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FARMER PERCEPTIONS ON CLIMATE CHANGE AND VARIABILITY IN SEMI-ARID ZIMBABWE IN RELATION TO CLIMATOLOGY EVIDENCE

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ABSTRACT

Farmers in semi-arid Zimbabwe prioritise climate variability as their major agricultural productivity-reducing problem. This paper raises the importance of considering local farmers' perceptions on climate risk, as this greatly influences on-farm investments and decision-making in agricultural management and production in semi-arid Zimbabwe. A study was conducted in two districts of semi-arid Zimbabwe using participatory research techniques, to investigate farmers' perceptions of climate variability and whether these perceptions correspond with historical climatic data. The study showed that farmers perceived climatic and weather patterns to have changed over the past decade or two, as indicated by erratic rainfall patterns, decreased rainfall and temperature increases, leading to crop productivity decline and increased livestock morbidity and mortality. Majority of respondents (75%; n=81) were highly risk-averse, perceiving that most of the seasons in any ten given years could be poor. The climatic data show no evidence that corroborates the farmers' perceptions, with only temperature showing a clear signal, indicating the influence of other non-climatic factors. The climate data show rainfall variability to be a normal characteristic of the study sites, with deviations from the climatic rainfall means (or the poor seasons) being cyclical and occurring once in every three seasons over the past 40 years. The study highlights strategies that farmers could implement to enhance agricultural productivity in the semi-arid areas to adapt to climate change and variability.

Key Words: Climate change and variability, climatology evidence, erratic rainfall patterns, farmer perceptions, risk aversion, temperature increase

RÉSUMÉ

Les fermiers des régions semi-arides du Zimbabwe mettent en priorité variabilité climatique comme facteur majeur de la réduction de la productivité agricole. Cet article évoque l'importance des perceptions paysannes eu égard au risque climatique étant donné son influence sur les investissements agricoles et la prise des décisions dans la gestion agricole et la production dans les milieux semi aride du Zimbabwe. Une recherche était conduite dans deux districts semi arides du Zimbabwe afin de faire état de perceptions paysannes sur la variabilité climatique et ses liens avec les données climatiques historiques. Une technique de recherche participative était utilisée pour cette fin. Les résultats de cette étude ont montré que les paysans perçoivent que les scenarios climatiques ont changé au cours d'une ou deux dernières décennies comme cela s'est manifesté à travers les pluies erratiques, la diminution des pluies et élévation de la température avec pour conséquences la diminution de la productivité des cultures l'augmentation de la morbidité et la mortalité du bétail. La majorité des répondants (75% ; n=81) était sous risque, percevant que la plupart des saisons pourrait être pauvre dans dix ans. Les données climatiques ne montrent aucune évidence qui confirme les perceptions paysannes, avec seule la température ayant un signal claire indiquant l'influence d'autres facteurs non climatiques. Les données climatiques montrent que la variabilité pluviométrique dans les sites d'étude présente une caractéristique normale, avec des déviations cycliques des moyennes des précipitations (les saisons pauvres) apparaissant une fois toutes les trois saisons au cours de 40 ans. L'étude met en évidence les stratégies auxquelles les paysans pourraient recourir pour améliorer la productivité des cultures en milieux semi arides pour l'adaptation au changement climatique et sa variabilité.

Mots Cés: variabilité et changements climatiques, évidence climatologique, pluies erratiques, Perceptions paysannes, risque d'aversion, augmentation de la température

INTRODUCTION

The year-to-year variability of rainfall is a significant constraint to the sustainability of rain-fed farming systems in poorer countries in sub-Saharan Africa (SSA) (Unganai, 2000). A strong dependence on rain-fed agriculture, high population growth rates, and unstable economic conditions compound the sensitivity to climatic variations and extremes (Martin *et al*., 2000) in semi-arid areas of Africa. Climate change and variability present many challenges in SSA (Hulme *et al*., 2005), and drought (both between and within seasons) is a recurrent feature of southern Africa. It is increasingly unusual for drought and other adverse climatic events not to occur each year (UNEP, 2002; Twomlow *et al*., 2006). Climate change scenarios generally predict an increase in temperatures for most of Africa (Tadross *et al.*, 2005) and these models predict a decrease and more variability in rainfall for most of southern Africa (Tadross *et al.*, 2005; IPCC, 2007). The scenarios indicate that climate variability will lead to increased droughts and more uncertainty about the onset and cessation of rains (Washington *et al*., 2004; IPCC, 2007). This type of evidence has led to interest in how farming systems cope and adapt to climate variability (Adger *et al*., 2005; Conway *et al*., 2005; Ziervogel *et al*., 2006). In Zimbabwe, three models used to analyse climate data predict a temperature rise of 2-4°C and an average rainfall decrease of 10-21% by 2100 (Mano and Nhemachena, 2006).

Rainfall variability tends to be the dominant source of livelihood and production risk in the drier environments, greatly affecting rain-fed smallholder agriculture (Zimmerman and Carter, 2003). The annual rainfall variation, including the onset, intensity, duration and cessation of rainfall greatly impact on socio-economic and agricultural activities in Zimbabwe (Unganai, 2000). Agriculture and the smallholder farming sector dominate Zimbabwe's economy, contributing 15-20% of Gross Domestic Product. It provides employment and direct livelihoods for about 70% of the population, including 30% of formal employment, and accounting for about 40 to 50% of the country's total export revenues (Anon., 2006; De Wit, 2006). Zimbabwe receives almost all of its rain during the five summer months from November to March, although the significant feature during the rainy season is its unreliability in terms of amount, duration and distribution.

Stakeholders, however, tend to over-estimate the negative impact of climate-induced risk when there are few local level evaluations in semi-arid Zimbabwe. Risk is associated with the likelihood and magnitude of harm; and management of risk is the action taken to reduce this harm and ultimately vulnerability. Under rain-fed agricultural systems, the seasonal rainfall variability means that farmers adopt a range of risk averse coping and livelihood strategies and this is evidenced by the highly variable production levels within different individual farmers' fields and among the farmers (Cooper *et al*., 2006). Climate shock impacts on household economies in southern Africa are usually worsened by diseases such as Human Immuno-Deficiency Virus (HIV) and Acquired Immuno Deficiency Syndrome (AIDS) and also insecure livelihoods (Vogel and O'Brien, 2006; Drimie and Gillespie, 2010).

One's perception depends on one's environment and its characteristics (Heathcote, 1969). Weber (2010) believes that most farmers' knowledge and exposure to climate change has been influenced indirectly by the media from events occurring in distant areas, e.g., the melting of ice sheets in the Antarctica rather than local events. Slegers (2008) also indicates that experience is an important factor that shapes individuals' perceptions, in terms of seasonality, with previous experiences of poor seasons bringing in memories and being responsible for how farmers may tend to describe different season types. Perception has been described as referring to a range of beliefs, judgments and attitudes (Slegers, 2008).

Bryant *et al*. (2008) suggests that the farmers' perceptions on climate change and variability are important in adaptation as they determine decisions in agricultural planning and management by the farmers. Farmers can be influenced by peers' perceptions and values within their community in terms of climate change and variability (Maddison, 2006). Perception of climate is based on economic and social impact it has on personal lives; and the farmers' perceptions of climate variability are important in adaptation as they determine decisions in agricultural planning and management (Slegers, 2008). The objective of this paper was to examine farmers' perceptions of climate variability and how these perceptions are reflected in the historical official meteorological data and to investigate whether farmers in the semi-arid areas of Zimbabwe over-estimate climate effects or not.

