). Higher proportions of Mazowe/Goromonzi respondents compared to Kadoma respondents mentioned crop production constraints such as high cost of inputs, lack of draft power, and low producer prices.

At the semi-arid study sites, the main constraints mentioned in Matobo district included erratic rainfall, limited access to inputs for crop production, shortages in agricultural equipment, and lack of labour. In comparison, the main constraints mentioned in Chiredzi district included erratic rainfall, high temperature, and lack of labour, in descending order for MHHs, and erratic rainfall, lack of equipment, lack of labour, high costs of inputs, and high temperatures for crop production for FHHs. Erratic rainfall, high temperature, and high costs of inputs were reported by more Chiredzi MHHs and

FHHs than Matobo MHHs and FHHs. More than 50% of Chiredzi district respondents mentioned high temperature constraints compared to fewer than 15% of Matobo households. Meanwhile, more Matobo MHHs perceived poor access to inputs and low soil fertility compared to Chiredzi MHHs.

Table 6.1 Climatic and non-climatic stressors to crop production mentioned by farmers at the study sites

Crop production stressors	Wetter analogue pair						Drier analogue pair					
	Male headed households			Female headed households			Male headed households			Female headed households		
	Maz/ Gor[1]	Kad[2]		Maz/ Gor	Kad		Mat[3]	Chir[4]		Mat	Chir	
	%[5]	%	χ^2	%	%	χ^2	%	%	χ^2	%	%	χ^2
Erratic rainfall	34.5	48.6	4.007*	34.8	53.8	3.634	73.3	100	31.455***	64.8	92.1	13.241***
High temperatures	14.9	24.3	2.663	21.2	15.4	0.540	8.6	66.7	74.749***	14.8	50.8	16.729***
Pest and disease attacks	32.2	19.8	3.950*	24.2	33.3	1.013	19	49	20.767***	7.4	41.3	17.487***
Wild animals	0	9	N/A	0	7.7	N/A	7.6	15.7	3.285	7.4	15.9	1.978
Low soil fertility	24.1	2.7	21.038***	13.6	2.6	3.488	26.7	1	28.336***	22.2	6.3	6.206*
Poor access to inputs	43.7	54.1	2.101	36.4	53.8	3.059	57.1	30.4	15.029***	53.7	41.3	1.805
Lack of labour	47.1	42.3	0.452	54.5	51.3	0.105	39	51	2.978	44.4	61.9	3.567
Lack of equipment	48.3	44.1	0.335	47	56.4	0.874	44.8	44.1	0.009	53.7	69.8	3.227
High cost of inputs	71.3	18	56.992***	81.8	17.9	41.077***	30.5	51	9.021**	25.9	50.8	7.537**
Lack of draft power	19.5	3.6	13.065***	22.7	0	10.341***	1	1	N/A	1.9	0	N/A
Low prices for output	25.3	0.9	28.251***	37.9	0	19.389***	2.9	N/A	N/A	1.9	N/A	N/A
n	87	111	N/A	66	39	N/A	105	102	N/A	54	36	N/A

[1]Mazowe/Goromonzi district (cooler) [2]Kadoma district (warmer) [3]Matobo district (cooler) [4]Chiredi district (warmer), [5]Percent of households that mentioned production constraint
*Significant at the 10% level; **Significant at the 5% level; ***Significant at the 1% level

6.3.1.2 Climate change and variability – farmer perceptions

In addition to climatic and non-climatic constraints on production, farmers often experience changes in climate and climate variability that pose threats to their livelihoods. More than 60% of farmers at each study site noticed changes in climate and climate variability. Similar proportions of Kadoma district farmers and Mazowe/Goromonzi district farmers perceived change in climate and climate variability (Table 6.2). At the drier study sites, more respondents from MHHs in Matobo than in Chiredzi noticed climate changes and variability (Table 6.2).

Table 6.2 Proportions of farmers that perceived climate change at the study sites

	Wetter analogue pair			Drier analogue pair		
	Mazowe/ Goromonzi district (cooler)	Kadoma district (warmer)	χ^2	Matobo district (cooler)	Chiredzi district (warmer)	χ^2
MHHs (%)	64.9	67.6	0.804	100	77.8	10.500***
FHHs (%)	95.8	92	0.576	89.5	85.3	0.186
Male Respondents (%)	63.3	66.7	0.792	100	60	10.155***
Female Respondents (%)	90.3	87.5	0.722	97.4	89.1	6.880

*Significant at the 10% level, **Significant at the 5% level, ***Significant at the 1% level, n= in brackets

Table 6.3 shows main changes reported by farmers included reduced rainfall amounts, short rain season, and late onset of rains, increased frequencies and intensities of mid-season droughts.

Table 6.3 Indicators of climate change reported by farmers

Main changes in climate reported by farmers	Wetter analogue par				Drier analogue pair			
	Males (%[1])		Females (%)		Males (%)		Females (%)	
	Mazowe/ Goromonzi district (cooler)	Kadoma district (warmer)	Mazowe/ Goromonzi district (cooler)	Kadoma district (warmer)	Matobo district (cooler)	Chiredzi district (warmer)	Matobo district (cooler)	Chiredzi district (warmer)
Reduced rains/low rainfall	10	4	10	6	35	13	47	20
Rains start late and end early	50	52	52	34	53	33	26	35
Short rain season	0	26	10	19	6	0	18	4
Droughts	0	0	0	0	24	20	32	7
Mid-season drought/long dry spell	7	4	3	13	18	7	13	7
Inconsistent rains	0	0	3	0	6	7	13	11
Increased temperature	0	0	13	3	12	0	11	9
Summers cooler	0	0	0	0	6	7	3	9
Warmer winter	3	0	3	0	6	7	5	2
Colder winter	0	0	0	0	0	0	13	0
Increase wind speed	0	0	0	0	0	0	3	17
Long season	0	4	0	0	6	7	0	0

[1]Percent of total responses, *Multiple responses

The main changes mentioned by farmers from both sub-humid study sites were late onset and early cessation of rains, and generally shorter growing seasons. Kadoma district male farmers mentioned shortening of rain seasons, but none from Mazowe/Goromonzi reported this. At the drier sites, the main changes noted included reduction in the amount of annual rainfall, increased variability in rainfall and distribution, and increased frequencies of droughts. Seventeen percent of female respondents from Chiredzi also mentioned increased speed of wind and changes in wind direction.

6.3.2 Capital assets of farmers in different climates

Capital assets of households at the reference sites and at the analogue sites differed. Table 6.4 shows differences in resource ownership for MHHs and FHHs in different climates. More Kadoma MHHs owned ox-drawn ploughs (75%) and scotch-carts (57%) compared to Mazowe/Goromonzi MHHs that owned ox-drawn ploughs (61%) and scotch-carts (41%). Farm sizes of Kadoma MHHs were higher but adult units of family labour were lower than Mazowe/Goromonzi MHHs. In comparison, FHHs in Kadoma had larger farm sizes, lower adult units per hectare, and lower education levels and farming experience compared to FHHs in Mazowe/Goromonzi. At the drier sites, the proportion with no education was higher, farm sizes were higher, and mean age of household heads were lower in Chiredzi district compared to Matobo district for both MHHs and FHHs. Notable was that Chiredzi FHHs had lower adult labour compared to Matobo FHHs, but these values were higher for Chiredzi MHHs compared to Matobo MHHs.

Table 6.4 Comparisons of capital assets between analogue pair sites

	Wetter sites (districts)						Drier sites (districts)					
	Male headed households			Female headed households			Male headed households			Female headed households		
	Mazowe/ Goromonzi (cooler)	Kadoma (warmer)	[a]*T-value / χ^2*	Mazowe/ Goromonzi (cooler)	Kadoma (warmer)	*T-value / χ^2*	Matobo (cooler)	Chiredzi (warmer)	*T-value / χ^2*	Matobo (cooler)	Chiredzi (warmer)	*T-value / χ^2*
n	87	111	*N/A*	66	39	*N/A*	105	102	*N/A*	54	36	*N/A*
% FHH[1] that are De–juri	*N/A*	*N/A*	*N/A*	97	97.4	.019	*N/A*	*N/A*	*N/A*	92.6	82.5	2.629
% HHH[2] with no basic education	3.4	2.7	-	22.7	5.1	5.596*	10.5	28.4	10.699***	11.1	33.3	8.089**
Mean age of HHH[3]	3.91	3.96	*-0.270*	4.77	4.72	*0.244*	4.41	3.82	*3.103***	4,87	3.22	*5.207****
HHH mean school years	8.9	8	*1.718*	5.5	5.5	*-.094*	6.6	5.1	*2.500**	5.4	4.6	*1.438*
HHH mean farming experience (years)	19	17.9	*0.649*	30.3	23.3	*2.772***	22.6	22.1	*0.450*	28.3	19.4	*3.092***
HHH Full time Farmer (%)	80.5	76.6	0.433	98.5	97.4	.144	61	81.4	10.481 ***	81.5	92.1	2.913
Household size (n)	6.1	6.5	-1.187	5.8	6.1	-0.485	6.7	7	-0.586	5.8	5.9	-0.141
[4]Adult units ha^{-1}	2.1	1.2	6.386***	2.8	1.7	2.867**	1.2	2.0	3.893***	2.9	1.7	3.308***
Family labour (n)	3.2	3.3	0.157	2.9	3.1	-0.508	2.9	3.6	-1.626	2.6	2.6	-0.091
Adult male labour (n)	1.51	1.57	-0.467	1.02	1.03	0.060	1.4	1.66	-1.975	0.85	0.79	0.332
% Owning cattle	59.8	64	0.365	45.5	61.5	2.539	65.7	68.6	.199	46.3	46	.001
% Owning goats	46	44.1	0.066	36.4	48.7	1.547	42.9	70.6	16.191***	37	50.8	2.229
TLU[3]	2.8	3	*-0.391*	1.7	2.5	*-1.454*	3.3	3.7	*-0.410*	1.8	2.1	*-0.307*
% Owning Ox - drawn plough	60.9	74.8	5.059*	56.1	74.4	3.516	72.1	67.6	.489	46.3	36.5	1.151
% Owning Scotch-cart	41.4	56.8	5.304*	40.9	46.2	.275	38.1	35.3	.108	7.4	22.2	4.902*
% Owning Cultivator	39.1	41.4	0.238	39.4	17.9	5.231*	28.6	6.9	15.779***	7.4	3.2	1.071
Farm size (ha)	2.1	3.8	*-8.576****	1.6	2.5	*-3.442****	1.4	2.5	-6.839***	1.2	2.3	-4.683***
Mean Income 2010/2011 (US$)	1538.1	2429.5	*-1.727*	974.9	1013.5	*-0.100*	831.4	500.2	2.426	280.4	396.6	-1.059
Per capita income ($)	336.2	333.4	*0.037*	188.97	212.48	*-0.320*	159.4	78.7	2.833	121.96	72.51	0.598

[a]T-value for continuous variables and Chi-square for categorical data; *Significant at the 10% level; **Significant at the 5% level, ***Significant at the 1% level; [1]FHH = female headed household; [2]MHH = Male headed households; [4]HHH; [5]Age of head of household (1=18 - 25 years; 2= 26 - 35 years; 3= 36 - 45 years; 4= 46 - 55 years; 5= 56 - 64 years; 6= above 65 years); , [4]adults units per hectare (of total cultivated area for the 2010/2011 season)

6.3.2.1 Share of income from different sources

Sources of household income during the 2010/2011 season included crop production, livestock production, and non-farm employment (Figure 6.1). Incomes were based on farmer recall and were therefore estimates. The results, however, give insights into livelihood sources for farmers in different climates. Based on estimates, shares of incomes from crop production and sales followed by regular employment were the main sources of income for MHHs at the sub-humid study sites. The share of income from crops and horticultural sales was 47% among Mazowe/Goromonzi MHHs and 19% from regular employment (Figure 6.1a). The main sources for FHHs were crop production and sales, followed by remittances from outside (Figure 6.1b). Meanwhile Mazowe/Goromonzi FHHs obtained 55% of their income from crop sales and 32% from remittances. The main source of income in Kadoma was crop sales. The main income source for Kadoma MHHs was crop sales (56%) followed by regular employment (13%), while in FHHs 70% was from crop sales and 16% from remittances (Figure 6.1b).

Matobo MHHs received income mainly from crop sales, regular employment of household members, running their own businesses, and remittances. Meanwhile Chiredzi MHHs received income mainly from remittances from outside, sale of crops, regular employment, and livestock sales. The main income sources for FHHs were fewer and included sale of crops and remittances in Matobo, and sale of other products, casual employment, and regular employment of family members in Chiredzi (Figure 6.1d). With respect to share of income, Matobo MHHs obtained 21% each from sale of crops, regular employment, and running their own business, and 20% from remittances (Figure 6.1c). Female-headed households received approximately 42% of their total income from crop sales and 31% from remittances.

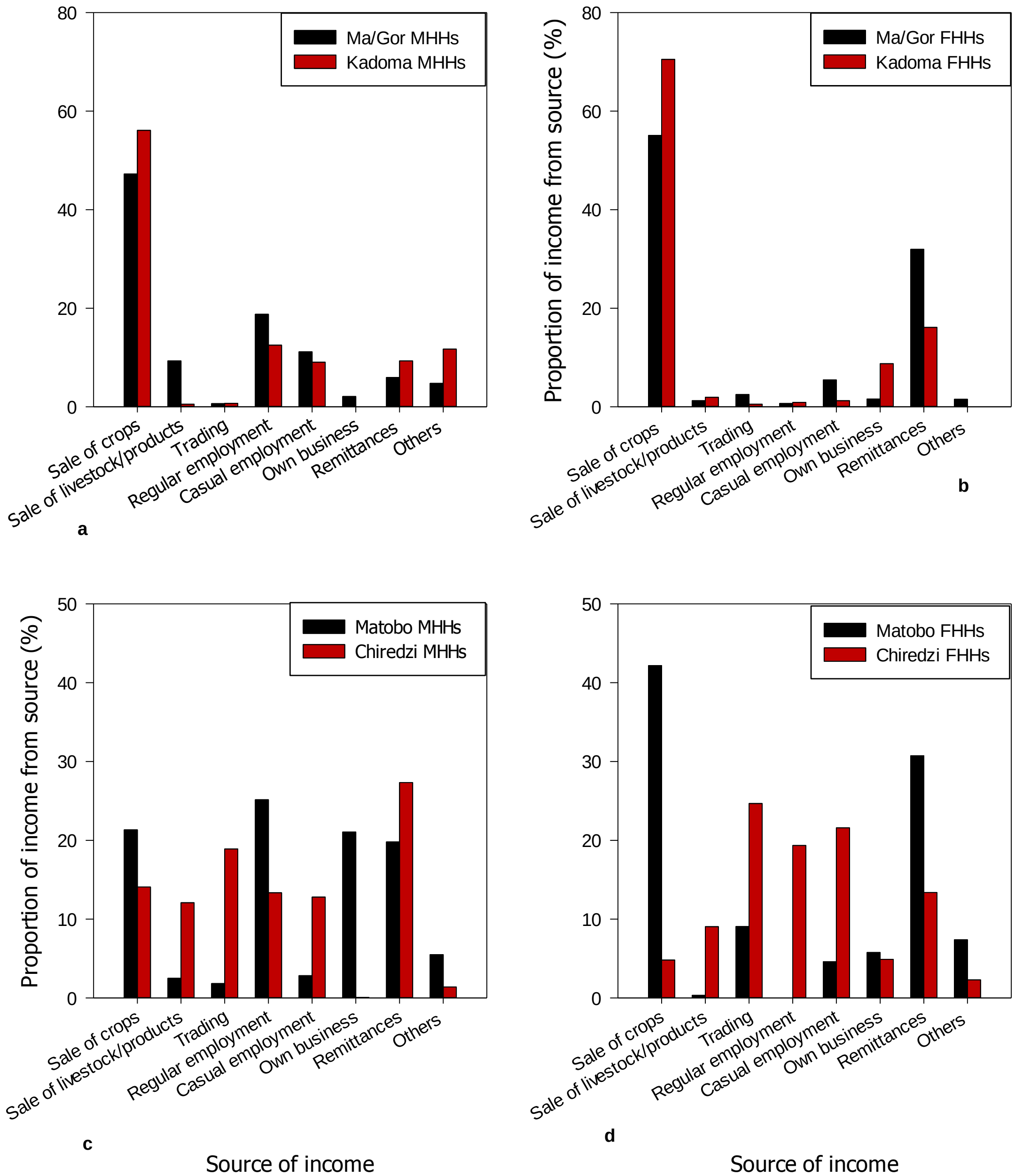

Figure 6.1 Share of income from different sources at the analogue sites

Chiredzi MHHs received income from remittances (27%), regular employment (19%), sale of crops (14%), sale of livestock 12%, and casual employment (13%; Figure 6.1d). Chiredzi FHHs obtained 25% of total income from trading, 22% from casual employment, and 19% from regular employment (labour migration). The head of household (Figure 6.1d) obtained most of the income in both MHHs and FHHs. Matobo and Chiredzi districts households also received income through other family members who engaged in casual employment, regular employment, and sale of non-agricultural products.

6.3.3 Maize production practices

Management of maize crops was assessed in the context of area, fertilizer use, and labour inputs (Table 6.5). Climate analogue comparisons show that for the 2010/2011 season Kadoma farmers used less fertilizer than Mazowe/Goromonzi farmers. In Mazowe/Goromonzi 42% of both MHHs and FHHs hired labour compared to 17% of MHHs and 26% of FHHs in Kadoma.

Table 6.5 Comparisons of maize production practices during the 2010/2011 season between analogue pair sites

			mean area	**fertilizer use**	**Amount of N applied**	**Labour input**
		Districts	ha	% hhds	kg ha^{-1}	Man-days ha^{-1}
	MHH[1]	Mazowe (cooler)	1.00	97.7	70.5	82.4
		Kadoma (warmer)	1.20	68.2	30.1	100.4
Wetter		T-value/ $\chi2$	-1.991	27.750***	7.696 ***	-1.723
Analogue pair	FHH[2]	Mazowe (cooler)	0.70	98.5	70.4	70.3
		Kadoma (warmer)	0.70	71.8	49.2	84.8
		T-value/$\chi2$	-0.085	17.252***	2.305**	-1.480
	MHH	Matobo (cooler)	0.68	68.6	28	78.76
		Chiredzi (warmer)	0.79	0	0	38.98
Drier		T-value/ $\chi2$	-1.303	N/A	N/A	5.783***
Analogue pair	FHH	Matobo (cooler)	0.67	61.1	23	70.625
		Chiredzi (warmer)	0.749	0	0	37.39
		T-value/ $\chi2$	-0.772	N/A	N/A	3.378***

[1]male-headed households; [2]female-headed households
*Significant at the 10% level; **Significant at the 5% level; ***Significant at the 1% level

The mean maize area of MHHs and FHHs in Matobo was 0.7 hectares per household. The mean maize area at Chiredzi study sites was 0.8 and 0.7 ha per household for MHHs and FHHs respectively. At the drier Chiredzi site, farmers did not apply any fertilizer to the maize crop. In Matobo, 10% and 18% of MHHs and FHHs, respectively, hired labour for some of the activities of maize production. Hiring of labour was lowest in Chiredzi district. Nine percent and 7% of MHH and FHH, respectively, hired labour.

6.3.4 Estimated maize yields for the 2010/2011 season

Maize yields for the 2010/2011 season gave partial estimates of farm productivity. Calculations of yields were based on farmers' stated land area and harvest obtained. Yields were therefore indicative. Mean maize yields were lower ($P<0.001$) at the 95% level at the analogue sites compared to the reference sites for both MHHs and FHHs (Figure 6.2). Mean maize area of MHHs in Mazowe/Goromonzi, for example, was 2026 kg ha^{-1} compared to 1298 kg ha^{-1} for Kadoma MHHs (Figure 6.2a). Mean maize area for Matobo MHHs was 374 kg ha^{-1} compared to 72 kg ha^{-1} for Chiredzi MHHs (Figure 6.2b).

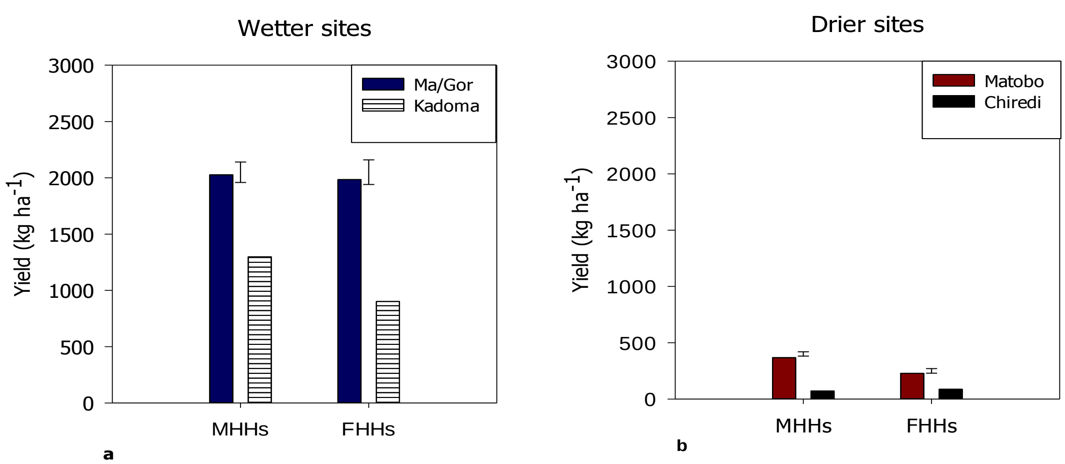

Figure 6.2 Comparisons of crop yields between analogue pair sites

6.3.5 Household food security

Of the survey households, 12% in Mazowe/Goromonzi compared to 20% in Kadoma, and 66% in Matobo compared to 72% in Chiredzi, mentioned that they experienced food shortages during at least one month of the year (2010/2011 season; Table 6.6).