MATERIALS AND METHODS

Study area. Zimbabwe's semi-arid areas are classified as agro-ecological zones (AEZ) or natural regions (NR) IV and V (Table 1). Campbell (1994) revealed that the areas are unsuitable for crop production, with the Government of Zimbabwe recommending them for semi-extensive (NR IV) and extensive farming (NR V) (CSO, 1985).

The investigation was mainly conducted in Masvingo District, Wards 14 (Zano/Topora) (20.16^{0}S; 31.04^{0}E; Elevation of 1165m) and 19 (Mapanzure) (20.24^{0}S; 30.52^{0}E; Elevation of 901m) as well as in Hwange District, Wards 3 (Ndlovu/ Kachechete) (18.06^{0}S; 25.58^{0}E; Elevation of 987m) and 7 (Jambezi) (18.03^{0}S; 26.13^{0}E; Elevation of 896m) (Fig. 1). The study region (semi-arid Zimbabwe) is characterised by semi-subsistence farming, with low productivity in the communal areas and maize (*Zea mays* L.) yields averaging less than 600 kg ha^{-1} (Ahmed *et al*., 1997). The length of the growing period in the study areas is quite variable, ranging from 70-100 days in the south east Lowveld (NR V) to 100-135 days in the south east Middleveld, though it is less than 70 days in some of the areas of the Lowveld (FAO and ACFD, 1999). Semi-arid areas are subject to seasonal droughts and severe dry spells during the rainy season (mid season droughts).

The soils in the study areas are largely derived from granitic/gneissic parent materials and are thus sandy textured; characterised by low nitrogen, phosphorus and sulphur (Nyamapfene, 1991). They are also low in cation exchange capacity owing to low organic matter contents (Nyamapfene, 1991). Such soils have a limited ability to store organic matter and nutrients and soil fertility declines rapidly with cultivation.

The districts were purposively selected to represent semi-arid environments of Zimbabwe and based on their contrasting agricultural potential, with Masvingo having a higher agricultural potential than Hwange (Fig. 1). Other factors considered in selecting the districts included: the presence of meteorological stations and population density. The wards were also

TABLE 1. Agroecological characteristics of the semi-arid areas of Zimbabwe studied

Natural region	Description
IV	Annual rainfall is between 450-650 mm. The area is subject to seasonal droughts and severe dry spells during the rainy season (mid season droughts).The area is found in the hot, low lying land and is marginal for rain-fed maize. It is however ideal for drought resistant grain and fodder crops and livestock production
V	Annual rainfall is less than 450 mm, and the rainfall is too low and erratic for most crops. The area is very hot, in a low lying region that is suitable for extensive animal husbandry with drought resistant grain and fodder crops.

Source: Bird *et al*. (2002)

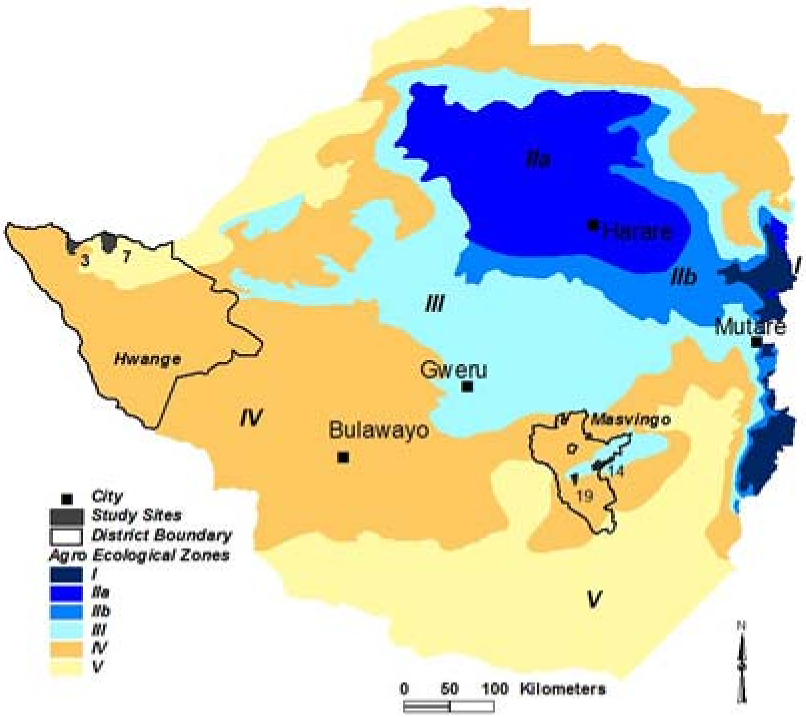

Figure 1. Map of Zimbabwe showing study locations and agro-ecological regions (*Generated by ICRISAT Matopos GIS Unit, 2010*).

purposively selected and simple random sampling was used to select the households (approximately 20 in each ward) interviewed (Table 2). A record of all farmers in the wards held by the Agricultural Technical and Extension Services (AGRITEX) officers was stratified into households participating in current agricultural innovations in the survey areas and those who did not, and then households from each group were randomly selected for interview.

TABLE 2. Summary of the study sites and number of respondents in semi-arid areas in Zimbabwe

District	Ward	Households interviewed
Masvingo	14	20
	19	20
Hwange	3	20
	7	21
Total		81

Survey data. Data were collected in August 2009 through two complementary approaches, namely (i) focus group discussions (FGDs) and (ii) farmer interviews using semi-structured household questionnaires. An FGD was held in each ward to collect qualitative information on the farming systems and farmer perceptions on climate variability and use of seasonal climate forecasts and on how they cope with variable climate. The FGDs enabled community perspectives to be captured and provided a more holistic picture of the survey areas in terms of climate-related issues and biophysical and socio-economic constraints farmers face due to climate variability. A total of four FGDs (i.e. one for each ward) were held, comprising about 15-20 mixed farmers (mixed in terms of gender, age, resource endowment, and level of education).

The household interviews were held with the key decision-maker within the household, especially on field crops and other farm enterprises such as livestock rearing, as well as any other members of the households regarded as key informants. The semi-structured questionnaire used both a qualitative and quantitative research approach (Bryman, 2008) to collect data on household level data on factors that may influence farmers' perceptions on climate variability. Some of the specific aspects covered in the questionnaire included:

(i) Demographic and socio-economic indicators;
(ii) What weather-related changes have been noted over the years and explanations for such changes;
(iii) Indicators of climate change;
(iv) Sources of weather- and climate-related information; and
(v) Farmers' coping mechanisms or strategies in face of climate variability i.e. what farm and agricultural management practices they employ in face of climate variability and other socio-economic coping strategies they employ.

However, this paper only presents analyses of how farmers perceive climate change and variability, comparing the perceptions to actual climatic data within the study sites.

Data were collected by a team of experienced bilingual enumerators who moved from the predominantly *siNdebele*-speaking region of Hwange to the *chiShona*-speaking district of Masvingo. This team had initially undergone a three day training workshop, specifically to undertake this survey followed by field-testing of the tools and the subsequent refinement of the questions. Upon arrival in each district, the team contacted the local AGRITEX officers and the local leadership, who facilitated farmer participation at FGDs. The AGRITEX officers helped with introductions of the research team to the district authorities and the communities; and household sampling and identification. The questionnaire focused on livelihood and farming activities at the onset and avoided leading questions on climate change and variability and in some instances used open-ended questions to allow farmers to introduce weather-related issues into the discussion. The semi-structured interviews were a two way process where respondents were free to express their opinions and ask questions.