Generally, more households at drier sites had food shortages compared to those at the wetter sites (Table 6.6). In both the sub-humid and semi-arid analogue pairs significantly higher proportions of MHHs from the analogue sites mentioned food shortages compared to MHHs from the respective reference sites.

Table 6.6 Households food insecure at study sites during the 2010/2011 season

	Wetter analogue pair			Drier analogue pair		
	Mazowe/ Goromonzi district (cooler)	Kadoma district (warmer)	χ^2	Matobo district (cooler)	Chiredzi district (warmer)	χ^2
MHHs[2] (%[a])	6.9	16.2	3.977*	59	72.5	127.281a***
FHHs[3] (%)	19.7	30.8	1.657	79.6	69.8	1.461
Total	12.4	20	3.212*	66	71.5	1.132

[1] =% of households who did not have enough food to meet family needs during at least one month of the year (2010/2011 season)
*Significant at the 10% level; **Significant at the 5% level; ***Significant at the 1% level
[2]MHHs; [3]FHHs

6.3.6 Impacts of climate change and variability – farmers' views

Farmers perceived different impacts of climate change and variability at reference sites and at analogue sites (Table 6.7). Climate change impacts perceived by respondents from Mazowe/Goromonzi and Kadoma MHHs included poor yields, reduced livestock pastures, and reduced water sources for livestock. In contrast, the main impacts of climate change perceived by respondents from Mazowe/Goromonzi FHHs included poor yields and increased hunger. Matobo MHHs perceived the main impacts of climate change and variability to be crop wilting, reduced livestock pastures, reduced water sources for livestock, and increased poverty. In contrast, the most-mentioned impacts perceived by Chiredzi MHHs were reduced livestock pastures. The FHHs at drier sites mentioned reduction in livestock pastures the most.

Table 6.7 Impacts of climate change and variability mentioned by farmers

	Wetter analogue sites				Drier analogue sites			
	MHHs		FHHs		MHHs		FHHs	
	Mazowe/ Goromonzi (cooler)	Kadoma (warmer)	Mazowe/ Goromonzi (cooler)	Kadoma (warmer)	Matobo (cooler)	Chiredzi (warmer)	Matobo (cooler)	Chiredzi (warmer)
Poor germination	✓	✓	-	✓	✓	✓	-	✓✓
Poor yields	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓✓
No yields	✓	✓	✓	-	-	✓	-	✓
Failure to match crops to season	✓	✓	✓	✓	-	✓	-	-
Low temperature affect sorghum tillering	-	-	-	-	-	-	-	✓
Stunted growth	✓	✓	✓	✓	✓	✓	✓	✓
Pests affect late planted sorghum	✓	-	-	-	-	✓	-	-
Damage crops	✓	-	✓	-	✓	✓	-	-
Improved yield	✓	-	✓	-	-	-	-	✓
No impact on crop production	✓	-	✓	-	✓	-	-	-
Rotting of seed	✓	✓	-	-	-	-	-	-
Crop wilt	-	-	✓	✓	✓✓✓	✓	✓✓	-
Increase in stalk borer	-	-	-	-	✓	-	✓	-
Reduced livestock birth rates	✓	-	✓	-	✓	✓	✓	✓
Reduced livestock pastures	✓✓	✓	✓	✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Reduced water sources for livestock	✓✓	✓✓	✓	✓	✓✓✓	✓	✓✓	✓
Increase in livestock death	✓	✓	✓	✓	✓	✓✓	✓	✓
Disease increase in livestock	✓	✓	✓	✓	✓	-	✓	-
No impact on livestock production	✓	-	✓	-	-	-	-	-
Increased poverty	✓	✓	✓	✓	✓✓✓	✓	✓✓	✓✓
Hunger	✓✓	✓✓	✓	✓✓	✓✓	✓✓✓	✓	✓✓✓
Dependency on non- farm livelihoods	✓	✓	-	-	✓	✓	✓	✓
Stress	✓	-	-	-	-	-	✓	✓
Destruction of structures/buildings	-	-	✓	-	✓	-	✓	-
Reduced water source for domestic	✓	✓	-	-	✓	-	-	-
Illness/stress	✓	-	-	-	✓	-	✓	-✓
No change in livelihoods	✓	-	✓	-	-	-	-	-
Improved livelihood	✓	-	✓	✓	-	-	-	✓
n	29	28	25	22	60	31	33	40

✓ represent 1-10 responses; ✓✓ represents 11-20 responses; ✓✓✓ represents >20 responses

6.4 Discussion

The effects of climate on male-led and female-led smallholders in rural Zimbabwe in terms of resource-based forms of smallholder practices and outcomes varied. According to farmer perceptions, crop production risks from climates as well as other biophysical characteristics such as soil quality varied between analogue sites. Reference-site households compared to analogue-site households managed constraints on production differently with respect to maize production. Further, maize yields at reference sites were lower than maize yields at analogue sites for both MHHs and FHHs.

At the sub-humid analogue pair, Mazowe/Goromonzi FHHs and MHHs had higher yields compared to Kadoma MHHs and FHHs, respectively. Climatic and non-climatic stressors influence yields in different smallholder areas (Walker and Schulze, 2006; Ncube et al., 2009). Management of these stressors will depend on the levels of resources of the farmers as well as their perceptions of climate-induced risks, in addition to other factors. In this study, asset ownership, e.g. of ox-drawn ploughs, was in general higher for Kadoma (warmer) households compared to Mazowe/Goromonzi (cooler) households. More households experienced draft power constraints in Mazowe/Goromonzi. Female-headed households in Kadoma district had more TLUs than Mazowe/Goromonzi FHHs, which could account for more households mentioning draft power constraints in Mazowe/Goromonzi district. Some farmers from both Mazowe/Goromonzi district and Kadoma district mentioned that they used reduced tillage methods to deal with draft power constraints. Average financial capital levels at the two study sites were similar. However, average farm size was higher in Kadoma compared to Mazowe/Goromonzi. Therefore, Kadoma households' resource levels were generally higher than those of Mazowe/Goromonzi households.

Smallholder cropping decisions are also related to climates (Wood et al., 2014). Maize yields also depend on climates, for example in South Africa (Walker and Schulze, 2006) and in Ethiopia (Kassie, et al., 2014). Although Rao et al. (2011) noted that some farmers are more risk averse, i.e. they mentioned changes that were not corroborated by climatic data, farmer perceptions regarding climate change often agree with climatic data (e.g. Moyo et al., 2012). Therefore, farmers' perceptions give indications of some of the climatic constraints on farm production. At the study sites, higher proportions of Kadoma (warmer) MHHs and FHHs compared to Mazowe/Goromonzi (cooler) MHHs and FHHs mentioned erratic rainfall constraints. Farmers' views showed higher risks from climatic constraints in Kadoma district compared to Mazowe/Goromonzi district. Meanwhile, perceptions of reduced rainfall and shortening of the rainy season at both Mazowe/Goromonzi and Kadoma study sites were similar to general climate data trends that show shifts in maize growing seasons in parts of Zimbabwe (Tadross et al., 2007).

Soil fertility management, labour input, and cultivated area varied by analogue site. The higher use of fertilizer by Mazowe/Goromonzi MHHs and FHHs compared to Kadoma MHHs and FHHs could be associated with the differences in soil quality. Smallholder farmers in Mazowe/Goromonzi mentioned soil fertility constraints. In contrast, Kadoma farmers perceived their soils to be generally fertile. Farmer perceptions regarding soil fertility status at both study sites were supported by findings from studies that show smallholder areas in Zimbabwe are generally associated with low soil fertility (e.g. Nyamangara et al., 2000). However, Kadoma soils are some of the more fertile in Zimbabwe (e.g. Nyamapfene, 1991). Access to fertilizer could also contribute to different rates of fertilizer applied by the farmers. Mazowe/Goromonzi district farmers and Kadoma district farmers had similar levels of financial capital that enabled them to purchase inputs. However, Kadoma district farms were larger. Kadoma farmers also cultivated cotton that required other different types of inputs such as fertilizer and pesticides. Meanwhile Mazowe/Goromonzi farmers practised horticulture. Fertilizer was either purchased, donated by NGOs, or obtained through inputs credit schemes. Climate risks could also partly explain the different rates of application. There were no differences in labour input for maize production at the study sites. Mean cultivated area, however, was larger in Kadoma compared to Mazowe/Goromonzi and adult units were lower. Assessments of management practices implemented by farmers at the sub-humid sites were not exhaustive. Farmers at both study sites mentioned the use of soil and water management strategies during FGDs.

Against a background of higher climate risk perceptions, more agricultural resources, generally higher soil fertility, and lower fertilizer use, Kadoma district maize yields were lower than Mazowe/Goromonzi district yields. Implications are that Mazowe/Goromonzi yields may decline due to warmer climates by the middle of the 21st century under rain-fed farmer-managed conditions. Similarly, Waha et al. (2013) also showed positive effects on maize yields of temperature increases in currently temperature-limited high altitude areas and negative effects in other regions of SSA. Model-based studies also predict declines in productivity for most of SSA due to warmer climates in the 2050s (e.g. Matarira et al., 1995; Schlenker and Lobell, 2010). This study has further shown that even though both MHHs and FHHs may experience yield reductions, the extent may differ depending on the gender of the head of household.

Lower yields can influence household food security, household resources, and livelihoods. Kadoma households for example were food insecure compared to those at the reference site Mazowe/Goromonzi. Greater effects of lower yields in FHHs were evidenced by the generally higher proportion of FHHs than MHHs that mentioned food insecurity. Shifts in land values due to climate change, i.e. resulting from changes in crops grown and livestock kept (e.g. Kurukulasuriya et al., 2006; Kurukulasuriya and Mendelsohn, 2008; Seo and Mendelsohn, 2008), can either increase net farm income or reduce net farm income and thus influence the disposable incomes of households. Comparable incomes for households in Mazowe/Goromonzi and Kadoma districts can be explained by the different strategies for obtaining household income at the study sites. Despite lower yields, Kadoma farmers allocated a larger cultivated area to cash crops such as cotton, while in Mazowe/Goromonzi farmers also practised horticulture production and farmed several other minor crops such as soybean. Therefore, the main source of income in Kadoma was crop production and in Mazowe/Goromonzi, it was crop production and horticulture, particularly for MHHs.

At the wetter sites, the implications are that agriculture will continue to be a main source of livelihood for Mazowe/Goromonzi and other smallholder areas with similar characteristics in 2050s climates, in particular for FHHs. Projected negative effects of warmer climates may increase vulnerability of households headed by women, which are more dependent on agriculture. These results indicate that at the sub-humid sites there was potential to increase income from crop production through crop choices that are suitable to specific environments. Econometric modelling results show general reductions in net farm revenue due to climate change in several regions of Africa (Kurukulasuriya et al., 2006; Kurukulasuriya and Mendelsohn, 2008).

At the semi-arid analogue pair, farmers from the warmer Chiredzi district (analogue site) had lower maize yields compared to those from the cooler reference site in Matobo district. Findings from other sites show similar trends to those observed in this study. Matobo district maize yields average 800 kg ha^{-1} (District Agricultural Extension Officer, 2005, cited in Ncube et al., 2009), and Chiredzi district yields average 550 kg ha^{-1} for Chiredzi (Unganai and Murwira, 2010).

Management practices that could have contributed to observed differences in yields include soil fertility management, and soil and water management. Matobo district farmers applied fertilizer while Chiredzi district farmers mentioned that they do not usually apply fertilizer to their crops due to high risks associated with low rainfall and temperature. Chiredzi farmers also mentioned that they rarely used soil and water management technologies in crop production. Higher labour input in maize production in Matobo compared to Chiredzi may be explained by crop failure in some Chiredzi district households. While the proportion of farmers owning agricultural resources are generally similar at both semi-arid sites, Matobo farmers owned more agricultural equipment compared to Chiredzi farmers.

Chiredzi district farmers perceived higher climate risks to crop production compared to Matobo farmers. The study results indicate that male and female farmers have similar perceptions of climatic constraints. The proportion of farmers that perceived temperature constraints to crop production was higher in Chiredzi (drier/warmer; 76% from MHHs, 51% in FHHs) compared to Matobo district (drier/cooler; 9% from MHHs, 15% from FHHs) and align with climate data. These results are consistent with climate data showing higher temperatures in Chiredzi compared to Matobo. Therefore, management practices may be associated with risk perceptions.

Lower maize yields at the reference site in Matobo district than at the 2050s analogue site in Chiredzi district suggest declines in yields under rain-fed farmer-managed conditions. These findings agree with model-based findings for semi-arid SSA (e.g. Matarira et al., 1995; Schlenker and Lobell, 2010). Higher proportions of Chiredzi MHHs mentioned food insecurity compared to Matobo MHHs. Meanwhile FHHs at the reference site and analogue site showed similar levels of food insecurity. The implications are that FHHs at the semi-arid study sites are more vulnerable to food insecurity. There may also be increased food insecurity in the semi-arid Matobo district in 2050s climates in the absence of effective intervention strategies.

Wise et al. (2013) noted that climate change affects social and natural systems of smallholder farmers. Changes in the 2050s could affect the social and cultural environments of smallholder farmers at the semi-arid sites in different ways. Firstly, Chiredzi households compared to Matobo households had lower household income. Chiredzi (warmer) district households' share of income from crops was lower than that of Matobo (cooler) district households. Lower crop yields and lower income from crop production contributed to this difference. In turn, livestock production's contribution to household income was higher in Chiredzi than in Matobo. Farmers in Chiredzi mentioned that they usually sold livestock as a coping strategy, i.e. livestock are a safety net. Crop/livestock systems provide resilience to farming systems in Africa (e.g. Seo et al., 2009). Therefore, the proportion of income from livestock sales could be higher depending family needs. Shifts in land values due to climate change, i.e. due to changes in crops grown and livestock kept (e.g. Kurukulasuriya et al., 2006; Kurukulasuriya and Mendelsohn, 2008; Seo and Mendelsohn, 2008), can either increase net farm income or reduce net farm income and thus influence the disposable incomes of households. Econometric modelling results, however, show general reductions in net farm revenue due to climate change (Kurukulasuriya et al., 2006; Kurukulasuriya and Mendelsohn, 2008).

Male labour migration is also a common phenomenon in response to climate changes and disasters (e.g. Agwu and Okhimambe 2009; Nelson and Stathers, 2009). Lower levels of adult units in both MHHs and FHHs at the drier sites in Chiredzi (drier/warmer) as compared to their counterparts in Matobo (drier/cooler) can be explained by high levels of labour migration, including seasonal migration. Farmers mentioned in FGDs that males frequently migrate in search of other sources of livelihoods. Further, there were higher proportions of *de facto* female heads of households in Chiredzi than in Matobo and at drier sites compared to wetter sites (Table 5.1), indicating higher levels of male labour migration at the semi-arid sites and in particular in Chiredzi. The FGDS at the drier sites revealed that young males seek employment as alternative sources of income by migrating (sometimes seasonally). Younger, more productive males migrate more often than more mature males. This then results in younger female heads of households in Chiredzi. Younger *de facto* FHHs also partly account for the presence of fewer resources, i.e. they have had a shorter time to accumulate resources, in particular with their male spouses. Younger women therefore have the burden associated with crop production in addition to domestic and reproductive responsibilities. Meanwhile gendered impacts of climate change also include reliance of FHHs on trading and casual employment.

These results show that sub-humid and semi-arid smallholder areas experience different climatic constraints on production that require different management practices. In general, the impacts of these climates vary by site and by gender of head of household.

6.5 Conclusion and recommendations

Cross-sectional data from this study has shown that the sources of vulnerabilities for MHHs and FHHs differed between the reference sites and the analogue sites. Further resource-based forms of smallholder practices were variable for MHHs and FHHs at the analogue sites compared to MHHs and FHHs at the reference sites. Yields and food security were lower at the analogue sites compared to the reference sites.

At the sub-humid study sites, Kadoma district households generally owned more agricultural resources compared to Mazowe/Goromonzi district (cooler) households. Their soils were more fertile and they used less fertilizer for maize crop production. Perceived climate risks were higher in Kadoma compared to Mazowe/Goromonzi. Yields were lower in Kadoma district compared to Mazowe/Goromonzi district for both MHHs and FHHs. Yields may be lower in Mazowe/Goromonzi by the middle of the 21st century. Women who rely mainly on crop production may be the most vulnerable to the impacts of climate change. Mainstreaming gender is required to reduce the impacts of climate change on smallholdings in SSA.

At the semi-arid sites, Chiredzi district farmers had more natural capital with respect to arable land size and livestock ownership than Matobo district (cooler) farmers. The results show more human capital constraints in Chiredzi than in Matobo. Matobo farmers applied more fertilizer and more labour and management practices compared to Chiredzi households. Chiredzi farmers perceived higher crop production risks from climates than Matobo farmers. Lower yields in Chiredzi compared to Matobo imply warmer climates may negatively affect yields in Matobo district, and that beyond the 2050s Matobo district may become unsuitable for maize production. Income from crop production is lower in Chiredzi district compared to Matobo district, while the share of income from livestock production is higher. The impact of climate varies for MHHs and FHHs. There is higher male labour migration in response to climate impacts, and higher dependency on trading and casual employment by members of FHHs. This study illustrates the need for different packages for climate change in Zimbabwean smallholder areas, packages that require an in-depth understanding of the biophysical environments and socio-economic characteristics of smallholder farmers.

6.6 Summary

Gendered processes result in different levels of access to resources for male-managed and female-managed households in smallholdings. Climate change may affect MHHs and FHHs differently in terms of productivity and accesses to resources. Responses to climate change due to gendered differences in resources and outcomes may vary. Planning for future climates requires that the effects of climate on the environment of smallholders be estimated. Information from exploratory studies of the potential impacts of climate change on MHHs and FHHs can give insights into some of the likely strategies that may be required to respond to climate change. This study sought to assess the likely effect of climate change on male-led and female-led smallholders in rural Zimbabwe in terms of resource-based forms of smallholder practices and outcomes. Stressors to production, maize management strategies, and capital assets were identified through household surveys and FGDs. These were then compared between FHHs at the cooler reference sites and FHHs at warmer analogue sites. Similar comparisons were made for MHHs.

The results from the study showed that sources of vulnerability for crop production differed between reference sites and their analogues. The main climatic constraint was erratic rainfall at the wetter sites in Mazowe/Goromonzi and Kadoma districts. The main constraints included changes in the length of seasons and inconsistent rains at wetter sites and in Matobo district. At the drier Chiredzi study sites (warmer), the main climatic constraints on crop production perceived by farmers included low unpredictable rains associated with mid-season droughts and high temperature. Resources that may be affected by changes in climate include labour for FHHs as well as livestock ownership profiles. Management practices with respect to cropped area and fertilizer application rates also differed by analogue site. The results show that warmer 2050s climates may reduce maize yields in both the semi-arid Matobo district and the sub-humid Mazowe/Goromonzi district study sites in the absence of significant technological interventions. Beyond the 2050s, Matobo may become unsuitable for maize production and more suitable for sorghum, pearl millet, and other stress-tolerant crops. Women are therefore more vulnerable to the impacts of climate change and variability. Reduced overall production may result in male labour migration.

7.0 An assessment of climate change adaptation options and requirements in male-led and female-led households in smallholder areas of Zimbabwe

7.1 Introduction

Warmer climates by the middle of the 21st century may present both opportunities for and constraints on smallholder agricultural production. Climates are projected to warm by an average of 3°C in most of sub-Saharan Africa by the middle of the 21st century. Many studies have estimated the negative impacts of warmer 2050s climates on crop yields and livelihoods of most smallholdings in sub-Saharan Africa (e.g. Schlenker and Lobell, 2010; Zinyengere et al., 2014). Food security may thus be reduced in SSA smallholder areas. It is therefore important to plan for agricultural adaptation to environmental challenges that may be imposed by climate change. Smallholder farmers, who are the most vulnerable to climate change, encounter numerous non-climatic stressors (Morton, 2007) that present limits and barriers to adaptation (Adger et al., 2009). Differences exist between FHHs and MHHs with respect to access to the resources required for production (Quisumbing, 1995; Doss, 2001; Odame et al., 2002). Socially constructed roles of males and females also differ. Local adaptation to climate change in smallholder areas therefore requires mainstreaming of gender in technological, informational, organisational, and behavioural forms of change. Micro-level analysis of smallholder adaptation strategies for current and future climates in differently managed households can enhance adaptation through gender mainstreaming in climate change adaptation.

Adaptation can be differentiated according to purposefulness, timing, temporal scope, spatial scope, function, form, and performance (Smit et al., 1999). Strategies used in African smallholder farming systems often include crop choices (Kurukulasuriya and Mendelsohn, 2008), use of different crop varieties (Nhemachena and Hassan, 2007; Deressa et al., 2009), crop diversification, and use of different planting dates. Farmers also use soil and water management strategies (Deressa et al., 2009) that include different forms of conservation agriculture (e.g. Mazvimavi and Twomlow, 2008) and diversification from farming to non-farming activities (Nhemachena and Hassan, 2007).

Female-headed households often have lower levels of resources compared to male-headed households, and this results in lower levels of technology adoption and/or lower yields and productivity. Mazvimavi and Twomlow (2009), for example, showed that FHHs adopted fewer components of conservation agriculture compared to MHHs in some Zimbabwean communities. Similarly, more MHHs compared to FHHs in the Nile Basin of Ethiopia used soil conservation and crop varieties for adaptation (Deressa et al., 2008). The gender of the head of household, however, did not influence adaptation using planting dates and irrigation. Men and women often have different preferences in agricultural production, e.g. in crops and crop varieties (Defoer et al., 1997; Mulatu and Zelleke, 2002). These differences also influence management pathways and adoption of technologies. Information on adaptation requirements of male-led and female-led households in different farming systems is important for mainstreaming gender in climate change planning and potential future strategies. This study was based on the theory that women and men have different access to resources and that these gendered differences result in different management strategies for differently managed households.

Approaches for recommending, prioritizing, and selecting adaptation options include modelling (Deressa et al., 2009), use of indigenous knowledge systems, cost-benefit analysis, multi-criteria analysis (e.g. Webb et al., 2013), cost-effectiveness analysis, and expert judgement. Comparison of farmer practices at analogue pairs assists in exploration of possible adaptation options for the future (Williams and Jackson, 2007). The objective of this study was therefore to assess adaptation options for current and for future climates of MHHs and FHHs through climate analogue analysis. The research question of the study was: How will gender affect adaptions to climate change, smallholder practices, and outcomes in rural Zimbabwe?

7.2 Analytical framework and data analysis

Analogue sites were selected based on climate data. The analogue pairs consisted of the sub-humid pair Mazowe/Goromonzi (reference site) and Kadoma (analogue site representing Mazowe/Goromonzi 2050s climate), and the semi-arid pair Matobo (reference) and Chiredzi (analogue site representing Matobo 2050s climate). Management choices and factors influencing the choices as well as farmer preferences were identified through triangulation of methods, i.e. surveys, FGDs, and participatory evaluations (Chapter 4). Farmer perceptions of factors that influence management strategies were also assessed. Descriptive statistical methods and qualitative content analysis were used to analyse management strategies used by MHHs and by FHHs at each site, as well as the farmers' preferred strategies. Strategies used in management were categorized and frequencies obtained for MHHs and FHHs and for analogue sites. Strategies used by farmers in response to perceived changes were also categorized and manually coded. The codes were entered into SPSS and frequencies obtained. In-depth interviews and case studies were also carried out.

7.2.1 Analysis of crop choices

Crop choices for adaptation to current and future climates were assessed using three approaches. The first involved analysis of crop production profiles at the study sites. Profiles of crops grown in the 2010/2011 season were assessed through household surveys. Crop production profiles were analysed using descriptive statistics. The proportion of households that grew each crop was compared by site and by gender. The mean area of the main crops grown per site for MHHs and FHHs were calculated based on farmer area estimates at the household level.

Secondly, farmer preferences were assessed in focus groups by ranking crops choices and assessing selection criteria. The composition of the focus groups was described in Chapter 4. Farmers in FGDs identified the main crops that were grown at each site. The farmers then ranked the crops in order of preference. Farmer crop preferences were assessed using the multi-criteria approach (MCA; Sadok et al., 2008; de Bruin, 2011; Derak and Cortina, 2014). 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). Farmers were asked to identify selection criteria for crop choices. Each criterion was scored based a scale of 1–10. The total weight for each choice was obtained by adding scores of the selection criteria.

Lastly, farmer assisted evaluations of on-station trials enabled analysis of criteria that farmers consider important for crops and varieties. The groups were comprised of males and females. The female group consisted of both female household heads and spouses of male household heads. These evaluations were for cereals and legumes mainly grown in smallholder areas of Zimbabwe. On-station trials of four crops and three varieties for each (see Table 4.2), conducted during the 2012/2013 cropping season under rain-fed conditions, were evaluated at physiological maturity from April to May in 2013. Data analysis for participatory evaluations comprised complementary qualitative and quantitative techniques. Data were analysed using the Statistical Package for Social Sciences (SPSS) version 19. Mean scores and rankings of varieties were obtained. Farmers evaluated crop performance through pairwise ranking of the four crops at each site.

7.2.2 Soil and water management, and soil fertility strategies

Soil and water management and soil fertility management options for smallholders in different climates were assessed qualitatively and quantitatively by comparing farmer preferences and by assessing farmer practices across analogue sites. Farmers were asked which strategies they commonly use to manage soil and water. The proportions of MHHs and FHHs that use each strategy were compared using Pearson’s chi-square analysis for each analogue pair. Farmer preferences were ranked during FGDs. The MCA was used to identify farmer selection criteria for soil and water management.

7.2.3 Social capital and social innovations by farmers

Indicators of social capital include membership in farmer groups, roles in farmer groups, and strength of associations with these groups. Social capital that can be measured through informal institutions and private social networks enhances access to new information and financial transfers, and facilitates cooperation that increases access to agricultural resources such as labour and agricultural equipment. In this study, social capital was assessed by identifying farmer groups that household members belonged to for FHHs and MHHs at each site. Social capital assessed during the second household survey included analysis of membership in groups. Descriptive statistics were used to analyse the data.

7.2.4 Farmer strategies in response to climate change and variability

Responses of farmers to climate change were coded and transcribed. Frequencies of responses were obtained using SPSS version 21.

7.2.5 Livelihood strategies – farmer preferences

Male and female FGDs at each site identified the main sources of livelihoods at each site. Each group then ranked livelihood sources according to importance, and the views expressed by different farmers in each group were noted.

7.3 Results

The environments of the smallholder farmers at each analogue site differ in non-climatic constraints as well as in climatic constraints including rainfall amount and distribution, temperature, and other biophysical factors such as soil fertility. The results from this study show different management strategies with regard to crop production profiles, soil and water management, soil fertility management, livelihood strategies, and institutional organisations that assist in adaptation endeavours.

7.3.1 Crop choices

7.3.1.1 Cropping patterns

Based on the proportion of households and the share of cropped area, the main crops grown during the 2010/2011 season were maize and groundnut in Mazowe/Goromonzi district (wetter, cooler), and maize, groundnut, and cotton, a cash crop, in Kadoma district (wetter, warmer; Table 7.1; Table 7.2). Mazowe/Goromonzi MHHs and FHHs allocated approximately 85% and 82% of total cultivated area to maize compared to 51% and 56% by Kadoma MHHs and FHHs, respectively.

In Matobo district, the main crops grown were maize, groundnut, Bambara nut, and cowpea (Table 7.1). Matobo MHHs farmers allocated 78% of cultivated land to maize, 5% to sorghum, 8% to groundnut, and 3% to cowpea. Female-headed households allocated 83% to maize and 7% to groundnut (Table 7.2). In Chiredzi MHHs allocated 35% to maize and 40% to sorghum, while FHHs allocated 42% to maize, 35% to sorghum, and 6% to pearl millet.

Table 7.1 Cropping patterns at study sites in 2010/2011 season

Proportion of households that grew crop (%)	Wetter analogue pair				Drier Analogue pair			
	MHHs		FHHs		MHHs		FHHs	
	Mazowe/ Goromonzi district (cooler)	Kadoma district (warmer)	Mazowe/ Goromonzi districts (cooler)	Kadoma district (warmer)	Matobo district (cooler)	Chiredzi district (warmer)	Matobo district (cooler)	Chiredzi district (warmer)
Maize	100	99.1	100	100	100	88.2	100	93.7
White Sorghum	-	2.7	-	-	12.4	54.9	7.4	61.9
Red sorghum	-	1.8	-	2.6	1	41.2	-	38.1
Pearl Millet	-	-	-	-	3.8	20.6	3.7	22.2
Finger Millet	3.4	-	10.6	-	-	-	-	-
G. nut	51.7	57.7	56.1	56.4	56.2	48	48.1	52.4
Cowpea	4.6	1.8		2.6	30.5	20.6	16.7	30.2
B. Nut	11.5	1.8	9.1	2.6	33.3	30.4	27.8	33.3
Cotton	2.3	78.4	1.5	41	-	21.6	-	11.1
Sugar bean	8	-	4.5		-	-	-	3.2
Sunflower	2.3	-	-	-	-	2	-	3.2
Sugar cane	6.9	-	4.5	-	1	-	-	-
Mean area (ha)								
Maize	1	1.2	0.7	0.7	0.7	0.8	0.7	0.7
White Sorghum	-	0.5	-		0.3	0.9	0.3	0.6
Red sorghum	-	0.5	-	0.4	0.8	0.7	-	0.5
Pearl Millet	-	-	-	-	0.4	0.4	0.4	0.4
Finger Millet	0.2	-	0.1	-	-	-	-	-
Ground nut	0.2	0.4	0.2	0.3	0.1	0.2	0.1	0.2
Cowpea	0	0.2		0.2	0.1	0.1	0.1	0.2
Bambara Nut	0.1	0.1	0	0.1	0.1	0.1	0.1	0.1
Cotton	0.6	1.1	0.2	0.9	-	1.1	-	1.1
Sugar bean	0.1	-	0.1	-	-	-	-	0.1
Sunflower	0.2	-	-	-	-	0.4	-	0.1
Sugar cane	0.3	-	0.2	-	0.1	-	-	-

Table 7.2 Aggregate area shares of cultivated crops at sites

Crop	Wetter analogue pair				Drier analogue pair			
	MHH		FHH		MHH		FHH	
	Mazowe/ Goromonzi (cooler)	Kadoma (warmer)	Mazowe/ Goromonzi (cooler)	Kadoma (warmer)	Matobo (cooler)	Chiredzi (warmer)	Matobo (cooler)	Chiredzi (warmer)
	%[1]							
Maize	85	51	82	56	78	35	83	42
White sorghum	0	1	0	0	4	26	3	23
Red sorghum	0	0	0	1	1	14	0	12
Pearl millet	0	0	0	0	2	5	2	6
Finger millet	1	0	1	0	0	0	0	0
Groundnut	8	9	14	14	8	4	7	5
Cowpea	0	0	0	0	3	1	1	3
Bambara nut	1	0	0	0	4	2	4	3
Cotton	1	39	0	29	0	13	0	7
Sugar bean	1	0	1	0	0	0	0	0
Soybean	2	0	1	0	0	0	0	0
Others	1	0	0	0	0	0	0	0

[1]percent of total cropped area

7.3.1.2 Farmer selection criteria

Mazowe/Goromonzi, Kadoma, and semi-arid Matobo district (cooler) farmers preferred maize (Table 7.3). Chiredzi district (warmer) farmers preferred sorghum. The highest ranked legume crop was groundnut. Mazowe/Goromonzi district male and female farmers' mean crop rankings for cowpea, sorghum, and Bambara nut were different (Table 7.3). In Kadoma district males preferred maize and cotton while females preferred maize and groundnut.

Selection criteria at the sub-humid analogue pair were mostly similar. Criteria used to rank crops in Mazowe/Goromonzi and Kadoma districts included affordability of seed, availability of seed, crop product taste, ease of management, suitability for rainfall, suitability for soil type, market availability, and market prices.

At the semi-arid sites, Matobo district farmers' selection criteria for crops included affordability of seed, availability of seed, taste, ease of management, suitability for temperature, suitability for rainfall, suitability for soil type, market availability, market prices, and other uses (e.g. as animal/chicken feed). In Chiredzi district the criteria used by farmers included availability of seed, crop product taste, suitability for temperature, suitability for rainfall, suitability for soil type, marketability, early maturity, labour requirements, drought tolerance, and yield stability. Based on multi-criteria analysis, Mazowe/Goromonzi district farmers' scores were highest for sweet potatoes, groundnut, maize, and cowpea (Table 7.4). In Kadoma district, mean scores for most crops were high. At the semi-arid site, mean scores were mostly low except for sorghum and pearl millet. Mazowe/Goromonzi male groups' mean scores were highest for maize and cowpea, and Kadoma farmers' mean scores were highest for maize, sorghum, and groundnut. Scores were highest for maize, groundnut, cowpea, and Bambara nut for Kadoma FHHs, and for Mazowe/Goromonzi FHHs scores were highest for maize, groundnut, and cowpea.

Table 7.3 Crop mean ranks

Crop	Wetter analogue pair				Drier analogue pair			
	Male FGDs[1]		Female FGDs		Male FGDs		Female FGDs	
	Mazowe/ Goromonzi district (cooler)	Kadoma district (warmer)	Mazowe/ Goromonzi district (cooler)	Kadoma district (warmer)	Matobo district (cooler)	Chiredzi district (warmer)	Matobo district (cooler)	Chiredzi district (warmer)
Maize	1	1.5	1	1.5	1	2.5	1	2
Sorghum	6	5.5	9	6.5	2	1	2	1
Finger millet	-	6	8	-	-	-	-	-
Pearl millet	-	-	-	-	6	2	6	5
Ground nut	2	3	2	2.5	2.5	4	2.5	4
Cowpea	3	4	4.5	3.5	4.5	5	4.5	3
Bambara nut	4.5	5.5	7.5	5	3.5	4.5	4.5	6
Beans	-	-	-	5	-	-	-	-
Cotton	6	1.5	-	3	-	4	-	-
Potato	-	-	9.5	-	-	-	-	-
Pumpkin	8	-	-	-	-	-	-	-
Soya bean	6.5	6	4.5	7	-	-	-	-
Sugar bean	4	6	4.5	-	-	-	-	-
Sunflower	9	-	11	8.5	-	-	-	-
Sweet potato	3	-	5	-	5	-	3	-
Tobacco	8.5	6	6	8	-	-	-	-

[1]Focus group discussion

At the drier sites, Matobo male farmers' scores were highest for pearl millet, groundnut, and Bambara nut, and Chiredzi males scored sorghum and pearl millet highest. One of the Matobo female groups scored cowpea, groundnut, pearl millet, and sorghum highest. Chiredzi female farmers scored pearl millet, cotton, and sorghum highest.

Table 7.4 Mean scores for different crops

	Wetter analogue pair								Drier analogue pair					
	Male FGDs[1]				Female FGDs				Male FGDs			Female FGDs		
	Mazowe/ Goromonzi district (cooler)		Kadoma district (cooler)		Mazowe/ Goromonzi district (cooler)		Kadoma district (warmer)		Matobo district (cooler)		Chiredzi district (warmer)	Matobo district (cooler)		Chiredzi district (warmer)
Group	1	2	1	2	1	2	1	3	1	3	1	1	2	1
Maize	7.6	7.2	6.3	7.5	6.6	7.8	7.6	8.1	2.1	5.2	4.8	4	7.2	3
Sorghum	5.9	-	5.9	8	-	-	5.9	7.1	-	4.3	8.8	-	8.4	7
Pearl millet	-	-	-	-	-	-	-	-	-	5.9	8.6	-	8.4	7.8
Finger millet	-	-	-	5.9	4.3	-	-	-	-	-	-	-	-	-
Ground nut	6.6	7.7	5.7	8.1	7.1	8	6.6	8.3	1	5.7	-	2.2	8.4	-
Cowpea	8.8	-	6.6	9	7.1	6.9	8.8	10	0.6	5.3	-	2.6	9.4	-
Bambara nut	6	6.2	5	7.9	6.7	5.7	6.3	8.5	1.8	5.7	-	1.6	6.8	-
Cotton	6.6	-	6.3	5.4	-	-	6.6	7.4	-	-	6.8	-	-	8
Soya bean	4.6	5.3	-	-	4.7	5.5	5.1-	-	-	-	-	-	-	-
Sugar bean	-	6.9	-	7.1	5.1	5.9	-	8.2	-	-	-	-	-	-
Sunflower	6.6	-	-	-	-	-	6.6	7.7	-	-	-	-	-	-
Sweet potato	-	9.2	-	-	8.6	-	-	-	2.8	-	-	3.4	-	-
Irish Potato	-	-	-	-	5.3	-	-	-	-	-	-	-	-	-
Tobacco	3.6	-	-	-	-	-	3.6	-	-	-	-	-	-	-

[1]Focus group discussion

7.3.1.3 Participatory on-station crop evaluations

Mazowe district males ranked sorghum highest at Henderson Research Station (Table 7.5). Kadoma district male and female farmers also ranked the performance of sorghum highest compared to other crops. However, Mazowe/Goromonzi, Kadoma, and Matobo districts farmers preferred maize, the main staple crop. Maize is also a cash crop, particularly in Mazowe and Kadoma districts. Chiredzi farmers preferred sorghum. Farmer criteria for crop rankings were yield related and plant morphology related. Matobo farmers ranked performance of sorghum highest followed by groundnut. Chiredzi male farmers chose groundnut and female farmers selected sorghum.

Table 7.5 Farmer rankings of crops grown at analogue sites

pair	Station	Group	Crop Rank			
			1	2	3	4
Wetter pair	Mazowe (cooler)	Mazowe/Goromonzi male farmers	Sorghum	Maize	Groundnut	Cowpea
	Kadoma (warmer)	Mazowe/Goromonzi male farmers	Sorghum	Cowpea	Maize	Groundnut
		Kadoma male farmers	Sorghum	Maize	Cowpea	Groundnut
	Mazowe (cooler)	Mazowe/Goromonzi female farmers	Maize	Sorghum	Groundnut	Cowpea
	Kadoma (warmer)	Mazowe/Goromonzi female farmers	Sorghum	Cowpea	Maize	Groundnut
		Kadoma female farmers	Sorghum	Maize	Cowpea	Groundnut
Drier pair	Matopos (cooler)	Matobo male farmers	Sorghum	Groundnut	Cowpea	Maize
	Chiredzi (warmer)	Matobo male farmers	Sorghum	Groundnut	Cowpea	Maize
		Chiredzi d male farmers	Groundnut	cowpea	sorghum	Maize
	Matopos (cooler)	Matobo female farmers	Sorghum	Groundnut	Cowpea	Maize
	Chiredzi (warmer)	Matobo female farmers	Groundnut	Maize	Sorghum	Cowpea
		Chiredzi female farmers	Sorghum	cowpea	Groundnut	Maize

1 = best performance 4 = least performance

7.3.2 Soil and water management

7.3.2.1 Soil and water management strategies used in different climates

At the sub-humid sites, more than 40% of households used reduced tillage and mulching for soil and water management (Table 7.6). Higher proportions of Kadoma district farmers compared to Mazowe/Goromonzi district farmers used various reduced tillage methods such as conservation agriculture. Meanwhile, use of contour ridges was lower in Kadoma district compared to Mazowe/Goromonzi district. At least 40% of households used reduced tillage, contour ridges, and mulching in Matobo district. The proportion of MHHs and FHHs in Matobo that used reduced tillage and contour ridges was higher compared to Chiredzi MHHs and FHHs. Use of mulching and winter ploughing was also higher in Matobo district compared to Chiredzi district for MHHs.

Responses from household surveys showed that the main reason given for using soil and water management was to improve yields. In addition, Matobo farmers mentioned that reduced tillage eased farming operations and was being widely promoted. Some farmers mentioned that mulching was easy to manage. In Mazowe district, farmers mentioned that they used reduced tillage to improve yields and mulching for controlling pests/diseases. Other reasons for using soil and water management are mentioned in detail in the discussion section. Use and knowledge of soil and water management technologies did not differ by gender for the analogue pairs.

The most commonly used soil fertility strategies were fertilizer, manure, and compost application (Table 7.6). More than 90% of households at the sub-humid analogue pair used chemical fertilizer (Table 7.6). The proportion of households that used different fertility management strategies was similar at the wetter analogue pair, with the exception of chemical fertilizer. Kadoma FHHs used less fertilizer compared to Mazowe/Goromonzi FHHs. Eighty five percent and 75% of households in Mazowe/Goromonzi and Kadoma, respectively, used animal manure. Use of chemical fertilizer, animal manure, and compost was higher in Mazowe/Goromonzi compared to Kadoma. At the drier sites, the proportion of both MHHs and FHHs that used either chemical fertilizer or animal manure and chemical fertilizer was higher in Matobo district than in Chiredzi district.

7.3.2.2 Farmer preferences – soil and water management strategies

The criteria used by farmers to select soil and water management methods included labour requirements, availability of resources and effectiveness, and suitability and wide promotion. The highest ranked strategies included winter ploughing and ridging. In contrast, matrix scores were highest for reduced tillage and mulching (Table 7.7).