The data were entered and analysed in the Statistical Package for the Social Sciences (SPSS) and MS Excel. Statistics were mainly descriptive including means, frequencies and standard deviations where applicable. These were used to identify the differences that prevail between different categories of farmers such as gender, age, level of education, wealth status and access to technical/extension advice.

Climatology evidence. To ascertain if farmers' perceptions of climate change and variability correspond to actual long term climatic records,, climatic data for Hwange and Masvingo districts collected by the Zimbabwean Meteorological Department, were analysed and compared to findings from the farmer survey. The study sites had been selected as close to the meteorological stations to minimise impact of spatial variability. For Hwange, data consisted of daily rainfall totals from 1962/63 to the 2008/9 cropping season and annual rainfall totals for the period from 1905/06 to the 2008/09 cropping season. In the case of Masvingo, data consisted of daily rainfall totals from the 1951/52 to the 2008/9 cropping season. For the temperature data, the daily maximum values were summarised on a monthly basis, giving the mean of the daily maxima and the two extremes within the maximum temperature (i.e. highest maximum temperature and the lowest maximum temperature). The same was calculated for the daily minimum temperatures and this was collected for the national mean from 1962 to 2002.

RESULTS

Household characteristics. The majority of the respondents in the survey were male-headed households (Table 3) and most of the household heads who attended the most number of years in school were found in Masvingo (seven years) compared with six years for Hwange. The most experienced farmers in terms of average number of years of farming within their localities were also in Masvingo (approximately 26 years), compared with Hwange (Table 4). The average household sizes were seven and six for Masvingo Hwange, respectively.

TABLE 3. Household headship characteristics in study districts in semi-arid parts of Zimbabwe

Household headship	Percentage of sample (n=81)
Male headed	73
De facto Female Headed Household (with husband living away)	4
De jure Female Headed Household (without husband i.e. widow, single, divorced)	23

TABLE 4. Means of the different household characteristics by district in semi-arid parts of Zimbabwe

District	Masvingo (n=40)	Hwange (n=41)
Age of the decision-maker	47	52
Years spent in school by the decision-maker	7	6
Years since the decision-maker started farming	26	22
Current household size	6.6	6.2
Number of chronically ill persons	0.1	0.2
Full time labour available for smallholding agriculture	3	3
Part time labour available for smallholding agriculture	1	2

The absence of chronically ill persons in both districts may imply that the impact of HIV and AIDS on agricultural production is not prevalent since presence of chronically illness within a household can be used as proxy for the pandemic. HIV and AIDS is assumed to be one of the major agricultural production constraints as household members have to spend valuable work time taking care of the ill and this may also strain household resources in terms of health expenses (Table 4).

Farmer perceptions on climate variability and the effects. Farmers were asked how the weather had changed over the years, i.e. what the weather was like a long time ago and what changes they had observed over the past decade or two. Almost all the respondents (98% of the 81 farmers that were interviewed) believe that the climate is changing and is no longer as it was some years back. They indicated that these changes were mainly associated with rainfall amount, distribution and temperature Table 5).

The farmers reported that over the years in question, the onset of the rainy season had shifted from around the third dekad in October to end of November and early December. During the FGDs in both districts, the farmers revealed that in most years they tend to receive fairly high rainfall amounts in January lately. Another change noted was that the season had become more unpredictable; with the rainy season ending abruptly and early (Table 5). In the FGDs, the farmers in both districts (n=60) revealed that their season ended as early as beginning of March. A farmer in his late 60s indicated that:

"…in the past when I was younger, effective rains used to start early in the month of October, but nowadays, the rainy season starts at the end of November and even in December, and this is now confusing farmers, rains are now very unpredictable…."

The farmers also reported that effective rains now fell within one month, mostly December and the distribution had become more unpredictable and erratic in both districts. The farmers noted that in the past, rainfall distribution over the season was even (normal) and they could manage to plan their agricultural activities properly and effectively, knowing when to expect significant dry and wet spells. It was also noted during the FGDs that farmers are now experiencing increasing spatial rainfall variation, with some places receiving evenly distributed rainfall, whilst their neighbouring areas received erratic rainfall. About 40% (n=60) of the FGD participants in both Masvingo and Hwange districts reported a rise in temperatures, with the perceptions that the winter months were no longer as cold as in

TABLE5. Weather changes that farmers have noted over the past two decades in semi-arid parts of Zimbabwe before 2009

Perceived change	Percentage of sample (n=81)
Increased number of seasons without enough rainfall	51
Rainfall starts late and ends early	72
Extremes in temperatures	38
Long dry spells during the season	58
Rains do not come when they normally used to	58
Rainfall starts late	7
Prolonged/extended winter season	6
Short winter seasons	1
Too much rain	4
Rainfall distribution within seasons now poor	1

the past. The farmers also mentioned that they now received rains in the month of June, which is normally the dry winter period in Zimbabwe.

Regarding the perceived changes that affect their livelihoods, about 87% of the respondents(n=81) indicated that they had experienced reduced crop production due to some of the weather changes. High morbidity (2% of the sample) and mortality (10% of the sample) rates in livestock were also experienced and perceived to be due to climatic changes .

Farmers' perceptions of weather-related changes. More than 60% of respondents in both Masvingo and Hwange districts reported that the perceived weather changes (Table 5) had frequently been occurring, being witnessed in every 5-6 years in a 10 year period (Table 6). One farmer aged 59 years, during a FGD explained that:

"……in our youth, it was unheard of to have 2-3 poor rainfall seasons in a row. Nowadays, these poor seasons are more pronounced, occurring on a regular basis and usually accompanied by unusually high temperatures, even in winter, but especially in the months of October and November…..".

The FGDs indicated that climate effects "are the work of God and cannot be influenced". About 48% of farmers indicated that the perceived weather changes are generally caused by cultural and religious factors (Table 7). The majority of the respondents (52%), however, attributed the perceived weather-related changes to natural climatic processes. On the other hand, the FGDs in the districts revealed that ancestors were angry due to the fact that most cultural norms and beliefs were being ignored; hence, they had brought in climatic changes, mostly being adverse, as punishment to modern society. The following are some of the expressions from the farmers, indicating that God and the ancestors are angry:

"…..we have now abandoned our ancestors, and we are following the modern world so much that

TABLE 6. Frequency of perceived weather-related changes in the last 10 years in semi-arid areas of Zimbabwe

Frequency	Percentage of sample (n=81)
Once	2.5
Twice	10
Three times	20
Four times	23
Five times	16
Six times	14
Seven times	11
Eight times	2
Nine times	1
Ten times	0

TABLE 7. Farmer perceived causes of the changes farmers are seeing in semi-arid parts of Zimbabwe

Perceived cause	Percentage of sample (n=81)
Natural changes in climate	53
Cultural and religious reasons	48
Political problems leading to "gods" being angry	5
Depletion of natural resources	1
Air pollution	2

we no longer even go to "Njelele", the rainmaking shrine to pray to our ancestors for a good rainy season….."

"….lots of unusual things are now happening in our midst, so many women being raped, a lot of murders, immorality and God is not happy, hence is punishing us by not bringing any rains….."

It also emerged from the FGDs that an erosion of religious values and beliefs had been perceived to cause some of the weather changes they had noted over the years. From the political standpoint, the tensions witnessed in Zimbabwe over the last 10 years were also attributed to these weather-related changes, with farmers stating the "owners of the land" or ancestors were not happy with what was happening (political upheavals), hence, were also punishing society by bringing in these mostly adverse weather changes presented in Table 5.