Mean scores were generally highest for reduced tillage methods and mulching for males at the wetter sites of Mazowe/Goromonzi and Kadoma (Table 7.7). Scores of females in Kadoma were highest for reduced tillage in one of the focus groups and mulching in the other group. Meanwhile, reduced tillage methods had the highest scores at the drier, cooler Matobo study sites (Table 7.7). Farmers' selection criteria for fertility management strategies included effectiveness, low cost, and availability of inputs. Use of chemical fertilizer was the most preferred method for soil fertility improvement across all sites. Mean scores of multiple criteria were highest for chemical fertilizer at the wetter sites and in Matobo district (Table 7.7). Chiredzi district focus groups did not evaluate strategies for soil fertility amendments. Chiredzi households' use of soil amendments was low. Chiredzi farmers mentioned that unreliable rainfall and high temperatures limit the use of organic and inorganic fertilizer. In scoring for soil fertility management strategies, most focus groups scored chemical fertilizer use the best, based on effectiveness. Exceptions were the second group of Mazowe/Goromonzi farmers who scored reduced tillage highest, and Matobo male farmers who gave higher scores to reduced tillage and manure.

Table 7.6 Use of soil and water management technologies

Strategies	Wetter sites						Drier sites					
	Male-headed households			Female headed households			Male headed households			Female headed households		
	Mazowe/ Goromonzi (cooler)	Kadoma (warmer)		Mazowe/ Goromonzi (cooler)	Kadoma (warmer)		Matobo (cooler)	Chiredzi (warmer)		Matobo (cooler)	Chiredzi (warmer)	
	%	%	χ^2	%	%	χ^2	%	%	χ^2	%	%	χ^2
Soil and water management												
Tied ridges	13.8	23.4	2.917	9.1	15.4	0.959	10.5	5	2.254	14.8	1.6	-
Water harvesting	10.3	2.7	-	0	2.6	-	3.8	2.9	-	3.7	1.6	-
Pot holing	10.3	0.9	9.071**	1.5	0	-	0	0	-	1.9	14.3	-
Contour ridges	34.5	6.3	25.483***	30.3	0	14.599***	51.4	33.7	6.183*	38.9	14.3	9.231**
Reduced tillage	49.4	82	24.035***	57.6	84.6	8.186**	53.3	8.9	47.585***	53.7	9.5	27.070***
Mulching	58.6	62.2	0.256	63.6	69.2	0.341	31.4	13.9	8.123**	24.1	15.9	2.012
Winter ploughing	3.4	15.3	8.702**	3	12.8	-	10.5	1	8.543**	11.1	1.6	-
Gulleys	5.8	0	-	0	0	-	0	2	-	1.9	1.6	-
Multiple weeding	0	0	-	0	0	-	1.9	3	-	0	7.9	-
Soil fertility management												
Animal manure	86.2	73.9	5.666*	84.9	79.5	0.496	78.1	29.7	47.495***	63	17.5	25.751***
Compost	73.6	64.9	1.716	72.7	61.5	1.424	68.6	19.8	48.411***	79.6	14.3	47.670***
Crop rotation	52.9	62.2	1.728	56.1	66.7	1.149	41.9	27.5	4.185*	24.1	22.2	.056
Chemical fertilizer	98.9	97.3	0.594	100	92.3	?5.226*	91.4	5.9	151.486***	87	3.2	84.014***
n	87	111	*N/A*	66	39	*N/A*	105	102	*N/A*	54	63	*N/A*

*Significant at the 10% level, **Significant at the 5% level, ***Significant at the 1% level

Table 7.7 Soil and water management strategies mean scores

	Wetter sites								Drier sites			
	Male FGs				Female FGs				Male FGs		Female FGs	
	Mazowe/ Goromonzi district		Kadoma district		Mazowe/ Goromonzi district		Kadoma district		Matobo district		Matobo district	
	1	2	1	2	1	2	1	2	1	2	1	2
Soil and Water management strategies												
Reduced tillage methods	5.4	8.2	-	7.3	-	8	5.4	7.8	8		8.4	
Contours	-	-	-	-	7.3	-	-	-	-		-	
Cultivation	-	-	6.4	-	-	-	-	-	-		-	
Deep ploughing	-	-	-	-	-	-	-	-	6.4		-	
Manure	5.8	5.8	-	-	-	-	5.8	6.3	-		-	
Mulching	8.2	-	5.2	7.8	6.3	4.2	8.2	6.8	-		-	
Ridging	7	-	7.2	5.8	-	-	7	7.5	-		-	
Tied ridges	5.6	-	7.2	-	-	-	5.6	-	-		-	
Water harvesting pits	-	-	-	-	-	-	-	-	4.2		-	
Winter ploughing	-	-	7.2	6.3	-	-	-	-	6.4		6.6	
Soil fertility management strategies												
Reduced tillage	-	6.8	-	-	-	-	-	-	-	-	-	-
Compost	6.5	-	5	6.8	7.3	6.8	5.4	6.5	2.5	-	5.8	7.6
Crop rotation	-	-	-	8.3	-	7.2	-	-	5	2.3	-	-
Chemical Fertilizer	8.8	5.5	7.5	8.3	9.8	8.4	7.2	9.5	5	4.3	5.5	6.6
Leaf litter	-	-	4.8	-	-	-	-	-	-	-	-	-
Lime	-	-	-	-	8	-	-	-	-	-	-	-
Manure	7	3.4	5.3	5.8	7	7.2	6	6.5	3.8	3.8	5.3	5
Termitaria	-	-	-	-	4.8	4.5	-	4	-	-	2.8	6
Winter plough (green manure)	-	-	-	6	-	-	-	-	-	-	-	-

*FGs = Focus groups; NB. Chiredzi farmers mentioned that they do not usually use soil and water management strategies

Constraints on the use of mulching identified by respondents from Matobo, Chiredzi, and Kadoma districts include labour intensiveness and lack of inputs such as the mulch. Chiredzi respondents also cited the irrelevance of mulching in their area because of high temperatures and mainly fertile soils. Respondents from both MHHs and FHHs regarded labour demands as the main constraint on reduced tillage use. High proportions of respondents from Chiredzi and Mazowe/Goromonzi who know of reduced tillage are not yet confident enough to use the technology.

7.3.3 Social innovations by farmers

Farmers organised themselves into informal (self-help) groups and formal social groups (e.g. formal co-operatives) to counteract socio-economic challenges and human capital deficits (Table 7.8).

The social groups mentioned at the study sites included those in which farmers assisted each other in soil and water management, increased access to financial capital through money clubs, and supported poultry production at the wetter sites. At the drier sites, farmers had nutrition and income-generating projects (Table 7.8).

At the sub-humid study sites, family members from MHHs mainly participated in conservation agriculture groups, and members from FHHs in Mazowe/Goromonzi mainly participated in conservation agriculture and HIV/AIDS support groups. At the drier sites, Matobo and Chiredzi MHH members belonged to nutrition and income-generation groups in addition to conservation agriculture groups for Chiredzi MHHs. Meanwhile, Matobo and Chiredzi FHHs participated in behavioural change activities. In addition, Chiredzi FHH members belonged to nutrition and income-generation projects. The nutrition and income-generation projects included cooperatives for market gardening.

Table 7.8 Membership to farmers groups at study sites

Purpose of group	Wetter sites				Drier sites			
	MHH		FHH		MHH		FHH	
	Mazowe/ Goromonzi district	Kadoma district	Mazowe/ Goromonzi district	Kadoma district	Matobo district	Chiredzi district	Matobo district	Chiredzi district
Produce seed and improve seed availability	0	0	0	0	0	3.7	0	0
Management of soil and water	24.3	26.5	16.7	4.0	2.8	18.5	0	5.9
Nutrition and income generation	0	5.9	0	4.0	13.9	37.0	0	32.4
Labour groups	0	0	4.2	8.0	0	0	5.3	5.9
Acquiring inputs	0	0	0	0	0	0	0	2.9
Baking for income	0	0	0	0	0	0	0	2.9
Money lending clubs	2.7	2.9	4.2	8.0	0	3.7	0	8.8
Poultry production	0	2.9	4.2	4.0	2.8	0	0	0
Burial planning	5.4	0	0	0	25.0	0	10.5	0
Building community facilities	0	0	4.2	0	0	3.7	0	0
HIV/AIDS support groups	2.7	0	33.3	28.0	2.8	0	15.8	58.8
Sewing	0	2.9	0	0	0	0	0	0
n	*36*	*27*	*19*	*34*	*37*	*34*	*24*	*25*

7.3.4 Farmer strategies in response to climate change and variability

Farmer response strategies to climate change and variability are summarised in Table 7.9. At the sub-humid study sites of Mazowe/Goromonzi the most mentioned strategies used by MHHs in response to climate change and variability included growing short-season varieties and livestock supplementary feeding. The farmers also searched for alternative sources of water for livestock and, in addition to farming activities, they increased dependence on other livelihood sources. Kadoma MHHs mostly depended on other livelihood sources followed by labour sales. Other strategies implemented in response to climate change and variability included dozing/vaccination of livestock and alternative sources of water for livestock. Meanwhile, FHHs at the sub-humid study sites mainly mentioned dependence on other livelihood sources as a response strategy to climate change and variability.

At the semi-arid study site in Matobo district MHHs mainly used short-season varieties, implemented supplementary livestock feeding, and bought grain food in response to climate change and variability. Chiredzi MHHs mainly mentioned supplementary livestock feeding, market gardening, and buying of grain food. They also engaged in other livelihood activities. Matobo FHHs' most mentioned response strategy was to use supplementary feeding, and Chiredzi FHHs' most mentioned strategies included supplementary livestock feeding, market gardening, and diversification to other livelihoods sources.

Table 7.9 Farmers' adaptation/coping strategies

Strategies	Wetter sites				Drier sites			
	MHHs		FHHs		MHHs		FHHs	
	Mazowe/ Goromonzi district	Kadoma district	Mazowe/ Goromonzi district	Kadoma district	Matobo district	Chiredzi district	Matobo district	Chiredzi district
Continue with usual practices	✓✓	✓	✓	✓	✓✓✓	✓✓	✓✓	✓✓
Wait for rain before planting	-	-	-	-	✓	-	✓	-
Early land preparation	-	✓	-	-	-	-	✓	-
Staggering	✓	✓	✓	✓	✓	✓	✓	✓
Seed priming	-	-	-	-	✓	✓	-	✓
Replanting	✓	✓	-	✓	✓	✓	✓	✓✓
Dry planting	✓	✓	✓	✓	✓	✓	-	✓
Reduced tillage methods (basins, CA, no till)	✓	✓	✓	✓	✓✓	✓	✓	✓
Mulching	✓	-	✓	-	✓	-	✓	-
Construction of small dams	-	-	-	-	✓	-	✓	-
Spraying to control crop pests(pest control)	✓	-	-	-	✓	-	✓	✓
Growing short season varieties	✓✓	✓✓	✓	✓	✓✓✓	✓	✓✓	✓
Soil fertility management	-	-	-	-	-	-	✓	-
Culling herd/of old stock	✓	✓	-	✓	✓	✓	-	✓
Livestock supplementary feeding	✓✓	✓	✓✓	✓	✓✓✓	✓✓	✓✓✓	✓✓✓
Feeding livestock with *Neorautanenia amboensis* (Schinz) *	-	-	-	-	-	✓✓	-	✓✓
Look for alternative pastures	-	-	-	-	-	✓	-	✓
Reserving part of arable land for grazing	✓	✓	-	-	✓	✓	✓	✓
Look for alternative water sources	✓✓	✓✓	✓✓	✓✓	✓	-	✓	-
Buy salt for livestock to increase appetite	✓	✓	-	-	-	-	-	-
Dozing /vaccinating	✓	✓✓	✓	✓	✓	✓	✓	✓
Labour sales	✓	✓✓	✓	✓	✓✓	✓	✓✓	✓✓
Gardening/market gardening	✓	✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓✓
Small grain seed multiplication and sales	✓	-	-	-	✓	-	-	-
Bought food/grain	✓	✓	✓	✓	✓✓✓	✓✓	✓✓	✓
Migrating for employment	✓	-	-	-	-	✓	-	-
Sale of livestock	✓	✓	-	✓	✓	-	✓	✓
Food aid	-	-	✓	✓	✓	✓	✓	✓
Hospital assistance	✓	-	-	-	✓	-	-	-
Walking long distances to fetch water	-	-	-	-	✓	-	✓	-
Other livelihoods	✓✓	✓✓✓	✓✓✓	✓✓✓	✓	✓✓	✓✓	✓✓✓
n	29	28	23	22	60	30	32	40

✓ represents 1-5 responses ✓✓ represents 6-14 responses ✓✓✓ represents greater than 15 responses

*Tuber shrub known as *'Zhombwe'*

7.3.5 Livelihood strategies – farmer preferences

Livelihood sources at the study sites included crop and livestock production, non-farm employment, and remittances from family members (Table 7.10).

Table 7.10 Farmers' livelihoods

Livelihood	Description
Crop production	May include maize, groundnut, cash crops such as cotton, small grains
Livestock production	Cattle, goats, local chicken
Horticulture	Vegetables, tomatoes, onions
Remittances	Remittances from family members
Non-farming activities	Craft, weaving, selling thatching grass, petty trading, beer brewing, selling firewood, selling fruits, sandal making/repair, fishing, gold panning, poaching
Casual employment	Brick moulding, building, labour sales, labour migration
Pension	
Formal employment	Teaching, selling in shops

Rankings of livelihood sources for MHHs and FHHs varied by analogue site. Crop production was the most important followed by market gardening, livestock production (poultry production), and fishing for Mazowe district male farmers. Rankings in order of importance were crop production, livestock production, buying and selling, and building for Goromonzi male farmers. Differences in preferences of older farmers and younger farmers were also apparent during the discussions. Goromonzi district older male farmers (>35 years) preferred crop production and the younger male farmers (<35 years) preferred horticulture (vegetables and tomatoes). Kadoma male farmers' rankings of livelihood sources were crop production, livestock production, gold panning, fishing, gardening, brick moulding, selling firewood, and poultry production, in descending order. The second group of males concurred that crop production was most important followed by livestock production, gold panning (younger men) and remittances (older men), fishing, poultry production, and lastly donor aid.

Goromonzi district female farmers' rankings of livelihood sources were market gardening, crop production, poultry production, internal savings and lending, brick making, and selling firewood, in descending order. The most important for Mazowe females was crop production followed by petty trading at local markets. Other livelihoods mentioned in Mazowe district included selling firewood, peanut butter making, and sewing. The first Kadoma female group rankings were, in order, crop production, gardening, buying and selling and crafts (weaving), selling thatching grass, poultry production, off-farm labour, livestock production (goats), sewing, and brick moulding.

Semi-arid Matobo district (cooler) farmers' rankings of livelihood sources were market gardening, crop production, livestock production, formal employment, casual/self-employment, selling thatching grass, fishing, selling firewood, and gold panning, in descending order for first male group. The second male FGD rankings of livelihoods, in order of importance, were crop production followed by livestock production, market gardening, brick moulding, fishing, crafts, building chicken projects, and sandal making/repair. Elderly males preferred market gardening and younger males preferred brick moulding. Younger males also perceived gold panning and fishing to be important sources of livelihoods. The first Chiredzi male focus group ranked crop production (maize, sorghum) highest, followed by livestock production (selling cattle and milk), selling (craftwork, bricks, thatching grass, fish, firewood), and working in neighbouring countries; and female rankings were, in order, selling firewood, labour sales, beer brewing, and vegetable gardening. The second Chiredzi group ranked livestock production as most important followed by crop production, beer brewing, and then labour sales.

Matobo female FGD rankings were, in order, gardening, crop production, poultry, livestock production, selling of fruits, vending, selling thatching grass, building, selling firewood, and traditional crafts. Chiredzi females preferred crop production (maize, tobacco, sorghum) followed by selling (petty trading, vegetables, thatching grass, beer brewing), brick moulding, rearing local chickens, and fishing. In Chiredzi, farmers mentioned that younger men migrate to seek employment.

7.3.6 Case studies of adaptation strategies in different smallholder areas of Zimbabwe

Conservation agriculture

Kadoma District (Sanyati, Gambiza) – Mr. and Mrs. L, interviewed in May 2013, mentioned that they had been using conservation agriculture (CA; basins) since the 2009/2010 season. They reported that few households in the community used the technology due to the high labour demands. However, their household used CA because it enabled them to plant with the first effective rains. According to the farmers, CA improved nutrient available for plants and increased amount of soil moisture available for plant growth. This, in turn, resulted in higher maize yields compared to maize grown using conventional practices. According to the farmer, before practising CA the household obtained harvests ranging from 1.5 -6.7 bags and harvests averaging 12 bags on the same size of land. The farmers reported that conventional practises sometimes resulted in crops wilting whereas crops in basins where more tolerant to adverse conditions. Other benefits mentioned by the farmers included improved weed management since they applied herbicide to reduce weed challenges. To deal with high labour demands the 58 years old farmer said they start preparation early.

a

Mr. and Mrs. Mutsa of Goromonzi started using CA in 2011 when the technology was introduced by various NGOs and government. According to the farmers, the CA technology enables farmers to plant with first effective rains. They mentioned that due to shortening of the rain season, early land preparation and planning was necessary. According to the farmers, before using CA maize harvest was about 7 bags of maize from the 2 acres but after introduction of CA technologies harvest increased to about 70 bags (3.5 tons). According to the farmers, since they started mulch, weed challenges were fewer. The female farmer also highlighted that fewer males participated in farmer groups involved in soil and water management such as CA.

b


C


d

Irrigation in a Chiredzi.
A well –resourced MHH installed facilities for micro-irrigation at its homestead. The household produced horticultural products that included vegetables and sold them to the local community (c). They also irrigated maize for household consumption. Small livestock such as goats were provided with water from the borehole (d) using the borehole water. The household demonstrated that it was possible to adapt to adverse conditions, depending on resources available.


e

Other sources of income for Chiredzi FHHs
Many female headed households in Chiredzi are resource poor and depend on different forms of livelihoods amongst them brick-making. This photo shows that mainly women and children were involved in brick making.

7.4 Discussion

The analysis of climate changes and their impacts on agriculture, the identification of possible response options to climate change, and the prioritization of response options (Lee et al., 2014) are important in the development of local adaptation strategies to climate change in agriculture. This study explored resource-based adaptation pathways/transitions and requirements for MHHs and FHHs in sub-humid and semi-arid smallholdings of Zimbabwe using climate analogue analysis. Wood et al. (2014) showed that in West Africa, wealth (as measured by household and agricultural production-related assets) was associated with households that were making farming changes, i.e. cropping decisions related to climatic variability. These farming changes included agricultural timing, land management and increased fertilizer use. Male-led and female-led households at the study sites had different resources that influenced agricultural adaptation to climate change. A summary of differences in resource ownership and access between MHHs and FHHs at the study sites is given in Table 7.11.

Table 7.11 Summary of FHHs capital assets compared to MHHs at study sites

Assets	Sites	Mazowe/Goromonzi district	Kadoma district	Matobo district	Chiredzi district
Human capital	Age	Older	Older	Older	Younger
	Farming experience	Higher	Higher	Higher	Lower
	Education level	Lower	Lower	Lower	Lower
	Family size	Similar	Similar	Smaller	Smaller
	Family labour	Similar	Similar	Similar	Lower
	Male adult labour	Lower	Lower	Lower	Lower
	Head of household full-time farmers	More	More	More	Similar
Natural capital	Farm size	Smaller	Smaller	Similar	Similar
Physical	TLUs	Lower	Similar	Lower	Lower
	Agricultural equipment	Similar	Similar	Lower	Lower
Financial	Income	Lower	Lower	Lower	Similar
	Per capita income	Lower			

(black)	Denotes similar levels	(blue)	Denotes higher levels/more	(red)	Denotes lower levels

Lower levels of human capital (e.g. education levels) of females at all sites may be related to preferences for educating males compared to females. Education levels and skills can influence access to resources such as credit, alternative livelihoods, and knowledge of farming technologies. Policies and advocacy for the education of female children may improve education levels of women and improve their options for livelihoods and access to credit. Lower levels of financial capital in FHHs than in MHHs was also noted in other studies (e.g. Doss, 2001). Lower financial capital of FHHs compared to MHHs may in part be due to lower productivity as well as to fewer alternative livelihood sources. Males at the study sites either produced more cash crops, particularly at the sub-humid sites, and/or engaged more in off-farm employment compared to women, and therefore had a wider range of sources of income. Female-headed households had lower productivity, in part due to low land size and lower resources. Access to financial capital may influence the ability of these households to implement management strategies with high financial demands and access agricultural equipment or hired labour. The lower financial capital assets of FHHs compared MHHs also account for the limited access to physical assets, for example agricultural equipment in Matobo and Chiredzi.

Male-led households also owned more land in sub-humid areas with higher agricultural potential compared to FHHs, whereas farm size was similar between MHHs and FHHs at the lower-potential semi-arid study sites. In addition, males mainly owned large livestock (Njuki and Mburu, 2003). Most of the female-led households were *de jure* FHHs. Absence of adult male labour could affect timing of farming activities that include land preparation, as well as adoption of technologies with high labour demands such as most of the soil and water management strategies. Therefore, based on the resources assessed in this study, FHHs at the study sites encountered more barriers to climate change adaptation compared to MHHs. Addressing current socio-economic challenges is necessary to enhance adaptation to current and future climates.