Farmers talked of a "good year" or a "bad year" when evaluating cropping seasons, and any problem that limits harvests is perceived as leading to a bad season, with climate-related factors, especially rainfall being the major problem. The actual "climate variation" in a specific area was described by the farmers within this study as a deviation from their ideal climate that was necessary for a successful livelihood. Most commonly, the majority of the farmers (90%, n=60) during the FGDs described seasons' status based on weather conditions, namely the amount and distribution of rainfall and the prevailing temperatures within a given season and the maize yields attained during different seasons. A bad season was widely regarded by more than 90% of the farmers in the FGDs (n=60) as a season with irregular rainfall distribution, where rains could fall at the start of the season and the season would then be characterised by very long dry spells, leading to crop wilting and ultimately failure or poor yields. The farmers also indicated that in a poor season, grain prices usually shot up and tended to be unaffordable.

A normal season was generally considered to be that season where the maize yields were enough only for household consumption, without any surplus for sales; with normal rainfall amounts and a fair/steady rainfall distribution within the season. A good season was considered to be a season with evenly distributed rainfall, where crops grew very well and there was enough maize yields for household consumption, as well as a surplus (and related grain sales) for the majority of the different households within the study areas. Good seasons were reportedly characterised by above normal rainfall amounts, with a very good distribution within the different months of the season, i.e. early start of the rains, without long dry spells within the season, and rains falling up to the month of April. Farmers within the FGDs also indicated that during good seasons, the market price of grain was usually low due to too much competition as most households had surplus grain.

Farmers' perceptions and expectations of different season types. The farmers were asked about their maize yield expectations in a poor, average and good season. In this case, the assumption was that farmers had the same amount of inputs as in 2008/9 season, which was considered by the majority of the farmers in both districts to be a normal season. The farmers in Hwange indicated that they would expect to get about 500 kg ha^{-1} in an average season, while their counterparts in Masvingo indicated that they would expect double that in an average season (1.05 t ha^{-1}) (Table 8).

The farmers were also asked how they perceived seasons to fare in any given 10 years. The majority of the farmers in Hwange district (about 75%, n=41) (Fig. 2) were pessimistic, as

TABLE 8. Expectations of maize yields in different seasons in semi-arid parts of Zimbabwe

Season expectations	Masvingo yield in kg ha^{-1}(n=40)	Hwange yield in kg ha^{-1}(n=41)
Poor season	373.7	207.4
Average season	1023.2	489.6
Good season	1911.6	888.1

they tended to perceive the majority of the seasons in every 10 years as poor or average, with few good season expectations. For this study site, the mean rainfall for the period from 1905/6 season to the 2008/9 season was 698.3 mm, with the above normal rainfall being taken to be rainfall amount ≥ 872.9 mm; below normal was ≤523.7 mm,; while the normal was the range between 698.3 and 872.9 mm. The same was calculated for the 10 year period from 1999/2000 season to 2008/9 season, and the mean was found to be 719.31, with the below normal rainfall being 539.5 mm, the above normal being 899.1 mm; while the normal being the range from 539.5 to 899.1 mm.

The perceptions were similar in Masvingo district, where the majority of the farmers also indicated that they would expect to receive a higher percentage of bad seasons than average or good seasons in any given 10 years (Fig. 3). In the Masvingo study site, the mean rainfall for 107 years was found to be 635.54 mm, with the below normal rainfall taken as ≤75% of this long term mean, which was 480 mm; while the above normal rainfall was taken to be >125% of the long term mean and this was found to be 795 mm. Lastly the normal rainfall, which was the range between 75 and 125% of the mean rainfall over the 107 years, was found to be between 580 and 795 mm. The farmer perceptions were compared to the

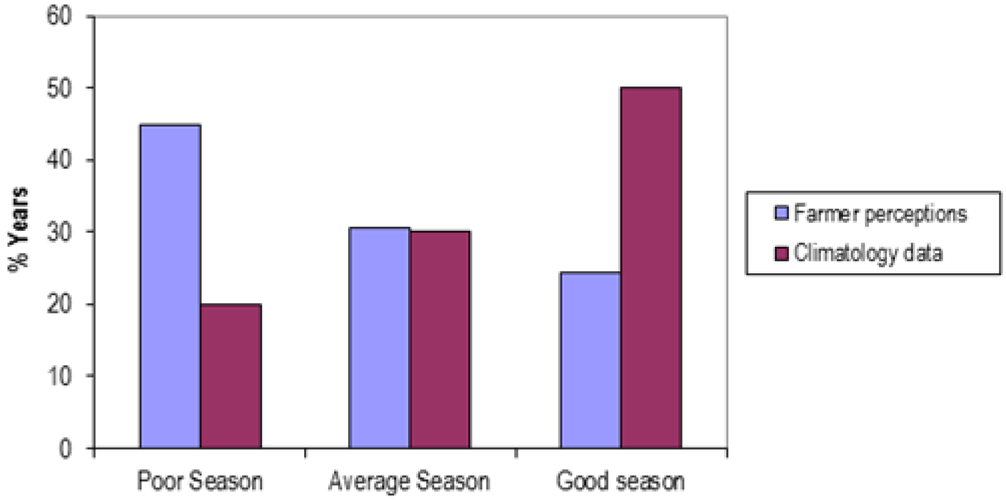

Figure 2. Hwange district farmers' perceptions of frequency of good, average and poor seasons compared with reality of climate data for the past 10 years in semi-arid Zimbabwe.

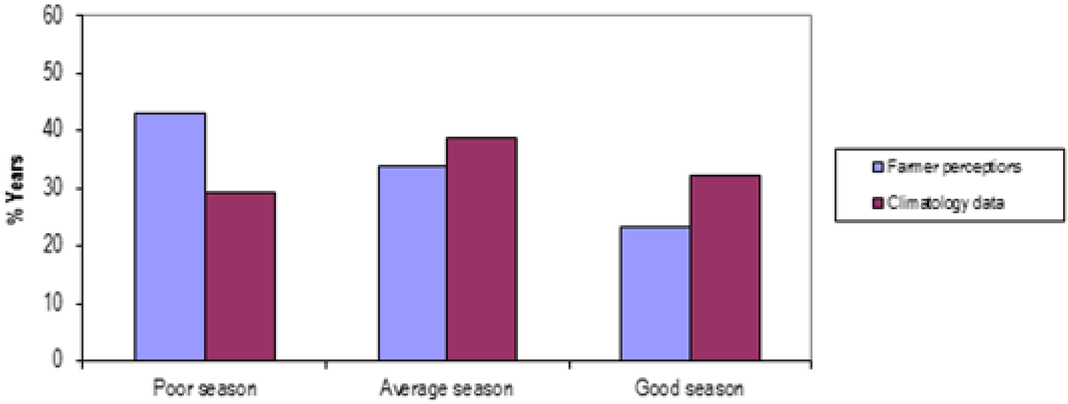

Figure 3. Masvingo district farmers' perceptions of frequency of good, average and poor seasons compared with reality of climate data for the past 10 years in semi-arid Zimbabwe.

actual rainfall that had been recorded in the study sites for the 10 years (1999/2000 to the 2008/9) season and it was found that the normal rainfall regime had frequently occurred, i.e., 6 out of the 10 season, with the below normal or poor season only occurring once in these 10 years. There are contradictions in the farmer perceptions compared to actual climatology data, with the majority of the years being perceived as poor by the farmers (Fig. 3).

A unanimous perception exists amongst the different farmer groups that there is a higher frequency of poor seasons in the farmers' localities. However, statistical analysis of the survey data showed no significant differences across the following categories: gender groups, levels of education, different age groups and access to agricultural extension advice.