Climate change may result in different levels of resource ownership. Different levels of resource ownership of farmers at the reference sites may be due to the impacts of climate or other factors associated with the socio-economic and physical environments of the farmers. Table 7.12 also shows variation in resource ownership between males at the different analogue sites as well as females at the different analogue sites.

Table 7.12 Resources of MHHs and FHHs at reference sites compared to those at analogue sites

Assets	Sites	Mazowe/Goromonzi district compared to Kadoma district		Matobo district compared to Chiredzi district	
		MHHs	FHHs	MHHs	FHHs
Human capital	Age			Older	
	Farming experience		Higher		Higher
	Education level		Higher	Lower	Lower
	Family size				
	Family labour				
	Adult family labour				
	Adult units/hectare	Higher	Higher	Higher	Higher
	Male adult labour				
	Head of household full-time farmers			Lower	
Natural capital	Farm size	Smaller	Smaller	Smaller	Smaller
Physical	TLUs			Goats	
	Agricultural equipment	Lower			
Financial	Income			Higher	

	Denotes similar levels		Denotes higher levels/more		Denotes lower levels

Notably farm size was smaller at the reference sites compared to the analogue sites. There were also more human capital constraints, labour in particular, at the warmer analogue sites compared to the reference sites. Optimizing the access to resources required for different adaptation pathways in MHHs and FHHs is necessary for mainstreaming gender in climate change adaptation. Policies for agricultural adaptation in smallholder agriculture should target both the causes of gendered differences in resource ownership as well as the effects of climate change on the socio-economic environment of smallholder farmers. Smallholder responses to climate change occur in different cultural, political, economic, environmental, and developmental contexts (Wise et al., 2014). The integration of adaptation responses to climate and global change with human development is therefore important for smallholder agriculture (Butler et al., 2014).

Farmers at both the sub-humid and semi-arid study sites can explore different adaptation pathways/transitions depending on resource availability. Individual households' adaptation pathways may include a combination any of the following: crop production, livestock production, horticulture, and other livelihood activities. Two transition pathways are outlined for MHHs and three for FHHs at the study sites. Firstly, MHHs and FHHs at the reference sites may transition to the practices of MHHs and

FHHs at the analogue site locations. Secondly, other transition pathways for both MHHs and FHHs can include practices not currently employed or fully explored due to resource limitations. Thirdly, FHHs adaptation pathways can also include those of MHHs provided gender differences in resource levels are addressed. Strategies used by MHHs are assumed to be more resilient. Adaptation pathways and/or transitions that Mazowe/Goromonzi MHHs and FHHs may explore in response to warmer climates by the middle of the 21st century are illustrated in Figure 7.1.

The current farming systems in Mazowe/Goromonzi consist of crop production, livestock production, horticulture, and off-farm farm employment, while the farming practices of Kadoma district mainly include crop production and livestock production. Kadoma farmers produced more cash crops with respect to scale, i.e. maize and cotton, while farmers at the sub-humid Mazowe/Goromonzi study sites, in particular male farmers, also depended on horticulture as a source of income. Aggregate share of cropped area shows that groundnut is also an important crop for Mazowe/Goromonzi and Kadoma FHHs. Farmer selection criteria appear to match closely the main crops grown. Mazowe/Goromonzi MHHs and FHHs may shift from growing only maize to growing other cash crops such as cotton for household income (Figure 7.1). Benefits such as increased productivity, market returns from innovation, ability to cope with adverse climatic and market events, food security, and maintaining traditional practices all may influence crop choices (McCord et al., 2015). Crop diversification therefore may be important for 2050s climates in Mazowe/Goromonzi.

Evidence from farmer perceptions at both sub-humid study sites, as well as from other studies (Tadross et al., 2005; 2007; Nyabako and Manzungu, 2012), also suggests that the growing season may become shorter. Farmers at the study sites also preferred short-season varieties of maize during participatory evaluations. Farmer responses to climate change and variability indicate that coping strategies at the study sites can include planting short-season varieties (Figure 7.1).

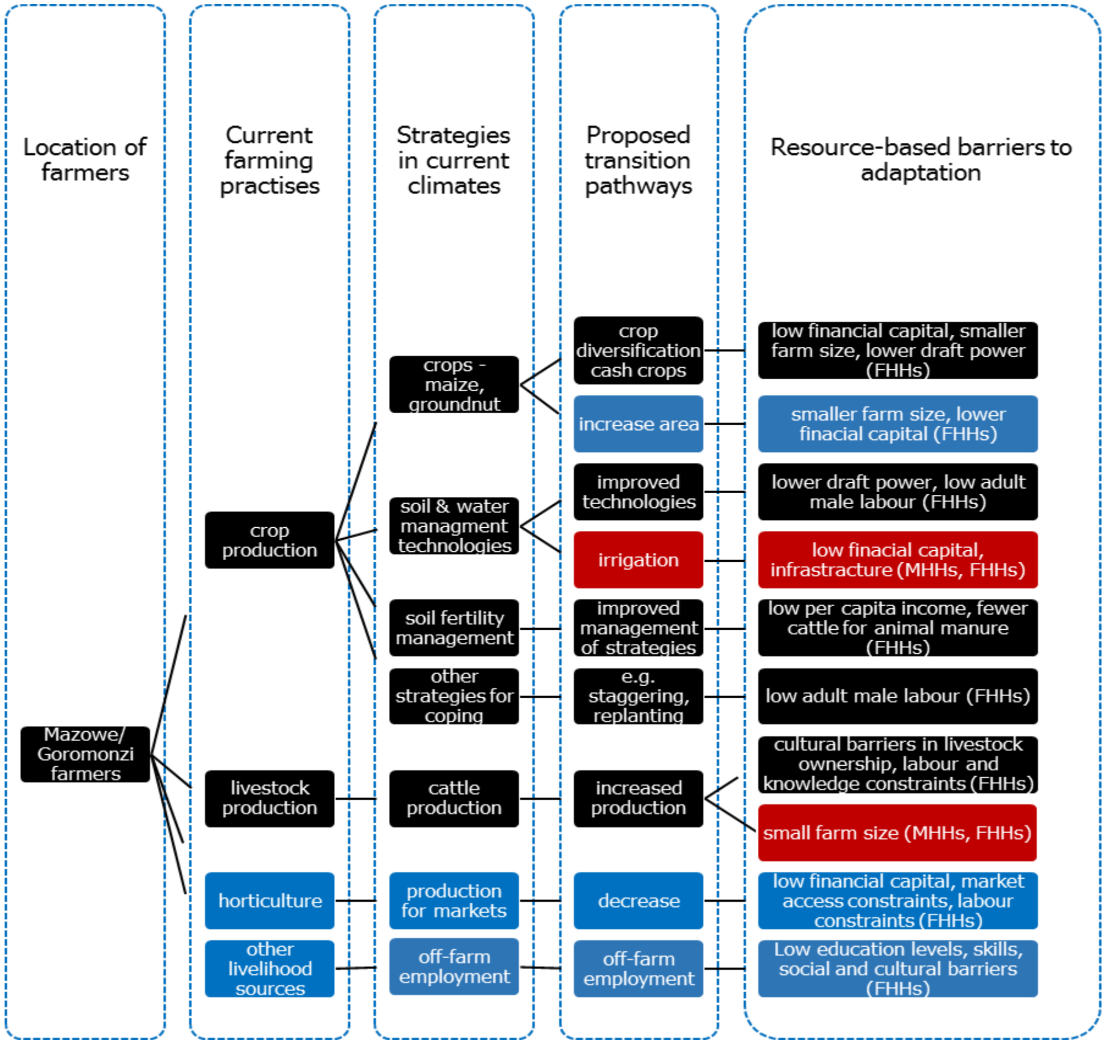

Figure 7.1 Adaptation pathways for Mazowe/Goromonzi households

Black boxes represent pathways that may be followed by both MHHs and FHHs. These are derived from comparisons of practices at the reference site in Mazowe/Goromonzi district and the analogue site in Kadoma district.

Blue boxes represent pathways of MHHs only, derived from comparisons of practices of MHHs at the reference and analogue sites. The FHHs can transition to these strategies provided differences in resource ownership are addressed.

Red boxes represent other pathways that may be explored by both MHHs and FHHs. These are currently not used at the study sites due to several barriers.

In addition to crop diversification, growing short-season varieties may become easier in future climates (Nyabako and Manzungu, 2012). Concerning crop production, there were no gendered differences in crop choices at the different sites, suggesting that both MHHs and FHHs may transition to similar crops, i.e. more cash crops and crop diversification.

At the study sites, MHHs mainly had large areas devoted to cash crops, in contrast to FHHs. Meanwhile, the crop area for legumes was mostly similar for FHHs and MHHs. More cultivated land and more maize area in Kadoma district than in Mazowe/Goromonzi district could be associated with higher land holding by farmers. Increasing the area under cultivation could also be a coping strategy for improving total production when yields become reduced due to climate change. However, average farm sizes in Mazowe/Goromonzi were lower than those in Kadoma district and may thus limit coping through increasing the cultivated area. Women owned smaller farms compared to men and are thus more limited with respect to increasing cultivated land areas. In addition, population pressure as well as land use change may further affect farm sizes. Transition pathways for FHHs could include growing cash crops in smaller areas compared to MHHs, a strategy that would allow them to deal with a shortage of the capital assets that are usually required for crops such as maize and cotton. Cash crops often have high capital demands for inputs such as seed, fertilizer, and hired labour. Female-headed households often grow fewer crops that require more resources and financial capital compared to MHHs (e.g. Mackenzie, 1998). Strategies that increase access to financial capital and farm sizes owned by women, and that may promote increasing farm areas to levels similar to those of MHHs, can include financing for women-managed income-generating projects.

Tied ridges, reduced tillage methods, and winter ploughing were used by higher proportions of Kadoma district farmers than Mazowe/Goromonzi district farmers, while there were no differences in the use of mulching. In contrast, contour ridges were used by higher proportions of households in Mazowe/Goromonzi than in Kadoma. These results suggest increased use of appropriate soil and water management strategies for adaptation to the warmer Mazowe/Goromonzi district climates. The types of strategies required may depend on effectiveness, resource levels, topology, and other soil characteristics. Multiple criteria analysis scores were in general highest for reduced tillage methods and mulching in Mazowe/Goromonzi and Kadoma.

Both MHHs and FHHs mentioned that soil and water management strategies have high labour demands. They also mentioned a lack of other resources such as mulch and manure that are required for some of the strategies. Andersson and D'Souza (2014) also referred to resource constraints on adoption of conservation agriculture. Despite the high labour demands associated with implementing soil and water management strategies, e.g. conservation agriculture (Mazvimavi et al., 2011), and lower adult male labour in FHHs, there were no differences in the use of strategies between MHHs and FHHs. The absence of gendered differences in the use of soil and water management strategies at the sub-humid study sites contrasts with findings from other studies that showed lower adoption of technologies by FHHs compared to MHHs (e.g. Ndiritu et al., 2014). Possible explanations for this observation could be that FHHs cultivated smaller areas and practised the technologies on smaller areas. In addition, they may have adopted fewer components of the different strategies or managed the technologies differently. In some Zimbabwean smallholder areas, for example, female-headed households adopted fewer components of conservation agriculture compared to MHHs (Mazvimavi and Twomlow, 2009). Meanwhile, dead level contours managed by males performed better than those managed by women (Munamati and Nyagumbo, 2010). They attributed this observation to the low resource endowment of females. Year to year variation in soil use and water management may occur. These results for soil and water management were based on one year's study. Panel data may be required to capture inter-seasonal variations.

The choice of adaptations will depend on other factors including biophysical characteristics such as slope, soil type, socio-economic characteristics, and farmer perceptions. Multi-criteria analysis and ranking showed that preferences varied by gender of household and by site. However, reduced tillage methods and mulching had high ranks at both sub-humid study sites. Case studies showed that households at each study site differed in their choices of soil and water management strategies, with some using the strategies despite high labour demands due to the topology as well as the perceived benefits of the technologies. Males were, however, mainly involved in the management of the technologies except in cases where groups of farmers assisted each other. Mazowe district males, for example, mentioned that labour demands for soil and water strategies were too high for women. Farmers mentioned that they start preparing for reduced tillage, i.e. conservation agriculture, early by enabling spatial distribution of labour. Indications are that technological interventions that reduce labour and form and enhance social groups that facilitate participation and resource exchange by both males and females may enhance the use of strategies by FHHs.

Irrigation remains largely unexplored for smallholder farming systems due to the high costs associated with its implementation, as well as the technical skills required. Investments in small-scale irrigation can be an option for increasing production. Investments in small-scale irrigation or in cooperatives can enhance productivity in FHHs.

Most smallholder areas are characterized by inherently low soil fertility and declining soil fertility (e.g. Nyamangara et al., 2000; Mafongoya et al., 2007). Survey results indicated that farmer perceptions of soil fertility risks to production were low, while FGDs revealed that farmers in Mazowe/Goromonzi were aware that their soils had low fertility and required fertilizer. There is therefore a need for soil fertility management. Chemical fertilizer, animal manure, and compost applications were the main strategies employed to improve soil fertility status in the sub-humid Mazowe/Goromonzi (cooler) and Kadoma (warmer) districts. Chemical fertilizer use was, however, the most preferred and most used soil management strategy. Soil fertility management can reduce the effects of rainfall variability in smallholder cropping systems (Rurinda et al., 2013). Concerning soil fertility management, FHHs applied fertilizer on smaller crop areas compared to MHHs. Lower accesses to financial capital for FHHs compared to MHHs can imply low capacity to buy the required amounts of fertilizer for crop production. The average cash crop area of FHHs was smaller than that of MHHs. This could be associated with a shortage of financial capital that limits the ability of these farmers to buy inputs such as fertilizer. During FGDs, farmers also mentioned constraints on access, i.e. buying and transporting the fertilizer needed for production.

In addition to crop production, farmers at the study sites also engaged in horticulture activities. More Goromonzi MHHs than FHHs engaged in horticulture for marketing, while vegetable production was mainly for household consumption in Mazowe and Kadoma districts. The higher levels of horticulture in Goromonzi district compared to Mazowe and Kadoma districts could be associated with a ready market for the produce, as well as available groundwater resources and ideal climates. Possible decreases in groundwater resources and constraints associated with increased temperature may have negative impacts on horticulture. Investments in irrigation facilities and financial assets, as well increased access to markets, may be required for sustainable horticultural activities. Female-headed households mentioned labour constraints for garden preparation and irrigation, as well as limited market access associated with the lower mobility of women. Females, due to labour demands and limited accesses to markets for produce, were therefore largely not involved in horticultural production. Strategies that improve market access for FHHs and reduce labour requirements or improve access to the labour required for horticulture can improve participation of FHHs in horticulture in current climates. Female farmers from both MHHs and FHHs ranked horticulture the most important livelihood source in Goromonzi.

Livestock production mainly consisted of cattle and poultry production at both sub-humid study sites. Increased livestock production may become necessary in future climates. However, Mazowe/Goromonzi farmers, and FHHs in particular, in general have small land holdings. They also mentioned that due to population pressures and land use change, livestock production was limited by pasture and water shortages. Female ownership of livestock production is generally low as is their participation in livestock production activities. Farmer responses to climate change and variability indicate that supplementary livestock feeding could be a coping mechanism at the two sub-humid study sites. Farmers also suggested forming dedicated land for paddocks. Women could also improve their participation in livestock activities.

Farmer responses to climate change and variability indicate that alternative livelihood sources for both sub-humid sites may be necessary to cope with the effects of climate variability. Other livelihoods strategies for male farmers mainly included off-farm employment at both sub-humid sites. This may be associated with their education levels as well as their skills for other forms of livelihoods. Females mainly depended on crop production and remittances. Increasing education levels and vocational skills of females can increase their prospects of obtaining part-time employment to supplement incomes from farm production.

The requirements and transition pathways for adaptation to climate change for MHHs and FHHs at the sub-humid Mazowe/Goromonzi site were demonstrated to differ. The adaptation pathways at the sub-humid sites show that variation in resources can influence the pathways of MHHs and FHHs. This information is important for different stakeholders such as those involved in technological developments, farmer-oriented development institutions, and farmer organisations.

Adaptation pathways for MHHs and FHHs at the semi-arid study sites are outlined in Figure 7.2. Matobo district farmers' transitions or adaptation pathways may shift from mainly maize and groundnut production to increased uptake of stress-tolerant crops such as small grains; there may also be increased crop diversification, extensive livestock production, small livestock production, and livelihood diversification. Agricultural diversification is important for adaptation in mixed crop-livestock systems, the backbone of smallholder production in developing countries in the tropics (Herrero et al., 2010; Thornton and Herrero, 2014).

Maize and groundnut were the main crops grown by Matobo district (cooler) households, whereas maize, sorghum, groundnut, and cowpea were the main crops in Chiredzi (drier). Therefore, transitions to drought-tolerant crops such as sorghum and pearl millet in 2050s climates by Matobo farmers can increase the resilience of their farming systems. In comparison, Kurukulasuriya and Mendelsohn (2008) showed that at the country level, maize, beans, and sorghum were the main crops in cooler regions of Africa, and in hot regions, farmers preferred cowpea and millet. Burke et al. (2009) suggested that the 2050s warmer climates will decrease the area suitable for maize and increase that suitable for sorghum production in many sub-Saharan countries. According to farmer perceptions, sorghum varieties performed better than maize varieties at the study sites. However, small grains are mostly grown in combination with maize because, in good seasons, maize performs better than these crops (Sukume et al., 2000). Increased uptake of drought-tolerant small-grain crops, such as sorghum and pearl millet, leads to increased workloads for women who are mainly involved in production and processing of small grains for household consumption. Women's ability to produce small grains may be limited by low availability of labour. Males tend to migrate in semi-arid areas. This implies that females are largely responsible for both the production and post-harvest processing of small grains in FHHs. Labour demands in small grain production for bird scaring/pest control during the grain filling stage (soft dough stage), as well as during harvesting, threshing, and processing are high. Therefore, there is need for investment in technologies that reduce labour requirements for small grain production and processing for women in both MHHs and in FHHs.

Crop diversification is often used by smallholder farmers, particularly in semi-arid areas of Zimbabwe, e.g. in Tsholotsho (AER IV; Ncube et al., 2009) and in Gutu district (AER IV; Chazovachii et al., 2012). McCord et al. (2015, page 239) similarly observed high crop diversification within semi-arid systems near Mt. Kenya. They also showed that wealth had a positive influence on crop diversity. Matobo district farmers can increase crop diversity to levels that may be comparable to those of Chiredzi district farmers for increased resilience in cropping systems. Similar to the findings from this study, Horrell and Krishnan (2007) found that *de jure* FHHs and MHHs achieve similar levels of crop diversification.

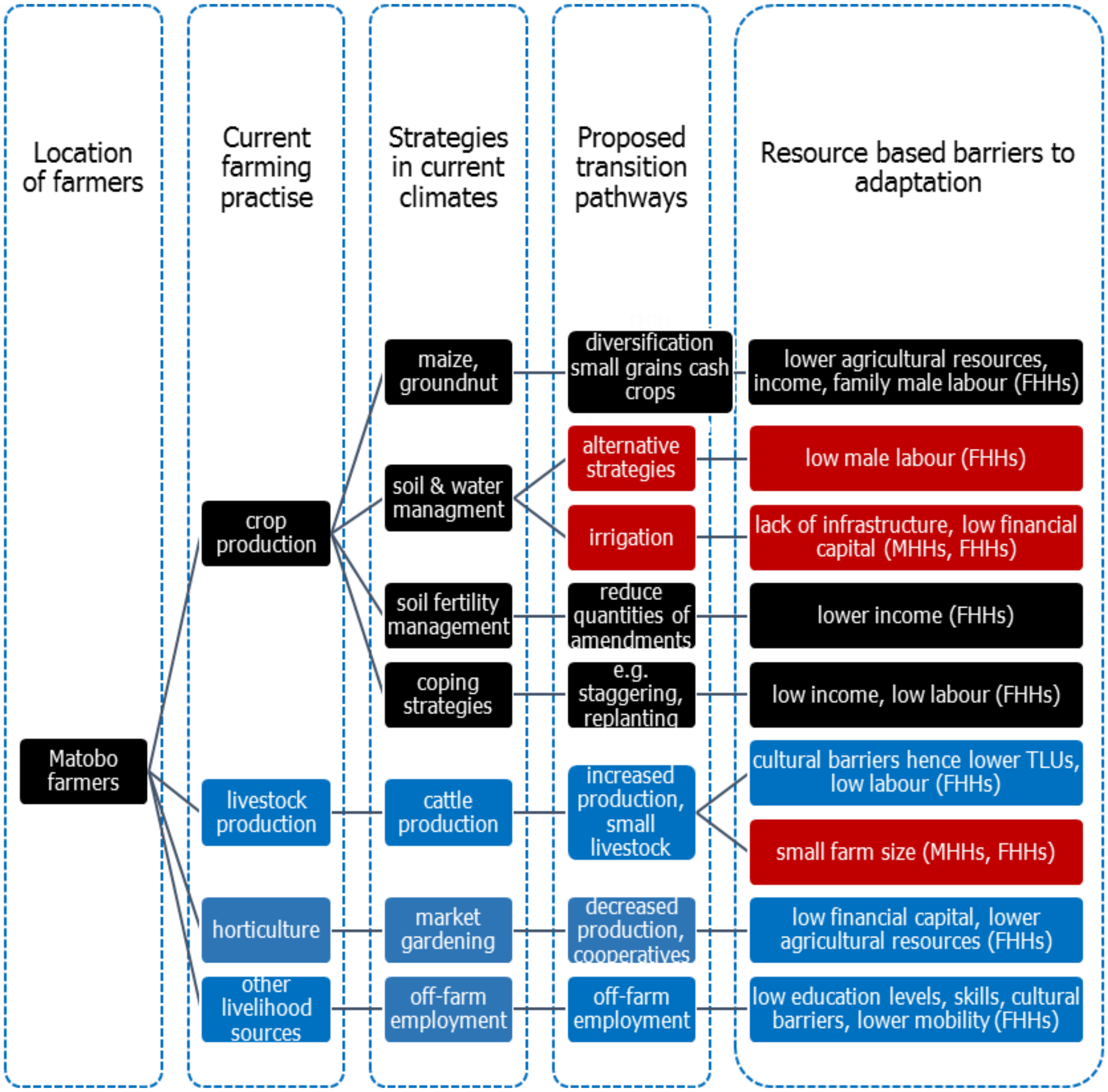

Figure 7.2 Adaptation pathways for Chiredzi households

Black boxes represent pathways that may be followed by both MHHs and FHHs. These are derived from comparisons of practices at the reference sites in Matobo district and the analogue sites Chiredzi district.