Farmers' perceptions of the recent seasons (2004/5 to 2008/9). Figures 4 and 5 summarise responses to the question posed to farmers on how the past five seasons could be classified in terms of being poor, average or good with respect to rainfall trends. It is clear that recent events usually have more weight in these farmer

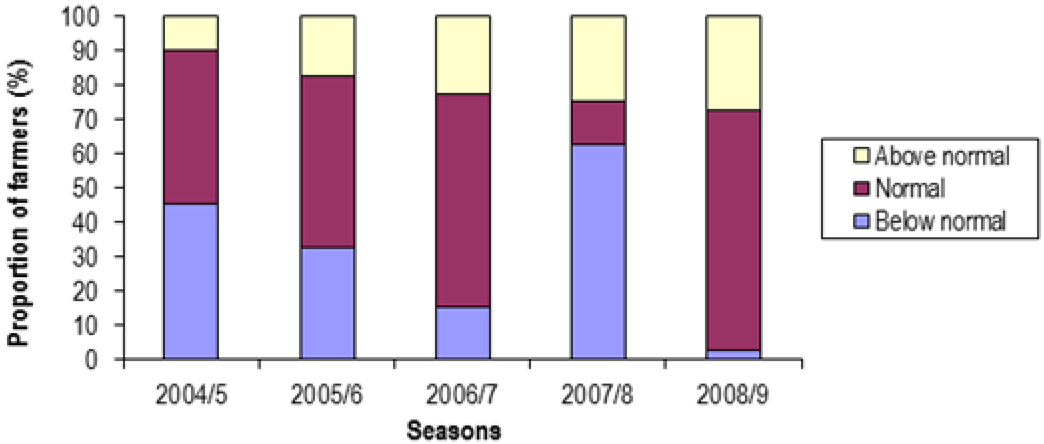

Figure 4. Farmers' perceptions and classification of the past 5 cropping seasons (2004/05 to 2008/09) in Masvingo district in semi-arid parts of Zimbabwe.

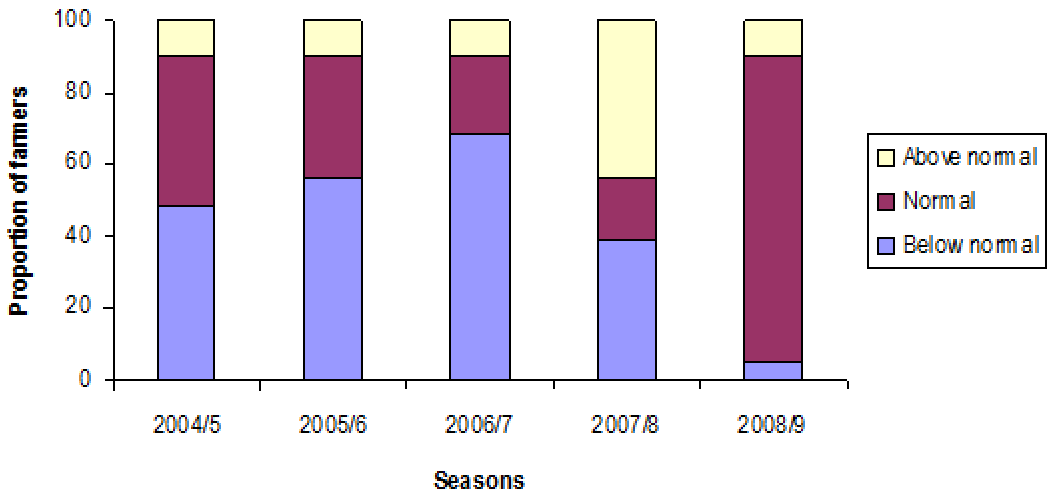

Figure 5. Farmers' perceptions and classification of the past 5 cropping seasons (2004/05 to 2008/09) in Hwange district in semi-arid Zimbabwe.

perceptions than distant events, with good agreement in terms of farmers perceptions for the 2008/9 season, than for the preceding season in both districts. Thus, in Masvingo for the 2008/9 season, there was generally good agreement (>90%, n=40) among the farmers that it was an average to above average season, and in Hwange for the 2008/9 season, there was also generally, good agreement (85%, n=41) that it was a normal season. During the FGDs, more than 90% of the farmers in both districts (n=60) had a vivid memory that the 1991/2 season had devastating effects to their livestock health, with many deaths reported and reduced crop yields leading to severe food insecurity security. Extreme events such as the 1991/2 drought, as well as the 1996/7 bad season, had an indelible effect in peoples' memories, similar to that of 2007/8 season that was said to have been affected by political tensions in Zimbabwe, in the run up to the national general elections.

The majority (>50% over the 5 years referred to in Figs. 4 and 5) of the farmers in the study reported that over the past five seasons, the seasons had either been normal to below normal, supporting what they had earlier alluded to that the majority of seasons were poor to average. Generally, there was a small population that believed that some of the seasons have been above normal in terms of rainfall distribution and amounts (Figs. 4 and 5).

Climatology evidence compared to farmers' perceptions

Rainfall data - Hwange study sites. When comparing the actual rainfall data for the past 5-10 years with the farmer perceptions as stated by the farmers (Fig. 5), there is generally good agreement among farmers that the 2008/9 season was a normal season. The results from Figure 5 also indicate that there is general agreement in Hwange district that the 2006/7 season was poor. These perceptions, however, contradict in some cases with the climate data available. In the case of Hwange, in the 2007/8 season, the total rainfall amount suggests that it was an above average season (Table 9). However, further analysis indicates that the rainfall distribution within the season, especially the intra-seasonal dry spells that was experienced in February, which only had four rain days, was very erratic.

The Hwange rainfall data were also analysed for the cycles of deviation from the long term mean for the period from 1960 to date. The mean was taken as zero, in the case of Hwange district the calculated mean was 665.8 mm for the period 1960/61 season to 2009/10 season. The analysis shows that the meteorological drought years tended to occur in every 2-3 years, with the worst drought being in the 1981/82 season, where there was a deficit of 413 mm from the long term mean (Fig. 6).

Rainfall data – Masvingo study sites. When comparing the actual rainfall data for the past 5-10 years with the farmer perceptions as stated by farmers in Figure 4, there was general concurrence among farmers that the 2007/8 and the 2008/9 seasons were normal. There was also general agreement in Masvingo district (about 70% of the households interviewed) that the 2006/7 season was a normal one (Fig. 4). There are, however, contradictions in farmers' perceptions of the seasons prior 2006/7. The farmer perceptions when compared to climatology data (Table 10) conflict in some years. In the 2004/5 season, where meteorological records indicate

TABLE 9. Total monthly rainfall (mm) for Hwange district for 2004/5-2008/9 cropping seasons in semi-arid Zimbabwe (Data source: Zimbabwe Meteorological Services Department)

Season	October	November	December	January	February	March	Total
2004/5	0	6.8	154.9	192.1	232.3	0	586.1
2005/6	0	59	236.8	158.9	35.1	44.1	533.9
2006/7	23.3	60.1	97.4	394.6	104.3	67.5	747.2
2007/8	1.9	40.2	291.2	184.9	60.6	171.7	750.5
2008/9	0	155	269.7	271.5	101.2	139.9	937.3

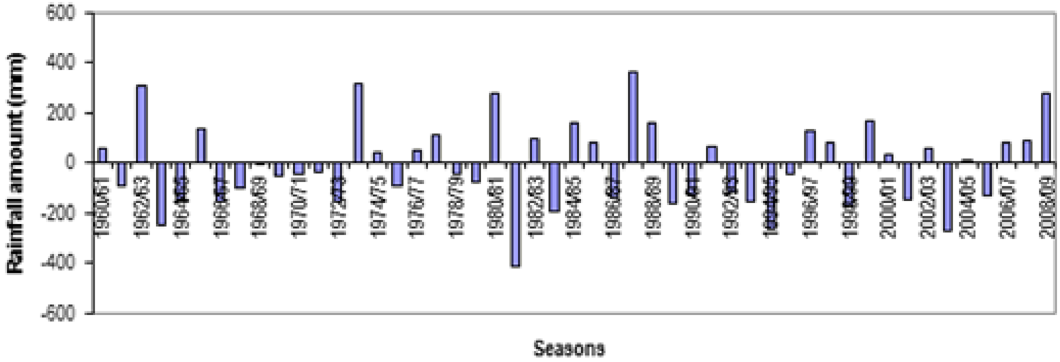

Figure 6. Hwange study area rainfall deviation from normal (mm) (1960/61 to 2008/9) in semi-arid Zimbabwe (Data source: Zimbabwe Meteorological Services Department)

TABLE 10. Total monthly rainfall (mm) for Masvingo district (2004/5-2008/9 cropping seasons) in semi-arid Zimbabwe (Data source: Zimbabwe Meteorological Services Department)

Season	November	December	January	February	March	April	Total
2004/5	17.6	189.6	154.9	91.3	28.8	0.7	482.9
2005/6	62	462.8	239.7	51.9	130.8	1.7	948.9
2006/7	104.4	86.8	85.5	94.8	23.4	70.9	465.8
2007/8	178.7	362.9	239.9	37.8	7.4	0	826.7
2008/9	59	194	148.4	128.1	40.6	15.7	585.8

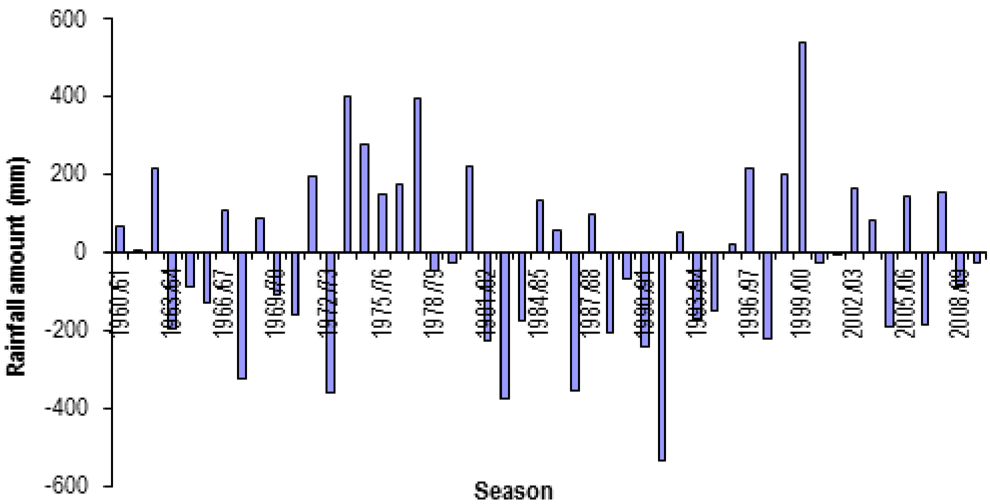

Figure 7. Masvingo district rainfall deviation from normal (mm) (1960/61 to 2009/10) in semi-arid Zimbabwe (Data source: Zimbabwe Meteorological Services Department).

that it was a poor season, the farmer perceptions seem to be in disagreement as only 40% of the respondents also indicated it was a poor season, with the majority of 60% of the respondents indicating that it was a normal to good season. There is therefore a contradiction between farmer perceptions and the meteorological data.

There are also contradictions in the farmer perceptions and the climatology data for the 2006/7 season, with meteorological data indicating that it was a poor season (465.8 mm), but farmers indicating that it was a normal to good season. However, further scrutiny of the season's rainfall trend indicates that there was fair distribution, though there was a long dry spell in January 2007. The 2007/8 season has been described by farmers as a poor season, though climatologically it could be indicated as a good season, with 826.5mm of rainfall. However, the farmers are correct in describing the season as poor as the season initially had good rainfall distribution in the months of November and December, but was accompanied by long dry spells in January (of more than 20 days) and there was a marked early cessation of the rains (around the 2nd of February 2008, instead of the usual 28 February (Table 11). For the most recent season that the farmers were asked about, there seemed to be good agreement amongst the farmers and between their perceptions and the meteorological data, with more than 90% of the respondents indicating it was a normal (to above normal season), and the climatology data also indicates it was between 75-125% of he long term mean of the area, which is classified as normal season.

The Masvingo meteorological rainfall data were analysed to elicit the occurrence of drought years and the analysis shows that the meteorological drought years tended to occur once in every three years, with the worst being in the 1991/92 season, where there was a deviation of 534 mm from the long term mean (Fig. 7).

The findings from the actual meteorological data indicate that there was no agreement in climatology data and the farmer perceptions that had been earlier stated in Table 5. The climatology data do not tally with most of the farmers' perceptions that there has been a reduction in rainfall amount, and an increase in cases of poor distribution of rainfall witnessed in every 3-6 years in a 10 year period. Analysis of the climatology data from 1970 to 2000 (Table 11) to determine the onset and cessation dates of the rainy seasons within the study sites, revealed that there had been no shifts in these, especially in the past 10 seasons. However, the rainfall data in Figure 7 for Masvingo study site indicates that between 1960 and 1993, there had been an increase in departure from normal that has been observed.

TABLE 11. Hwange and Masvingo study sites onset and cessation dates of the rainy season (1970-2000) in semi-arid Zimbabwe

Meteorologi-cal Station	Mean annual rainfall (mm)	Mean Onset	Standard Deviation (days)	Median Onset	Mean Cessation	Standard Deviation (days)	Mean Duration (days)	Standard Deviation (days)
Masvingo	617	23-27 Nov	25	23-27 Nov	28 Feb-2 March	35	95	44
Hwange	657	18-22 Nov	17	21-25 Nov	11-15 March	23	108	28

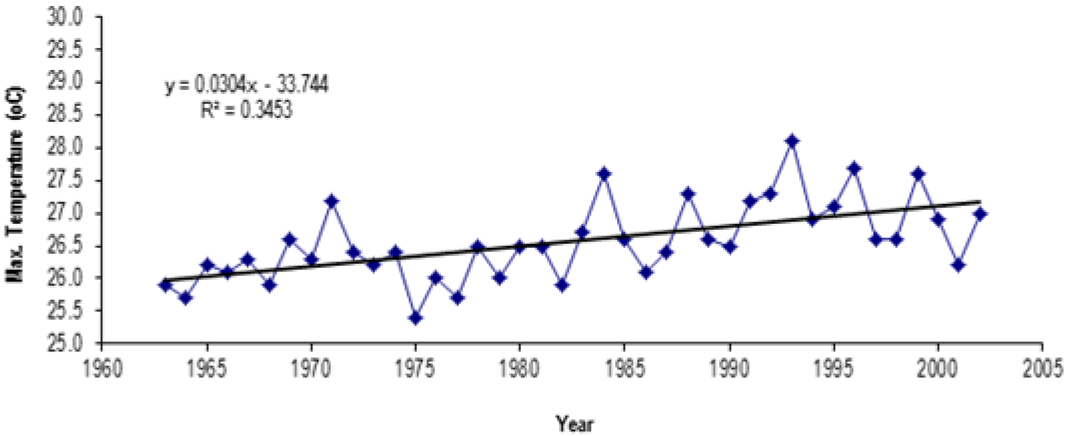

Figure 8. Annual mean maximum temperature trend (1962-2002) (Data source: Zimbabwe Meteorological Services Department).