Blue boxes represent pathways of MHHs only, derived from comparisons of practices of MHHs at the reference and the analogue sites. FHHs can transition to these strategies provided differences in resource ownership are addressed.

Red boxes represent other pathways that may be explored by both MHHs and FHHs. These are currently not used at the study sites due to several barriers.

Increased accesses to extension and seed systems or markets can enhance crop diversification in semi-arid farming systems. Resources that may be important for crop diversification include increased farm size and availability of seed.

Assessments of adaptation options often involve multiple criteria (Webb et al., 2013). In FGDs, Chiredzi farmers indicated that they preferred sorghum varieties with low labour requirements, for example in bird scaring and harvesting. Varieties with low labour requirements need to be explored, particularly those suitable for Chiredzi and Matobo district climates. In other studies, crop selection and variety selection criteria were also shown to depend on social groups and gender differences, for example in maize cultivar preference (Defoer et al., 1997; Mulatu and Zelleke, 2002) and in sorghum grain quality traits (Defoer et al., 1997; vom Brocke et al., 2010). Crop breeding research can target farmers' preferences for improving crop variety adoption. Selection criteria for crops and varieties that may be the basis of crop genetic improvement in semi-arid areas include drought tolerance, high yields, yield stability, early maturity, and labour requirements for sorghum and other small grains.

According to the responses of semi-arid farmers to climate variability, coping strategies can include increasing the area under cultivation for different crops, practising dry planting, early planting, and staggering. Labour availability as well as financial capital influences the implementation of these management practices. Livestock ownership also influences the timing of planting. Therefore, low ownership of livestock by FHHs may limit their abilities to implement these coping strategies.

Farmers at the semi-arid study sites mentioned that they use reduced tillage methods such as conservation agriculture because of inadequate access to draft power. Contrary to the expectation that there would be higher use of soil and water management for climate change and variability in semi-arid warmer climates, this study showed higher use of soil and water management strategies by both MHHs and FHHs in Matobo district compared to Chiredzi district. Lower use of technologies at the semi-arid Chiredzi district study sites could be due to either lack of knowledge or to labour-related constraints. The farmers may also perceive low benefits from technologies. During FGDs, Chiredzi farmers mentioned that they rarely used soil and water management strategies except for contours to protect soils from floods. Instead, Chiredzi farmers were more inclined to growing stress-tolerant crops. Therefore, use of soil and water technologies may be reduced in warmer Matobo climates. However, further explorations are required to make recommendations with respect to soil and water management strategies for future climates.

Labour challenges encountered in implementing soil and water management strategies have implications for their adoption by female farmers. Farmers needing access to financial resources and human capital can either hire labour or form social groups to assist each other during periods of peak agricultural labour demand. At the drier sites, farmers, in particular women and members of FHHs, were mainly involved in labour groups. These social groups cushion them from low levels of available family labour and limited access to financial capital. Some farmers, particularly at wetter sites, mentioned that labour groups were not sustainable as some farmers/households were not cooperative. They mentioned that farmers were no longer interested in these groups compared to previous years. This indicates that levels of internal social capital for increasing access to resources have declined in some communities. The World Bank argues/suggests that social groups may increase the exclusion of women and thereby increase inequality (World Bank, FAO, IFAD, 2009). Below et al. (2012), however, showed that strengthening social capital, agricultural extension, and microcredit services were successful in improving the adaptation of some farmers in the Morogoro region of Tanzania. Policies and innovations that promote labour-saving technologies are required to address labour shortages in smallholders. There is therefore a need to strengthen social capital in smallholder areas of Zimbabwe through training and skills exchange. Gender mainstreaming may thus require policies that address agricultural labour shortages and access to financial capital for resource mobilization. Irrigation schemes for cooperatives and household level irrigation may also be options for improved production.

Application rates, timing of application, and types of amendments used for soil fertility management may change due to risks associated with fertilizer use in moisture-limited soil conditions. Chiredzi farmers mentioned that they hardly used fertilizer due to high risks associated with climate extremes. Preferred criteria were high effectiveness and low labour requirements. Older farmers in Matobo perceived manure to be better than fertilizer as there was no need for yearly application thus reducing labour requirements and costs. However, constraints to soil fertility management mentioned by farmers included lack of availability of animal manure. Organic amendments are limited by low availability of crop residues due to low productivity in semi-arid smallholder areas. The most adopted and preferred method was chemical fertilizer by both MHHs and FHHs. Farmers mentioned that they micro-dose fertilizer using spoons and referred to the fact that this method affects their backs because the process includes bending down when applying fertilizer with teaspoons. Financial capital is therefore important in soil fertility management for purchasing inorganic forms of fertilizer. Availability of cattle manure depends on livestock ownership, in particular cattle. This study shows that FHHs have fewer livestock units compared to MHHs. Therefore, use of animal manure by FHHs may be limited.

Climate change affects livestock and livestock systems in developing countries. The impacts may range from quantities and qualities of breeds, impacts of heat stress, water shortages, and livestock diseases (Thornton et al., 2009). The results show generally higher livestock production, in particular in small livestock such as goats, in Chiredzi district compared to Matobo district. While the size of grazing land among other biophysical factors can influence quantities of livestock per household, the production of livestock, particularly small livestock, is generally associated with resilient farming systems in SSA. Chiredzi farmers mentioned that livestock production offers social safety nets when they fail to harvest any crops due to adverse climates. Chiredzi farmers, in particular MHHs, received more income from livestock sales compared to households in Matobo. Therefore, increased production of livestock and in particular small livestock can increase resilience in Matobo district farming systems. Addressing inheritance inequalities can also increase livestock ownership of FHHs. However, a constraint for both MHHs and FHHs is small farm size, which limits availability of grazing land. Supplementary livestock feeding can be an option for adaptation. Changing profiles of types and quantities of livestock for Matobo females can affect labour distribution. Female farmers lack knowledge of livestock production. There may be a need to increase the participation of women in livestock management programs.

Horticulture projects are a source of livelihoods in both Matobo and Chiredzi districts. In Matobo district, horticulture projects were mainly at the household level (MHHs), while in Chiredzi these were mainly cooperatives that were introduced through various governmental and NGO initiatives. According to observations during the surveys, vegetable production appeared to perform best in Matobo.

Analyses of livelihood strategies indicate that at both semi-arid sites, males engaged in more non-farm activities than females. Higher education levels, mobility, more vocational skills, socially constructed roles, and cultural factors may contribute to males' higher involvement in non-farming activities for income. There are higher numbers of adult males, particularly Chiredzi males, who migrate (mostly seasonally) for employment, while women engage more in casual employment such as brick moulding and trading. Male labour migration is a common response to climate change in Africa (Agwu and Okhimambe, 2009; Nelson and Stathers, 2009). Other activities of females include brick moulding and selling traditional craft works. Female farmers may be vulnerable because of some of the activities they engage in for alternative sources of income. There is therefore a need for strategies to improve access to gender-sensitive income generating projects and employment opportunities at the semi-arid sites.

This study has explored possible adaptation pathways and requirements in terms of the resources (capital assets) of MHHs and FHHs in sub-humid and semi-arid smallholder areas in response to warmer climates by the middle of the 21st century. Lyle (2015) noted that differing socio-economic and demographic profiles and types of social interactions within and between communities would influence climate change adaptation as well as individuals' beliefs and risk perceptions. Factors including technological, biophysical, social, and cultural considerations are also important in adaptation. Therefore, the pathways suggested serve as guides for developmental purposes.

7.5 Conclusion and recommendations

According to results of this study, gender affects adaptation to climate change with respect to requirements and transitions and/or pathways in some sub-humid and semi-arid smallholder areas of Zimbabwe. There were gendered differences in requirements for adaptation to climate change.

Crop production may continue to be the most important source of livelihoods at the sub-humid site Mazowe/Goromonzi, in particular for FHHs. Adaptation of Mazowe/Goromonzi households to 2050s climates may include increased uptake of cash crops for income, short season varieties, soil and water management, soil fertility management, and increased dependency on other livelihood strategies. The adaptation pathways for Mazowe/Goromonzi FHHs as compared to MHHs may involve decreasing cultivated areas, particularly of cash crops, and applying soil fertility, and soil and water management strategies on smaller areas. Adaptations of MHHs and FHHs require increased access to financial capital, farm size, and human capital, particularly with respect to labour, education, and/or agricultural skills. Compared to MHHs, female-headed households adapt by allocating less land area to maize and cash crops such as cotton that require high capital investments. Women may need to increase production of cash crops to increase income and access to agricultural land. This may be achieved by increasing access to inputs required for these crops. Women should also be encouraged to venture into high-value cash crops to increase their resource base. This can be taken into consideration in breeding research. Soil and water management strategies may remain viable options for MHHs and FHHs in managing climate risks for wetter/cooler Mazowe/Goromonzi farmers in 2050s climates.

At the semi-arid sites, contributions of crop production to household income may decrease and contributions of livestock production may increase for both MHHs and FHHs in Matobo. Diversification of livelihoods can help farmers adapt to 2050s climates. The adaptation transitions for Matobo farmers to 2050s climates may include increased uptake of small grains, and livestock production and labour migration. Adaptation requirements for Matobo MHHs include increased access to financial capital, agricultural equipment, and draft power. Education and skills training can also enhance their potential for off-farm employment. High labour demands associated with small grain production, i.e. labour required for bird scaring, harvesting, and processing, against a background of high male labour migration, may increase workloads for female heads of households. A changing food production and processing landscape, especially with respect to small grains, may need greater investment by different institutions in production, processing, and consumption technologies suited to different smallholder conditions and sensitive to differences between males and females. Farmer social groups can be important for adaptation. There may be a need for increased investment in water management research and development for drier areas where adoption appears to be low. Further, irrigation can be an option for crop management, in particular maize production. Adaptation requirements of FHHs include increasing access to education, labour, agricultural equipment, and draft power.

7.6 Summary

Multiple stressors that include climatic and non-climatic constraints negatively influence rain-fed smallholder productivity and livelihoods in SSA. Warmer 2050s climates may reduce the yield potential of cereal crops such as maize, further increasing the vulnerability of the smallholder sector. Climate change may negatively influence cereal yields (e.g. of maize, the main crop), the socio-economic environment of smallholders, and livelihoods. Technological, informational, organisational, and behavioural and ecosystem forms of local-level adaptation to climate change can reduce the impacts of warmer 2050s climates on differently managed smallholder farms. Differences in gender roles and access to resources may influence MHH and FHH transition pathways.

Female-headed households and MHHs may thus require different resources for adaptation. Policy makers, researchers, and governmental and non-governmental organisations that work with farmers can use information on smallholder requirements, possible transitions, and adaptation pathways for planning purposes.

This study explored potential adaptation options/transitions and resource requirements of MHHs and FHHs for current and warmer climates by the middle of the century through climate analogue analysis. Management practices for the 2010/2011 season and factors influencing choices and farmer preferences were identified through surveys, FGDs, and participatory evaluations. Triangulation of methods (within and between) enabled verification of some of the data presented.

Farming systems and management strategies employed by MHHs and FHHs differed by analogue site. Resource requirements also varied by gender. Male-led households in Mazowe/Goromonzi district mainly practise crop production, livestock production, and horticulture, while women mainly practise crop production and livestock production. In contrast, Kadoma district farmers mainly practise crop and livestock production. Profiles of crops choices and soil and water management strategies are similar between MHHs and FHHs. Males are mainly involved in off-farm employment as a source of income. Requirements for FHHs include increased financial capital, increased human capital with particular reference to education and labour (male labour), improved soil and water management, increased cash crop production, and increased yields of food-security crops such as maize.

In the semi-arid Matobo district, based on comparisons with Chiredzi district farmers, transitions may include a need to increase uptake of small grains to better manage climate risks for both MHHs and FHHs, as well as a need to increase small livestock production. Requirements for FHHs include increased access to human capital (labour), as well as increased participation and abilities in livestock management. The results also show that for soil and water management there is need for increasing social capital that increases access to resources. It can be concluded that FHHs mainly depend on crop production at all sites. Crop production will remain an important source of livelihoods at both the sub-humid Mazowe/Goromonzi study sites and the semi-arid Matobo study sites. Matobo (drier/cooler) farmers may also increase their dependence on livestock production.

8.0 General summary

8.1 Introduction

Multiple stressors negatively impacts rain-fed smallholder productivity and livelihoods in sub-Saharan Africa (Morton, 2007). Smallholdings, which constitute the largest sector in agriculture, are the most vulnerable to environmental stressors. Warmer 2050s' climates may negatively impact agricultural production, reduce food security, and further increase vulnerability of farmers. In African smallholdings, FHHs constitute between 30-40% of households. FHHs often have lower levels of resources compared to MHHs. Contributing factors to these different levels of resources include gender inequalities, some arising from social and cultural norms. The differences in levels of resources, and gendered roles of female household heads and male household heads, imply that MHHs and FHHs manage their resources and farming activities differently. This being the case, female–led households compared to male–led households often obtain lower yields. The implications of these differences are that MHHs and FHHs have different requirements for adaptation to climate change. Mainstreaming gender is pre-requisite for smallholder adaptation to climate change and reducing food security in smallholder settings. There is, however, inadequate information available on current, regional specific adaptation requirements of MHHs and FHHs necessary for mainstreaming gender in climate change planning.

This study sought to determine how the gender of household head affects smallholding and adaptation to climate change in smallholder areas of Zimbabwe. The study was based on the theory that women and men have different accesses to resources and that these gendered differences result in different management strategies for differently managed households.

Three research questions that guided this study were:

i. How do gendered patterns of resource ownership relating to the sex of household heads affect smallholder practices and their outcomes in rural Zimbabwe?
ii. What effect is climate change likely to have on male-led and female-led smallholders in rural Zimbabwe in terms of resource-based forms of smallholder practices and outcomes?
iii. Overall, how will gender affect adaptions to climate change in smallholders and outcomes in rural Zimbabwe?

8.2 Methodology

The analogue analysis approach (Adams et al., 1998) was adopted in this study to estimate the potential impacts and adaptation requirements of smallholder farmers in future climates. Burke et al. (2009) observed that climate analogues for the 2050s existed within and between African countries. In this study, it was therefore assumed that climate analogues for sub-humid and semi-arid smallholder areas, the predominant agricultural areas, existed within the country. Two pairs of analogue sites representing sub-humid and semi-arid sites were selected. Temperature may increase by about 2°C -3°C by the middle of this century (Hulme et al., 2001; Christensen et al., 2007). Climate analogue pairs of this study therefore consisted of the reference site, and its analogue site that had similar rainfall patterns, but the analogue was warmer than the reference by about 3°C to represent the effects of global warming. The sub-humid analogue pair consisted of reference site Mazowe/Goromonzi district (cooler) and analogue site Kadoma district (warmer). The semi-arid analogue pair consisted of the reference site Matobo district (cooler) and the analogue site Chiredzi district (warmer). An assumption in climate analogue analysis is that farmers at analogue sites i.e. those sites representing future climates have adjusted their practices to suite the warmer climates. In this study, it was therefore assumed that farmers at the reference sites might shift some of their practices to resemble those at the analogue sites in response to climate change.

Data was collected through methods that included household surveys, FGDs, and farmer participatory methods in evaluating field trials. To achieve the first objective male-led households and female-led households at each site were compared with respect to capital assets, perceptions of production constraints and crop production practices. The second objective was achieved by comparing MHHs at reference sites and MHHs at analogue sites, and FHHs at analogue pair sites. Production constraints, capital asset levels, maize production practices and yields as well as food security levels were compared. Agricultural management practices and preferences of farmers analogue pair sites were compared to assess adaptation pathways and requirements of farmers.

8.3 Summary findings and policy implications

Several insights from this study can contribute to existing and new policies for mainstreaming gender in climate change planning, and strengthen institutional frameworks for rural development. This study showed that at each study site, male-led households and female-led households had different levels of resources and different agricultural management practices. The main findings are summarised below.

- Resource levels i.e. capital assets required for sustainable livelihoods, of male-led and female-led households differed. Females had in general fewer capital assets compared to males. Resource levels that were lower for FHHs compared to MHHs at most sites include male adult labour, education levels and financial capital.
- With respect to human capital assets, female heads of households had lower education levels compared to male heads of households. The lower participation of female heads of households in off-farm employment may be attributed to lower education levels and fewer technical skills as well as to other gender related constraints such as limited mobility of females. Enhancing education and skills of females may assist increasing levels of off-farm employment. In addition to fewer skills and low education levels, adult male labour was lower in FHHs compared to MHHs. Some production

practices, however, require male labour input. The absence of adult male labour can therefore negatively impact on adoption of some labour intensive agricultural technologies. Technologies and innovations that reduce labour requirements can improve adoption of agricultural technologies and adaptation to climate change in female-headed households.

- Financial capital was lower in FHHs compared to MHHs in Mazowe/Goromonzi, Kadoma and Matobo. Fewer agricultural resources that include agricultural equipment in FHHs compared to MHHs may in part be attributed to lower financial capital. Farmers with low levels of financial capital have limited ability to purchase inputs such as fertilizer, improved seed varieties and to hire agricultural labour. Increasing climate financing, participation of women in income generating projects, vocational skills may assist females to increase their revenue base. Females can also intensify cash crop production to levels similar to those of their male counterparts.
- At the sub-humid study sites, Mazowe/Goromonzi and Kadoma, where agricultural productivity was generally high, women had smaller farm sizes compared to males. Subsequently cultivated maize and cash crops area was smaller in FHHs than in MHHs. Meanwhile, at the semi-arid study sites Matobo and Chiredzi districts, which are associated with lower agricultural productivity, farm size of MHHs and FHHs was similar.
- Crop management practices differed. Differences in management strategies for sub-humid smallholder farmers include growing maize and other cash crops on smaller area by FHHs compared to MHHs.
- There were also gendered differences in yields and food security of households except in Chiredzi district. Outcomes of lower resource levels in FHHs compared to MHHs and management practices included lower crop yields and lower levels of food security. Crop yields and productivity were higher in MHHs compared to FHHs in Mazowe/Goromonzi, Kadoma and Matobo during the 2010/2011 rain season. Development programs can target food insecure households, these mainly include FHHs.

Climatic and non-climatic stressors to agricultural production as well as management practices differed between analogue pair sites. Consequently, crop yields were lower at the analogue sites compared to the reference sites.

- Farmer reported climatic constraints to crop production included erratic rainfall constraints in Mazowe/Goromonzi and Kadoma districts. At the sub-humid study sites, fertilizer application rates were lower in Kadoma (warmer) compared to Mazowe/Goromonzi (cooler). The soil and water management strategies varied across the sites. Maize area was higher in Kadoma compared (analogue site) to Mazowe/Goromonzi (reference site). At the sub-humid Mazowe/Goromonzi study sites, climate change impacts may include reduction in crop yields.
- At the drier sites Matobo farmers mainly mentioned low and erratic rainfall constraints, meanwhile most Chiredzi mentioned low and erratic rainfall constraints and high temperature constraints. Matobo farmers applied more fertilizer in maize production, compared to Chiredzi farmers (due to climate-induced risks in Chiredzi). There were lower crop yields in Chiredzi than in Matobo. Implications are that warmer climates may reduce yields, and reduce food security in Matobo MHHs and FHHs. In addition, income from crop production was lower in semi-arid Chiredzi district compared to Matobo district indicating that warmer climates may reduce income from crop production. FHHs mainly relied on crop production for their income and may thus be impacted the most. Improving crop production in FHHs is important for food security and for improving their socio-economic profiles.

Agricultural technologies should therefore be designed to suite specific environments. Adaptation pathways and requirements for male-led and female-led households at the study sites differed.

- Adaptation pathways and requirements for MHHs and FHHs in Mazowe/Goromonzi district differed. Adaptation transitions of MHHs at the semi-humid site include venturing into cash crops, growing short season varieties, adopting improved soil and water management strategies, improved management of soil fertility, and increasing cultivated area. Farmers may also increase production of cash crops including those more tolerant of warmer climates such as cotton, increase livestock production, as well as venture more into off-farm sources of livelihoods.

- Adaptation pathways for female-led Mazowe/Goromonzi households include increased production of cash crops and livestock. Climate financing may enable them to cultivate more cash crops. Technologies that reduce labour requirements can increase adoption of soil and water management strategies in FHHs. Advocacy for policies that increase education levels of women, and vocational skills training can increase opportunities of females to participate in other off-farm activities for improved financial capital. Access to credit for women can also enhance financial capital access for FHHs, to improve agricultural production. Adoption of cash crops, soil and water management strategies, and soil fertility strategies at the sub-humid sites require that FHHS be adequately equipped in terms of financial capital, and labour as well as draft power. There is therefore need to develop low cost, low labour requiring technologies for example for soil and water management. Income generating projects, particularly agricultural related projects, can also increase financial capital of households.
- Adaptation pathways of Matobo MHHs and FHHs include increased uptake of resilient crops such as sorghum and pearl millet, increased uptake of resilient small livestock such as goats, and increased cattle production (extensive production and livelihoods diversification.
- Male labour migration in response to adverse climates at the drier sites may however result in labour constraints for females. In addition to increased burden of fetching firewood and water for domestic use, women may therefore face increased burden in agricultural production. Strategies that reduce labour for female heads of households such as increased access to

water, energy for domestic use since they have extra responsibilities in crop management production particularly for small grains whose processing is labour intensive. Technical research includes developing new crop varieties tolerant of salt, water, and heat stress, which could reduce women's workload (e.g. new West African rice varieties that smother weeds; DFID 2002). Lower use of soil and water management was lower in Chiredzi compared to Matobo indicate the need to develop/research on soil and water management strategies that are more suitable for drier conditions.

- There was increased dependence of livestock sales in Chiredzi compared to Matobo for both MHHs and FHHs. Livestock production is one the safety net for farmers. Crop production may become more risky in drier areas, necessitating increased integration of livestock in farming systems particularly in semi-arid systems.
- Enhancing skills and resources of farmer groups can improve their effectiveness in farm management and climate change adaptation.
- Policy recommendations may include climate financing particularly FHHs, policies that improve livestock production and increase income from livestock at the semi-arid study sites.

Therefore, gender mainstreaming can reduce impacts of climate change on male-led and female-led households in smallholder areas of Zimbabwe.

8.4 Limitations of the study

Participatory approaches in data collection presented opportunities for stakeholder involvement and enabled appreciation of farmer practices in different climates. The analogue approach enabled farmer-to-farmer/farmer-to-researcher interactions (i.e. bottom-up approaches). Farmers from cooler reference were also able to observe and learn from on-station trials at their future analogue climates. The analogue analysis approach enabled observation of farmer behaviour in different climates under different socio-economic conditions. However, adaptation pathways proposed serve as a guideline rather than prescriptive.

Limitations of analogue analysis in farming systems include the following:

- Analogue sites represent a crude window into the future. Assumptions are that differences in yield between analogue pairs are predominantly due to temperature differences. While rainfall differences were relatively poorly controlled in the study, models estimate low levels of declines in precipitation in 2050s climates variability and distribution may vary.
- Effects of increases in CO_2 concentrations were not controlled. Adaptation and CO_2 fertilization could potentially moderate the negative impacts of climate change. Positive impacts of increased concentrations of CO_2 are higher for C_3 plants compared to C_4 plants (e.g. Tubiello *et al.*, 2007) and these impacts depend on water and nutrient availability. The main food security crops in smallholdings in Zimbabwe utilise the C_4 photosynthetic pathway, therefore benefits associated with increases in CO_2 concentrations are low. At the sub-humid pair sites, for example, the main cereal planted was maize, a C_4 crop. Maize yield response to increases in CO_2 levels is lower than that of wheat, rice and soybean (Parry *et al.*, 2004). Further, higher proportions of households from Matobo may adapt to warmer drier climates through adopting sorghum and millet varieties that use the C_4 photosynthetic pathway.
- Models for projecting climate changes have their own limitations. Williams and Jackson (2007) noted that there might also be ecological surprises.
- Adaptation strategies evolve over time and therefore effectiveness may vary as strategies and technologies are improved over time.
- Socio-economic conditions are dynamic. The IPPC 2007 notes that future farming and food systems will face substantial, albeit distinct, changes in their environments. The systems will adapt in response to a number of factors that include political, social, technological environments. Therefore, recommendations for future climates are based on prevailing conditions. The strategies and options suggested are not applicable for all smallholder farmers in Zimbabwe. They are applicable to study sites and other smallholder areas

with similar rainfall and temperature characteristics and biophysical environments.

Other limitations of the study include reliability of surveys and information from farmers. Data was triangulated within methods and by use of different methods to increase reliability. KIIs were also carried out to verify information given by farmers. Farmer participatory/managed research is needed to compliment data observed on-station trials answer as in farmer fields under their own trials. Some of the information may require that data be collected over a long period of time. However, capital constraints limited the amount of data collected.

8.5 Recommendations

- More exploratory studies on how climate changes will manifest themselves in different agro-ecological of Zimbabwe and how social and natural systems will co-evolve with a gender perspective are required.
- Increasing farmer-to-farmer exchange visits can aid in participatory diagnosis of capacities and needs, thus aiding in the design of community-appropriate adaptation strategies.
- This study illustrates the need for different packages for climate change in Zimbabwean smallholder areas. Alongside these socio-economic studies and analogue analysis, there is need for more field-based evaluations of adaptation options for different farmers.
- Further, panel data can also assist in assessing the effects of inter-seasonal variability in climatic factors and heterogeneity.
- Adaptation in agriculture involves various stakeholders. Therefore, it is necessary to involve different players in the adaptation process.

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APPENDICES

Appendix A

Respondent Code ………………………………….

CONFIDENTIAL

Adaptation to climate change: Developing promising strategies using analogue locations in Zimbabwe

ICRISAT – Matopos Research Station

Please ask the household whether they are willing to participate in this survey interview. Respondents should understand that participation in this survey, and the answers provided, will not influence whether this household receives assistance of any sort in the future.

Introduction to questionnaire

ICRISAT is carrying out research into how smallholder farmers in Zimbabwe are coping with current environmental and socioeconomic conditions and how they might adapt to future changes. Accordingly you are invited to participate in this research study as we seek to identify technologies and processes that could increase the profitability of your farm enterprises and improve your capacity to adapt to change.

Please note the following:

- The answers you give will be treated as strictly confidential.
- The results of the study will be used to identify the current and future constraints on improved productivity and to collabouratively develop solutions that could improve yields and livelihoods. The results may also be published.

IDENTIFYING INFORMATION:

Name of the supervisor	
Name of the enumerator	
Date of Interview	
Interview Start time	
Country	
Province	
District/Ward	
Village	
Northings	
Eastings	
Elevation	

SECTION A: DEMOGRAPHIC PROFILE

1. Respondent and general household information:

Name of the respondent (confidential, not to be made public)	
Local Name	
Gender of interviewee	
Age of interviewee	
Marital status	
Level of education/No of years spent in school	
Employment status	
Is the respondent head of household?	
If not, relationship to head of household	
Name of head of household	
Gender of head of household	
Age of head of household	
Level of education of head of household	
Employment status of head of household	
Type of Household	

2. House characteristics:

House Number/ structure	No. of rooms	Roof Type	Wall type	Flooring

3. Household Composition (including respondent):

Age	**Total**		**Number of household members working on farm**		**Number of household members working off farm**		**Chronically ill for the past 6 months/disabled**	
	Male	Female	Male	Female	Male	Female	Male	Female
0 ≥14 years								
15 years and above								

SECTION B: LAND HOLDING AND CROP PRODUCTION

4. How long you have been farming? ……… Yrs

5. Land holding for the rain season - 2010- 2011

Ownership	**Homestead**		**Distant field**		**Gardens**		**Others rented in**		**Rented out** (includes share cropped, loaned and other arrangement)		**Total land owned**	
	Area	Units	Area	Units	Area	Units	Area	Units	Area	Units	Area	Units
Cultivated												
Fallow												

6. MAP of Crop Production - Rain season 2010 – 2011

We would like to draw a map that outlines your farm enterprises (i.e. fields, kraals, fowl runs and homestead). Start by showing your homestead compound. Then draw the fields and other enterprises closest and furthest in a picture on the ground. Our enumerator will transcribe this to the next page. Show any major landmarks near your homestead/fields like roads, school, and borehole**. (indicate the following on map, plot no, approximate size, crop grown previous season etc.)**

7. a. Input requirements - Rain season 2010 – 2011

Plot No.	**Crop**	**Variety**	**Area**	**Seeds**				**Fertilizer**					**Pesticide/herbicides**			
				Amount used	**Cost**		**Source ***	**Type**	**Amount used**	**Cost**		**Source ***	**Amount used**	**Cost**		**Source ***

b. Input requirements and yield for 2010/2011 season

Plot No.	Crop	Hired equipment				Yield	
		Type of equipment	Amount/ quantity hired	Cost (US$)	Source	Quantity/ Amount	Units

8. **a. Crop production labour requirements**

Crop*		Family labour																				Hired labour						Wage rate	
	Activity	Men										Women										men			Women			man	woman
		No	Total no. of. hours of each								Total hours worked	No.	Total no. of. hours of each								Total hours worked	# hired	No of hours each worked	Total worked	# hired	No of hours each worked	Total worked		
	Land preparation/ Ploughing																												
	Planting																												
	Weeding																												
	Fertilizer application																												
	Pest/Insect control																												
	Harvesting																												
	Threshing/shelling																												
	Bagging																												
	Land preparation/ Ploughing																												
	Planting																												
	Weeding																												
	Fertilizer application																												
	Pest/Insect control																												
	Harvesting																												
	Threshing/shelling																												
	Bagging																												

9. Perceptions on crop yields

Crop	Grown every season (1= Yes; 2=No)	Grow for	Yield[2] per unit area in good seasons			Yield per unit area in average seasons			Yield per unit area in poor seasons		

a. Have you stopped growing any crop/varieties in the past 5 to 10 years? 1= Yes; 2 = No

b. If Yes

What crop?	Which varieties?	Why?

a. Have you started cultivating new crops/varieties in the past ten years? Yes=1, No=2

b. If Yes

What crops?	Which varieties?	Why?

10. Tree production (including shrubs/bushes and other perennials)

Tree (local name)	Number of trees/ length of hedge	Where planted (see codes)	When planted	Main use of tree	Other uses			Unit of produce	Amount harvested/yr	Unit price
					1	2	3			

Where planted: 1=scattered in farm; 2=along boundary; 3=hedges within farm; 4=Home compound; 5=Woodlot; 6=Other (specify)

SECTION C: LIVESTOCK OWNERSHIP AND PRODUCTION

11. Livestock ownership:

Livestock	Number	Sources					
		A	B	C	D	E	F
Local cattle							
Crossbred cattle							
Donkey							
Local sheep/goat							
Improved sheep/goat							
Local pigs							
Improved pigs							
Local Chicken							
Improved chicken (Broilers)							
Improved chicken (Layers)							
Others (Specify)							

12. Livestock production during last 12 months

Type of animal	Cost								Production						
	Fodder		Supplementary feed		Drugs		Other costs								
	Amount used	***Cost***	***Amount used***	***Cost***	***Amount used***	***Cost***	***Amount used***	***Cost***	***Product 1(specify)***	***Qty***	***Price***	***Product 2(specify)***	***Qty***	***Price***	***Total***
Bulls/Cows															
Goats															
Sheep															
Pigs															
Chicken															
Other (Specify)															

SECTION D: PRODUCTION CONSTRAINTS

13. Crop production constraints (Please do not read out to farmers, please probe them)

Constraint	Rank (1=High; 2=Medium, 3=Low)
Lack of ready market	
Low soil fertility	
Low availability of water	
Lack of improved varieties	
Soil Erosion	
Soil Salinity	
Soil Acidity	
Pest and disease attacks	
High cost of inputs	
Lack of access to inputs	
High temperatures	
Erratic rainfall	
Lack of extension services/ Government support	
Small land holding	
Lack of labour	
Lack of knowledge	
Lack of equipment	
Low prices for output	
Others (Specify)	

14. Livestock production constraints (Please do not read out to farmers, please probe them)

Constraint	Rank (1=High; 2=Medium, 3=Low)
Low of grazing land	
Low availability of fodder	
Lack of ready market	
Lack of extension services/ Government support	
Low quality of fodder	
Pest and disease attacks	
Lack of improved breeds	
Lack of access to inputs (feed, drugs etc.)	
Availability of water	
Others (specify)	

15. Awareness and use of technologies

Technology	Do you know this technology? (1=yes; 2=No.)	Where did you learn about this technology?	Have you ever used this technology since you started farming on your own?	If yes, when?	If yes, on how much land?		If yes why?	If not, why not?
Soil and water management								
Tied ridges								
Water harvesting								
Pot holing								
Contour ridges								
Conservation Agric								
Mulching								
Others (Specify)								
Soil fertility management								
Animal manure								
Compost								
Crop rotation								
Chemical fertilizer								
Others (Specify)								
Crop management								
Row planting								
Seed priming								
Pest control								
Others (Specify)								

SECTION E: INCOME AND FOOD SECURITY

16. Household income

Income source	Do you get income from this source (Yes/No)	Who gets it?	What is the estimated amount that you have got in the last 12 months? (Specify units)		What importance would you give to this source? (1=Very high; 2=high; 3=moderate; 4=low)
			Amount	Units	
Sale of crops					
Sale of livestock/livestock products					
Sale of other products (firewood/trees etc)					
Regular employment					
Casual employment					
Running individual businesses					
Remittances from outside					
Gold panning					
Mopane worms					
Others (specify)					

17. Household food security

a. In the past 12 months, were there months in which you did not have enough food to meet your family's needs? Yes/No

b. If Yes, which months in the last 12 months that you did not have enough food to meet your family's needs?

Month	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Yes/No												

18. Household assets

	Type of assets	**1=yes; 2=no**	**Quantity**	**Source**			
				Bought	**Gift**	**Inheritance**	**Other (specify)**
<u>Agricultural</u>							
	Others (specify)						
<u>Household</u>							
	Other (specify)						

SECTION D: PERCEIVED CHANGES

19. What are the key changes you have experienced since you started farming on your own?

Practice	Change more than 10 years ago	Reason for change	Change in the last 10 yrs	Reason for change
Land available (1=increase; 2=decrease; 3=remained the same)				
Land preparation				
Crops grown				
Planting methods				
Water management				
Soil fertility management				
Pest incidence and control				
Weed management				
Input costs (1=increase; 2=decrease; 3=remained the same)				
Prices for outputs (1=increase; 2=decrease; 3=remained the same)				
Productivity (1=increase; 2=decrease; 3=remained the same)				
Soil quality (1=increase; 2=decrease; 3=remained the same)				
Labour availability (1=increase; 2=decrease; 3=remained the same)				
Access to credit (1=increase; 2=decrease; 3=remained the same)				
Access to markets (1=increase; 2=decrease; 3=remained the same)				
Livestock kept (1=increase; 2=decrease; 3=remained the same)				
Livestock productivity (1=increase; 2=decrease; 3=remained the same)				
Feed/fodder availability (1=increase; 2=decrease; 3=remained the same)				
Livestock diseases (1=increase; 2=decrease; 3=remained the same)				
Knowledge and access to information (1=increase; 2=decrease; 3=remained the same)				
Government support				
Collective action				
Others (specify)				

Thank you

Interview end time: ………………

Respondent ID......................................

APPENDIX B

CLIMATE CHANGE SURVEY QUESTIONNAIRE

ICRISAT – Matopos Research Station

Introduction to the questionnaire

ICRISAT is carrying out research into how smallholder farmers Zimbabwe are coping with current environmental and socioeconomic conditions and how they might adapt to future changes. Accordingly you are invited to participate in this research study as we seek to identify technologies and processes that could increase the profitability of your farm enterprises and improve your capacity to adapt to change.

Please note the following:

- The answers you give will be treated as strictly confidential. You cannot be identified in person based on the answers you give.
- Your participation in this study is very important to us.
- The results of the study will be used to identify the current and future constraints on improved productivity and to collabouratively develop solutions that could improve yields and livelihoods. The results may also be published in an academic journal.

IDENTIFYING INFORMATION:

Enumerator Name	
Date of Interview	
Interview Start time	
Interview Stop time	
Country	
Province	
District/Ward	
Village	
Northings	
Eastings	
Elevation	

Respondent ID.....................................

SECTION A: DEMOGRAPHIC PROFILE

9. Respondent and general household information:

	Name	**Gender**	**Relationship to Head of household**	**Age**	**Marital status**	**Level of education**	**No. of years spent**	**Employment status**	**Type of household**	**Family size**
Respondent										
Head of household (if respondent not head of household)										

2. Please may you tell us about your family membership.

Family member code	**Age**	**Gender**	**Contribution to farm labour**	**Chronically ill for the past 6 months/disabled**

3. May you tell us about your land holding for the 2012- 2013 rain season.

Ownership	Homestead	1. acres 2. ha 3. m^2	Distant field	1. acres 2. ha 3. m^2	1. Homestead Gardens 2. Cooperative gardens	1. acres 2. hectares 3. m^2	Others rented in	1. acres 2. ha 3. m^2	Rented out	1. acres 2. ha 3. m^2	Total land owned	1. acres 2. ha 3. m^2
Cultivated												
Fallow												

[1]Specify unit if local unit for land

Respondent ID.....................................

SECTION B: CROP PRODUCTION CHARACTERITICS

4 a Please tell us about your crop production practices for 2012/2013 season.

Plot No	Location	Crop	Variety planted	Area planted	Amount of seed used	units	When planted	Fertilizer type /soil fertility management	Fertilizer units	Pesticide/ herbicide type	Pesticide/ herbicide quantity	Pesticide/ herbicide units	No of times weeded

4 b. Please tell us about your crop production practices for 2012/2013 season.

Plot No	Location	Crop	Soil and water management strategy used	When harvested	Harvest	Harvest units	Did you sell?	Who sold?	Where did you sell the produce	How was income used?

SECTION C: CLIMATE AND PERCEPTIONS

5. We would like to find out about the indicators of different seasons and criteria you use to evaluate seasons in this area.

Type of season	**Indicators of types of rain seasons**	**Which periods (months) of the year are these indicators observed?**	**Are these usually wrong or right?**	**What actions do you take with respect to crop production?**	**Criteria to evaluate season**
Normal season					
Good season					
Poor season					

6 a How many years have you been practicing as a farmer in this area?............................

b Have you noticed any significant changes in weather patterns over the years in relation to agriculture? ___1=yes 2=no

c If answer to question 1 is YES what are the key changes you have experienced in your time as a practicing farmer?

	Observed Change **(PLEASE DO NOT READ OUT)**	**Months (specify week and month)**		**Since when observed** (year)	**Frequency of observation**
		Start	**End**		
	TEMPERATURE				
1	Winters colder				
2	Winters warmer				
3	Summers hotter				
4	Summers cooler				
5	Generally increased temperature				
	RAINS				
6	Floods				
7	Droughts				
8	Reduced rains/ Low rainfall				
9	Mid-season drought/long dry spells				
10	Rains start late and end early*				
11	Rains start early and end early*				
12	Rains start late and end late*				
13	Rains end early*				
14	Rains end late*				
	SEASON				
15	Short rain season				
16	Long season				
17	Inconsistent rains				
18	Morning frost				
19	Increased wind speed				
20	Decreased wind speed				
21	Wind direction				
22	Other (specify)				

*indicate previous

6 d. What were the impacts of these weather changes on your crop and livestock production, and livelihoods?

Observed Change	Impacts on crop production	What actions did you take?	Impacts on livestock production	Actions taken	Impacts on livelihoods	What actions did you take?

Access to information on climate and weather

7. a. Do you have access to climate information? 1= yes; 2 = no

b. Which were your most valuable sources of information on weather and climate for the 2012/2013 season?

Source of information on weather /climate	Type of information provided	When did you access this information for the 2012/2013 season?	How did this information influence your agricultural management decisions?	Relative importance (on a scale of 1-5)	Other comments

Respondent ID......................................

SECTION D: LIVELIHOOD OPTIONS

8. Please may you tell us about the activities that you normally carry out during different months of the year.

Month		**Time of day**																	
		0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
October	**M**																		
	F																		
November	**M**																		
	F																		
December	**M**																		
	F																		
January	**M**																		
	F																		
February	**M**																		
	F																		
March	**M**																		
	F																		
April	**M**																		
	F																		
May	**M**																		
	F																		
June	**M**																		
	F																		
July	**M**																		
	F																		
August	**M**																		
	F																		
September	**M**																		
	F																		

9. We would like to review local initiatives/groups for agriculture and livelihoods and importance
a. Are there local initiatives/groups for improved agriculture and livelihoods in your communities? 1 = yes; 2 = No
b. If yes may you please identify the purposes of the initiatives, indicate membership and importance for your household.