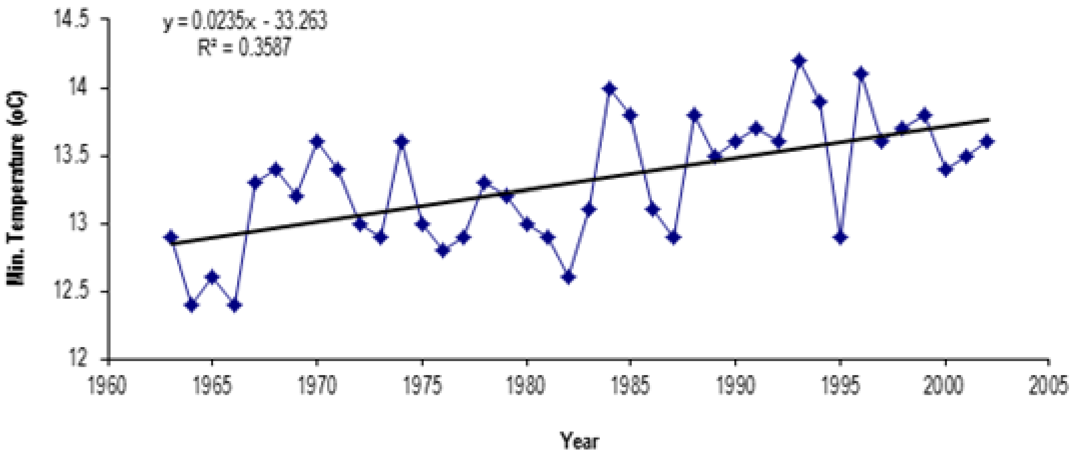

Figure 9. Annual mean minimum temperature trend (1962-2002) (Data source: Zimbabwe Meteorological Services Department).

Temperature data. The actual trends in both minimum and maximum temperatures (Figs. 8 and 9) show a clear increase, which is in agreement with the farmers perceptions recorded in Table 5. Temperature is the only variable that farmers perceived that had a clear signal in the climate record.

DISCUSSION

Farmers' perceptions on climatic change and variability. Smallholder farmers in Zimbabwe showed awareness of climate change and variability, mainly through their experiences. Studies on assessing farmer perceptions in semi arid environments of Africa have reported similar findings (Nyanga *et al.*, 2011; Rao *et al.*, 2011; Osbahr *et al.*, 2011). This study generally indicates that farmers believe that the climate is changing for the worse. The study revealed that the perceived climatic changes had led to changes in agricultural productivity (mostly a decline in crop production).

About 87% of the farmers in the study reported that the weather changes had affected agricultural productivity and this proportion was far higher than the reported perceived changes (55% and less), suggesting concurrence amongst the farmers that agricultural productivity has been affected. There is, however, divergence of perceptions amongst the farmers, as indicated by the results of what is causing these changes in agricultural productivity. Farmers reported a number of changes within their localities or areas though contradictions were apparent among the farmers about the exact nature of the changes and the magnitude of the changes. This may indicate that there are different perceptions of what changes have occurred, but maybe the most remembered or evident aspect the farmers associate with climate variability is the decrease in agricultural productivity.

There was uncertainty in terms of how seasons will fare, which in turn may discourage any beneficial investments in terms of agricultural production for farmers (Cooper *et al*., 2008). The farmers also reported considerable morbidity and mortality rates of their livestock which were attributed to the climatic changes the farmers had experienced over the years. This further limits their livelihood options as livestock are a major source of livelihood in southern Africa, apart from cropping.

Climatology data compared to farmers' perceptions. Farmers used the term "poor season" to refer to any year with reduced crop production due to insufficient rainfall and other crop production constraints. Perceptions of climate, according to Slegers (2008), are based on the livelihood impacts the climate has on individual farmers, i.e. the social and economic impacts. In this study, any season that negatively affected the farmers' livelihoods was described as poor. For example, the length of the dry spell was a major constraint in relation to crop failure as revealed by Masvingo farmers during the 2007/8 season. In this district and season, 827 mm of rainfall was received, which climatologically can be classified as above average, but was characterised by long dry spells in the month of February 2008 and was therefore classified as poor by the farmers. The Zimbabwe Meteorological Services Department classifies seasons according to whether they were below normal, normal or above normal. The Department classifies any season receiving $\leq$75% of the long-term mean (of 30 years) as below normal or poor; seasons ranging from 75% of the long-term mean to 125% as normal (or average in this study); and those seasons $\geq$125% of the long-term mean rainfall as above normal seasons or good seasons (Mugumbate, J., Zimbabwe Meteorological Services Department Official, 2011; personal communication).

The information on yield expectations helps inform us that farmers do not necessarily consider poor seasons strictly in meteorological terms. Even those seasons that might have a good rainfall distribution and above average rainfall (in terms of climate data) can be termed "poor" by farmers. This is partly an indication that for farmers, when evaluating cropping seasons, any problem that limits harvests leads to a bad season. The yield levels or expectations of the yield as earlier mentioned by farmers are mostly the ones that determine how to describe a season.

Contradictions in farmer perceptions were found between farmer perceptions performance of seasons in any given 10 years and climatology data, with the majority of the farmers perceiving seasons to be poor. In the case of Hwange, in the 2007/8 season, the rainfall total suggests that it was an above average season. However, further analysis indicated that the rainfall distribution within the season, especially the intra-seasonal dry spells that was experienced in February, which only had four rain days could have coincided with the anthesis stage of cereal crops and could have been detrimental to crop production. This observation is corroborated by various other studies reporting that in semi-arid southern Zimbabwe, the start of rain during November and December may be followed by a long dry spell, which can lead to crop failure (Stern *et al*., 1981; Stern *et al*., 1981; Dennett, 1987; Mupangwa, 2009).

Farmers' memory of past events can be faulty as well as their failure to differentiate between climate (the statistical expectation) and weather (what we get) patterns. This becomes problematic when investigating climate change as farmers may need to use personal experience, which could be unreliable. Rationally, farmers prefer to learn from experience instead of statistical descriptions, which may lead to flawed interpretation. Even though personal experiences capture farmers' attention, they are sometimes unreliable compared to more statistical information.

Expectations of change also played a large role in people's ability to detect changes in their environment. Weber (2010) reported that farmers in Illinois in the United States of America ,who were asked to recall temperature and rainfall statistics in the seven preceding years, had through their belief that climate was changing, recalled temperature and rainfall patterns consistent with their beliefs and expectations. Similarly, in this study in semi-arid Zimbabwe, farmers' expectations, more than statistical information influence farmers' perceptions on climate change and variability as evidenced by the contradictions between the farmers' perceptions and the official meteorological data, especially the rainfall received from the 2004/5 season to the 2008/9 season. The current study does resonate with some studies that indicate that climate change is real though studies on the long term climatology data, especially that of rainfall patterns in semi-arid Africa have not confirmed this (Scoones, 2004; Slegers, 2008). Osbahr *et al*. (2011) argued that there is nothing wrong with farmer perceptions as these may be social constructs but they usually have a statistically low correlation with climatology data.