Name/Type of groups	**What is the purpose of the group/initiative?**	**Does any member of your family belong to this group?** 1= Yes 2=No	**On a scale of 1 – 5 Rank of importance of group**

1 = not very important; 5 = very important

10. Which of the following can you say was true for you as a farmer at any point in time during the 2012/2013 season?

Coping Strategy	***Implemented by household member*** 1 = Yes 2 = No	***Who decided to implement strategy?***	***During which month/s of the year was this done***	***Reasons for the strategy***
Sold livestock				
Sold household assets				
Consumed seed				
Ate food that is not normally eaten (e.g. wild food)				
Reduced amount of food eaten				
Ate fewer meals per day				
Sought daily work outside farm				
Migrated				
Borrowed cash or food				
Sold firewood				
Rented out land				
Withdrew children from school				
Looked for relief				
Ate wild fruit				
Ate one meal per day				
Visited other relatives				
Other (specify)				

SECTION E: ASSET OWNERSHIP

11 Household assets

Type of assets	**Quantity owned**	**Who owns** 1= Male head of household 2= Female head of household 3= Male spouse 4= Female spouse 5= Children 6= relative) 7=joint ownership	**Source** 1= Bought 2 = Gift 3 = Inheritance 4 = Dowry 5= Other (specify)
Agricultural			
Ox-drawn Plough			
Scotch cart			
Cultivator			
Harrow			
Ridging plough			
Tractor			
Irrigation equipment (e.g.			
Sprayer			
Ripper			
Hoes			
Axe			
Planter			
Wheel barrow			
Others (specify)			
Household			
Radio			
Television			
Bicycle			
Mobile phone			
Sewing machine			
solar panel			
Watch /clock			
Paraffin stove			
Borehole			
Other (specify)			

12. We would like to find out about livestock ownership and sales during the past 12 months.

Livestock Type		Number	Sources	Did you sell livestock during the past 12 months?	Who sold?	Where did you sell the produce	How was income used?
1	Cattle						
2	Donkey						
3	Goats						
4	Sheep						
5	Pigs						
6	Local						
7	Broilers						
8	Layers						
9	Others						

SECTION D: PERCEIVED CHANGES

13. What can your household and community do to increase agricultural production?

Changes at	For improved crop production	For improved livestock production
Household level		
Community level		
Others		

Interview stop time ....

Crop Production - Rain season 2012 – 2013

We would like to draw a map that outlines your farm enterprises (i.e. fields, kraals, fowl runs and homestead). Start by showing your homestead compound. Then draw the fields and other enterprises closest and furthest in a picture on the ground. Show any major landmarks near your homestead/fields like roads, school, and borehole**. (indicate the following on map, plot no, approximate size, crop grown previous season etc.)**

APPENDIX C: GUIDELINES FOR FOCUS GROUP DISCUSSIONS

AGRICULTURAL ADAPTATION TO CLIMATE CHANGE
FOCUS GROUP GUIDELINES

Questions
1. What are the major livelihood activities in your area?
2. What are the major agricultural activities in your area?
3. What are the constraints/ opportunities for improving agricultural production for men and women?
4. What are the constraints and opportunities in accessing agricultural information in your area?

ACTIVITY 1
Objectives
To identify constraints (including climate constraints), gender roles, factors that influence management choices for different crops and livestock in smallholder areas of Zimbabwe.
1. List livelihood options/opportunities in your area
2. Rank them in order of importance
3. Who is involved (men/women/children) in each
4. Draw a village seasonal calendar to show time the activities are carried out including major household, natural resource management activities
5. What are the constraints to agricultural production in your area (and follow up on climate e.g. crop, livestock)?
6. Identify the major climatic events in your area.

ACTIVITY 2: Identification of preferred gender sensitive crop management options in different smallholder areas of Zimbabwe.
Objectives
To rank agricultural practices using multi-criteria analysis in order to identify constraints and opportunities
To identify gender –sensitive preferred options for improved agricultural production in different climates

1. List adaptation options to agricultural related problems in your area (i.e. soil, water, crops grown, temperature)
2. Rank adaptation options for each
3. Identify criteria for assessing the options/list characteristics that make you select strategy/technology (also from stakeholders)
4. Assign weights to each criterion based on preferences of the smallholder farmers (e.g. urgency, inputs, and effectiveness)
5. Give weights to each criteria
6. Identify gender constraints related to techniques/technologies above e.g. in relation to your other duties or your area
7. Is there any room for improvement in any of the strategies / Discuss gender specific (sensitive) strategies to improve these adaptation options/agriculture in your area.

ACTIVITY 3: Role/importance of social capital in adaptation
Objectives
To understand the role of institutions in climate –smart agriculture in villages or/
To identify how climate-smart agricultural practices taken up by men and women came about
To understand constraints and opportunities of women /men in accessing information in climate smart agriculture
1. Name the institutions or organizations both local and external that provide you with services related to agricultural practices.
2. What are their roles/objectives?
3. Which have achievement /impacted climate smart agriculture e.g. soil, water, land, forestry, livestock practices related, weather forecasting etc.
4. Draw circles, with size indicating importance of the networks in your agricultural activities overlaps show linkages of networks/arrows
5. Who belongs to these networks (leadership roles) i.e. men, women children, elderly?
6. Do women /men face more constraints in accessing services from these institutions? If so what are the constraints?
7. Suggest ways in which information dissemination can be improved for you.

Respondent ID......................................

APPENDIX D

PARTICIPATORY EVALUATION tool GUIDELINES

Questionnaire Code …………………………………

EVALUATION OF FIELD TRIALS

Introduction

ICRISAT is carrying out research into how smallholder farmers in Zimbabwe and Kenya are coping with current environmental and socioeconomic conditions and how they might adapt to future changes. Accordingly you are invited to participate in this research study as we seek to identify technologies and processes that could increase the profitability of your farm enterprises and improve your capacity to adapt to change.

Please note the following:

- The answers you give will be treated as strictly confidential.
- Your participation in this study is very important to us.
- The results of the study will be used to identify the current and future constraints on improved productivity and to collaboratively develop solutions that could improve yields and livelihoods. The results may also be published in academic journals.

Date	
District	
Ward	
Research Station	
Name	
Age	
Gender	
Marital status	
Level of education	
Employment status	
Relationship to head of household	

Zvinangwa

1. Kuenzanisa zvirimwa
2. Kuenzanisa mhando dzembeu
3. Kuenzanisa nzira dzekuchengetedza hunyoro nemwando hwezvirimwa mumunda
4. Kuenzanisa mhando ndzakasiyana dzemafertilizer nedzekuchengetedza hunyoro muminda yechibage nemapfunde
5. Kuenzanisa/kuongoroora musiyano pamazuva/misi yekudyara mbeu nenzira dzekumeresa mbeu ye chibage, mapfunde, nyemba nenzungu
6. Kuongoroora zvinhu zvakakosha pakusarudza zvirimwa nemhando yembeu, nenzira dzekuchengetedza zvirimwa mumunda.

Objectives of the exercise

1. Evaluation of crops - with respect to days to maturity, yield crop stand and management required etc
2. Evaluation of crop varieties
3. Evaluate water conservation techniques and plant population
4. Evaluate different fertilizer and water conservation (tillage) on maize and on sorghum
5. Evaluate different planting dates and planting methods (seed treatment) on maize sorghum, cowpea and groundnut
6. Define important criteria for farmers (crops and varieties)

1. a. Ranking of Crops

Crops	Maize	Sorghum	Groundnuts	Cowpea	Score	Rank
Maize	**X**					
Sorghum		**X**				
Groundnuts			**X**			
Cowpea				**X**		

b. Reasons for ranking

	Notes
Maize vs sorghum	
Maize vs groundnuts	
Maize vs cowpea	
Sorghum vs cowpea	
Sorghum vs groundnut	
Cowpea vs groundnut	

c. Varieties - Pair wise ranking
Ask group/respondent every time which variety they/he/she prefer(s), and reasons for preference

i. Maize

	C1V1	C1V2	C1V3	Score	Rank
C1V1	X				
C1V2		X			
C1V3			X		

ii. Sorghum

	C2V1	**C2V2**	**C2V3**	Score	Rank
C2V1	X				
C2V2		X			
C2V3			X		

iii. Groundnuts

	C3V1	C3V2	C3V3	Score	Rank
C3V1	X				
C3V2		X			
C3V3			X		

iv. Cowpea

	C4V1	C4V2	C4V3	Score	Rank
C4V1	X				
C4V2		X			
C4V3			X		

d. Matrix ranking/scoring of varieties

Identify important characteristics for comparing varieties from pair-wise ranking discussions and through brainstorming

Scale: 1-10 1 = low/bad 10 = very high/good

i. Maize

	Variety		
Characteristic	C1V1	C1V2	C1V3
Score			
Rank			

ii. Sorghum

	Variety		
Characteristic	**C2V1**	**C2V2**	**C2V3**
Score			
Rank			

iii. Groundnut

Characteristic	**Variety**		
	C3V1	C3V2	C3V3
Score			
Rank			

iv. Cowpea

Characteristic	**Variety**		
	C4V1	C4V2	C4V3
Score			
Rank			

2. Effect of water conservation and fertiliser application on productivity of maize and sorghum **- Pair-wise ranking**

a. Sorghum

	W0F0C1	W0F1C1	W0F2C1	W1F0C1	W1F1C1	W1F2C1	Score	Rank
W0F0C1	**X**							
W0F1C1		**X**						
W0F2C1			**X**					
W1F0C1				**X**				
W1F1C1					**X**			
W1F2C1						**X**		

b. Maize

	W0F0C2	W0F1C2	W0F2C2	W1F0C2	W1F1C2	W1F2C2	Score	Rank
W0F0C2	**X**							
W0F1C2		**X**						
W0F2C2			**X**					
W1F0C2				**X**				
W1F1C2					**X**			
W1F2C2						**X**		

3. Effect of water conservation and plant population on productivity of groundnut and cowpea**- Pair-wise ranking**

a. Ground-nut

	W0P0C1	W0P1C1	W0P2C1	W1P0C1	W1P1C1	W1P2C1	Score	Rank
W0P0C1	X							
W0P1C1		X						
W0P2C1			X					
W1P0C1				X				
W1P1C1					X			
W1P2C1						X		

b. Cowpea

	W0P0C2	W0P1C2	W0P2C2	W1P0C2	W1P1C2	W1P2C2	Score	Rank
W0P0C2	X							
W0P1C2		X						
W0P2C2			X					
W1P0C2				X				
W1P1C2					X			
W1P2C2						X		

4. Effect of priming and planting dates on performance of sorghum, maize, groundnut, cowpea **- Pair-wise ranking**

a. Sorghum

	P0S0CI	P0S1C1	P0S2C1	P1S0C1	P1S1C1	P1S2C1	Score	Rank
P0S0CI	**X**							
P0S1C1		**X**						
P0S2C1			**X**					
P1S0C1				**X**				
P1S1C1					**X**			
P1S2C1						**X**		

b. Maize

	P0S0C2	P0S1C2	P0S2C2	P1S0C2	P1S1C2	P1S2C2	Score	Rank
P0S0C2	**X**							
P0S1C2		**X**						
P0S2C2			**X**					
P1S0C2				**X**				
P1S1C2					**X**			
P1S2C2						**X**		

c. Groundnut

	P0S0C3	P0S1C3	P0S2C3	P1S0C3	P1S1C3	P1S2C3	Score	Rank
P0S0C3	**X**							
P0S1C3		**X**						
P0S2C3			**X**					
P1S0C3				**X**				
P1S1C3					**X**			
P1S2C3						**X**		

d. Cowpea

	P0S0C4	P0S1C4	P0S2C4	P1S0C4	P1S1C4	P1S2C4	Score	Rank
P0S0C4	**X**							
P0S1C4		**X**						
P0S2C4			**X**					
P1S0C4				**X**				
P1S1C4					**X**			
P1S2C4						**X**		

5. Identify major differences between Matopos Research Station and Chiredzi Research Station:

Crops performance	
Variety performance	
Water conservation techniques and plant population	
Different fertilizer and water conservation (tillage) on maize and on sorghum	
Different planting dates and planting methods (seed treatment) on maize sorghum, cowpea and groundnut	

APPENDIX E

Maize and sorghum grain yields at Kadoma (hot/wet) and Mazowe (cool/wet), Zimbabwe in the 2012/13 season

	Maize yield (kg ha^{-1})			Sorghum yield (kg ha^{-1})		
	SC403	SC513	SC727	Macia	SDSL89473	Pato
Kadoma	2202	1848	1552	3164	2085	1595
Mazowe	5222	4358	5531	1934	3172	1720
	P value	SED		P value	SED	
Site	<0.001	106.0		0.865	36.2	
Variety	0.002	129.8		<0.001	44.3	
Interaction	<0.001	183.6		<0.001	62.7	

Maize and sorghum grain yields at Chiredzi (hot/dry) and Matobo (cool/dry), Zimbabwe in the 2012/13 season

	Maize yield (kg ha^{-1})			Sorghum yield (kg ha^{-1})		
	SC403	SC513	SC727	Macia	SDSL89473	Pato
Chiredzi	469	270	266	1133	967	348
Matobo	3648	2844	2310	3131	1662	1543
	P value	SED		P value	SED	
Site	<0.001	109.4		0.018	473.9	
Variety	<0.001	134.0		0.155	580.4	
Interaction	0.004	189.5		0.544	820.7	

APPENDIX G

Groundnut and cowpea grain yields at Kadoma (hot/wet) and Mazowe (cool/wet), Zimbabwe in the 2012/13 season

	Groundnut yield (kg ha^{-1})			Cowpea yield (kg ha^{-1})		
	Nyanda	Natal common	Makhulu red	CBC1	CBC2	Landrace
Kadoma	163	470	1326	636	783	867
Mazowe	662	603	1027	306	692	514
	P value	SED		P value	SED	
Site	<0.001	36.4		0.018	94.1	
Variety	0.007	44.5		0.086	115.3	
Interaction	<0.001	63.0		0.476	163.0	

Groundnut and cowpea grain yields at Chiredzi (hot/dry) and Matopos (cool/dry), Zimbabwe in the 2012/13 season

	Groundnut yield (kg ha^{-1})			Cowpea yield (kg ha^{-1})		
	Nyanda	Natal common	Makhulu red	CBC1	CBC2	Landrace
Chiredzi	344	332	272	640	639	653
Matobo	520	467	385	982	1032	380
	P value	SED		P values	SED	
Site	0.009	45.4		0.001	36.5	
Variety	0.207	55.6		<0.001	44.7	
Interaction	0.853	78.7		<0.001	63.1	

APPENDIX F: VARIETY CHARACTERITICS – PARTICIPATORY EVALUATIONS

Crop	Variety	Period to maturity	Agronomic characteristics	Grain Color
Maize	SC403	Very early maturing (120 to 140 days)	Yield stability Drought tolerance	White
	SC513	Early -medium maturing (141 to 155 days)	Excellent yield, Wide adaptation, Tolerance to Grey Leaf Spot, Slightly susceptible to root lodging at high population.	White
	SC727	Late maturing (141 to 155 days)	Tolerance to Leaf Blight, cob diseases, Maize Streak and Mottle Viruses, and Grey Leaf Spot (GLS), decent stalk standability.	White
Sorghum	Macia	Early maturing	Good disease tolerance, dwarf, Drought resistant, adapts well to a wide range of soils, yield potential 3.0 to 6.5 t/ha	White creamy perica
	SDSL89473	Medium maturing	Semi-tall to tall, Ear separates well from head Good standability.	brown
	Pato	Medium to late duration (130-140 days)	Semi-tall to tall, Thick stems Fairly tillering, Yield potential 3.0 - 5.0 tons ha^{-1}	creamy white with purple specks
Groundnut	Nyanda	Shorter season (<90 days)	Drought and heat stress tolerance, Good yields in marginal areas , Susceptible to foliar diseases lacks seed dormancy. Growth habit erect	Tan kernels
	Natal common	Medium maturing (90-100 days)	Spanish bunch type, Potential yield of 1.0 -1.5 t/ha Has no seed dormancy	tan kernels
	Makhulu red	Late maturing (130-145 days) variety.	Virginia bunch type, Potential yield 2.0 to 2.5 t/ha. Adapts to loamy and sandy soils.	Red kernels.
Cowpea	CBC1	Early maturing (75-80 days).	Broad leaves, susceptible to aphid attack determinant growth habit	brown
	CBC2	Matures (app 85 days)	Thin elongated leaves , yielding potential of 4 000 kg/ha, Good resistance to scab, ascochyta, bacterial blight, most viral diseases. Good tolerance to drought.	brown
	Landrace	Late maturing variety over (150 days).	High biomass compared to grain yields Indeterminate growth habit.	spotted with grey ar creamy-white spots

Pair-wise ranking of crop varieties under different climates

tation	Focus group	Maize variety rank			Sorghum variety rank			Groundnut variety rank			Cowpea variety rank		
		1	2	3	1	2	3	1	2	3	1	2	3
Matopos	Matobo males	SC727	SC403	SC513	Macia	SDSL89473	Pato	Natal common	Makhulu red	Nyanda	CBC2	CBC1	Landrace
Research	Matobo females	SC727	SC403	SC513	Macia	SDSL89473	Pato	Natal common	Nyanda	Makhulu red	CBC2	Landrace	CBC1
	Mean rank	SC727	SC403	SC513	Macia	SDSL89473	Pato	Natal common	Nyanda/ makhulu red		CBC2	CBC1/Landrace	
Chiredzi	Matobo Females	SC403	SC727	SC513	SDSL89473	Macia	Pato	Nyanda	Makhulu Red	Natal common	CBC2	CBC1	Landrace
Research	Matobo males	SC727	SC403	SC513	Macia	SDSL89473	Pato	Natal common	Makhulu red	Nyanda	CBC2	CBC1	Landrace
	Mean rank	***SC403/SC727***		***SC513***	***SDSL89473/Macia***		***Pato***	***Nyanda***	***Makhulu Red***	***Natal common***	***CBC2***	***CBC1***	***Landrace***
	Chiredzi males	SC403	SC727	SC513	Macia	SDSL89473	Pato	Natal common	Nyanda	Makhulu red	CBC1	CBC2	Landrace
	Chiredzi females	SC727	SC403	SC513	Macia	SDSL89473	Pato	Natal common	Nyanda	Makhulu red	CBC1	CBC2	Landrace
	Mean rank	SC403	SC727	SC513	Macia	SDSL89473	Pato	Natal common	Nyanda	Makhulu red	CBC1	CBC2	Landrace
	Mean males	SC403	SC727	SC513	Macia	SDSL89473	Pato	Natal common	Nyanda	Makhulu red	CBC1	CBC2	Landrace
	Mean females	SC403	SC727	SC513	Macia	SDSL89473	Pato	Nyanda	Natal common	Makhulu Red	CBC1/CBC2		Landrace
	Mean rank	SC403	SC727	SC513	Macia	SDSL89473	Pato	Nyanda/Natal common		Makhulu Red	CBC1	CBC2	Landrace
Mazowe	Maz/Gor males	SC513	SC403	SC727	Pato	SDSL89473	Macia	Makhulu red	Nyanda	Natal common	CBC1	CBC2	Landrace
Research	Female farmers	SC727	SC513	SC403	SDSL89473	Pato	Macia	Natal common	Nyanda	Makhulu red	Landrace	CBC1	CBC2
	Mean rank	SC513	SC727	SC403	SDSL89473/Pato-		Macia	-	-	-	CBC1	Landrace	CBC2
Cotton	Maz & Gor males	SC513	SC727	SC403	Macia	Pato	SDSL89473	Nyanda	Natal common	Makhulu Red	Landrace	CBC2	CBC1
Research	Females	SC403	SC727	SC513	Macia	SDSL89473	Pato	Natal common	Makhulu red	Nyanda	CBC2	CBC1	Landrace
	Mean rank	-	-	-	Macia	SDSL89473/Pato-			Nyanda	Makhulu red	CBC2	Landrace	CBC1
	Kadoma males	SC403	SC727	SC513	Macia	Pato	SDSL89473	Natal common	Makhulu Red	Nyanda	Landrace	CBC2	CBC1
	Kadoma females	SC513	SC403	SC727	Macia	Pato	SDSL89473	Makhuku red	Nyanda	Natal common	Landrace	CBC2	CBC1
	Mean rank	SC403	SC513	SC727	Macia	Pato	SDSL89473	Makhulu red	Natal common	Nyanda	Landrace	CBC2	CBC1
	Total male mean rank	-	-	-	Macia	Pato	SDSL89473	Natal common	Nyanda	Makhulu red	Landrace	CBC2	CBC1
	Total female mean rank	SC403	SC513	SC727	Macia	SDSL89473/Pato			Natal common	Nyanda	CBC2	Landrace	CBC1
	Total mean rank	SC403	SC513	SC727	Macia	Pato	SDSL89473	Natal common	Makhulu red	Nyanda	Landrace	CBC2	CBC1