In concurrence with Ferrier and Haque (2003), the study showed that farmers remember the extremes in climate and they also remember the recent events (years) with reduced crop productivity. The recall by farmers of the extremes in weather has been described by Osbahr *et al*., (2011) as being consistent with human behaviour (human perception and memory). Farmers in this study may, however, be deemed to some extent, to be pessimistic as the majority perceived that poor seasons occurred frequently in any given 10 year periods and they would expect to get average to poor seasons most of the times. The over-estimation of poor seasons in the study insinuates that farmers perceive higher risk than is actually existing within their localities. According to Rao *et al.* (2011), this can influence decisions on adopting of new technologies such as fertiliser use and adoption of new seed varieties. Grothmann and Patt (2005) suggested that most farmers have resigned themselves to fate and they believe they cannot do much to alter the environment. There is, therefore, need for even the poorest farmers to understand that even with little resources they have, they can adapt and cope with climate variability.

The negative attitude manifested by respondents implies that farmers may tend to under-invest in resources such as inputs and labour as well as management practices or decisions as they always plan with "failure" on their minds, though this study has not really dealt with this aspect of finding out if the perceptions have an influence in decision-making. However, this may be understandable (the risk aversion and consequently the under-investment) as so much unpredictability hangs over everyone's heads in terms of how the seasons will perform. The risk aversion means that in most cases there is under-utilisation of opportunities that come with good seasons, hence more or less, the yields in good and poor seasons are similar (Cooper *et al*., 2008). The study also revealed that farmers may also be more concerned about within season rainfall variability, than inter-seasonal variation which seems to be the major factor constraining semi-arid agriculture, a finding also documented by Recha *et al.* (2008). Thus long-term planning becomes a challenge.

The analysis of long term rainfall data reveals that there is a large intra- and inter-season variations in the study sites. The study finds both farmers and climatology data reporting increases in temperatures. However, in terms of climate data, there is limited evidence to suggest that there have been significant changes in seasons to warrant what farmers and stakeholders report in terms of "climate change". The climate data show rainfall variability to be a normal characteristic of the study sites, with deviations from the climatic rainfall means (or the poor seasons) being cyclical and occurring once in every three seasons over the past 40 years. However, the farmers may be reporting overall rainfall decline, which could be ascribed to temperature increases. Osbahr *et al.* (2011) note that temperature increase lead to increased evapotranspiration rates, which ultimately leads to faster soil water depletion. The researchers note the high levels of soil water depletion resulting from high rates of evapotranspiration usually lead to crop wilting, and ultimately crop failure, which the farmers may be attributing to a decline in rainfall.

Farmers do have good memories of recent events, for example the past five years, and they tend to remember the worst seasons where crop failure was high and those seasons that had poor rainfall distribution e.g. in Masvingo in the 2007/8 season. There is also an overall mismatch in the farmers' perceptions and the evidence from the meteorological data, with farmers considering weather events as the major causal factor, even if there are other interrelated factors that should be considered when farm production is affected. The other factors that need to be considered and are vital when determining poor seasons include soil fertility, availability and functionality of markets, and in the case of semi-arid Zimbabwe, political and institutional factors that have prevailed in the past 10 years have led to decline in crop productivity. The macro-economic crisis, especially the hyper-inflationary conditions and institutional decline that prevailed in 2007/8 season could have resulted in exaggeration of farmers' perceptions of poor seasons of late or in the recent past. Thus the cause of poor seasons is not necessarily linked to rainfall only but macro-economic factors which can lead to poor micro-economic performance of households.

The understanding of how farmers perceive climate risk is valuable to other stakeholders such as extension service, providers and climate information providers as it can assist in tailor-making their services to suit the farmers' needs and support them to better cope and adapt with climate variability. The results in the study indicate that farmers have a biased estimation of poor seasons, probably because human behaviour attaches higher significance to negative events, and this could have a significant role in farm decision-making and farm investments. Osbahr *et al.* (2011) indicates that seeking to understand farmers' perceptions of climate variability is important as it determines the process of how to provide relevant meteorological services. The study reveals that farmers may also be more concerned about within season rainfall variability, than pan-seasonal variation which seems to be the major factor constraining semi-arid agriculture, a finding also documented by Recha *et al.* (2008)

Enhanced communication of climate-related information could be an option to assist in adaptation strategies and timely decision-making by farmers. The use of the seasonal climate forecasts could help farmers and stakeholders plan forward and make informed, sustainable as well as economically meaningful *ex ante* agricultural management decisions. Government of Zimbabwe could play an important role in creating a favourable policy environment that promotes dissemination of seasonal climate forecast information and improved extension service provision so that agricultural management practices are enhanced for improved productivity. Since within season rainfall is also one of the major problems, and the amount of rainfall cannot be influenced, then technologies that enhance water use efficiency could also be one of the major areas of research and development that should be integrated into the semi-arid maize farmers' existing strategies to adapt to climate variability and ultimately change.

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REFERENCES

Adger, W.N., Arnell, N.W. and Thompkins, E.L. 2005. Successful adaptation to climate change across scales. *Global Environmental Change* 15: 77- 86.

Ahmed, M.M., Rohrbach, D.D., Gono, L., Mazhangara, E., Mugwira, L., Masendeke, D.D. and Alibaba, S. 1997. Soil fertility management in communal areas of Zimbabwe: Current practices, constraints and opportunities for change. Results of a diagnostic survey. Southern and Eastern African Region. Working Paper No 6. International Crops Research Institute for the Semi Arid Tropics. 30pp.

Anonymous, 2006. Zimbabwe 2003 Poverty Assessment Study Survey Main Report. Ministry of Public Service, Labour and Social Welfare, Harare, Zimbabwe.

Bird, K., Sheperd, A., Scott, A. and Butaumocho, B. 2002. Coping Strategies of Poor Households in Semi-Arid Zimbabwe. Volume 2. Full Scientific Report. Natural Resources Systems Programme (NRSP). March 2002. Project Number: R7545. Final Technical Report. 251pp http://www.odi.org.uk/resources/docs/1812.pdf Accessed 23 December 2011.

Bryman, A. 2008. Social Research Methods. Oxford: Oxford University Press. 592 pp.

Campbell, B.M. 1994. The Environmental Status of Save Catchment. pp. 21-24. In: Matiza, T. and Carter, S.A. (Eds.). Wetlands Ecology and Priorities for Conservation in Zimbabwe. Giland, Switzerland: International Union of Conservation of Nature and Natural Resources (IUCN).

Conway, D., Allison, E., Felstead, R. and Goulden, M. 2005. Rainfall variability in East Africa: Implications for natural resources management and livelihoods. *Philosophical Transactions of the Royal Society: Mathematical, Physical and Engineering Sciences* 363: 49-54.

Cooper, P.J.M., Dimes, J., Rao, K.P.C., Shapiro, B., Shiferaw, B. and Twomlow, S.J. 2006. Coping better with current climatic variability in the rainfed farming systems of sub-Saharan Africa: A dress rehearsal for adapting to future climate change? Global Theme on Agro-ecosystems Report No. 27. P.O. Box 29063-00623, Nairobi, Kenya, ICRISAT. 24pp.

Cooper, P.J.M., Dimes, J., Rao, K.P.C., Shapiro, B., Shiferaw, B. and Twomlow, S.J. 2008. Coping better with current climatic variability in the rainfed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? *Agriculture, Ecosystems and Environment* 126:24-35.

CSO. 1985. Statistical Year Book of Zimbabwe. Harare, Zimbabwe: Zimbabwe Central Statistics Office (CSO). Ministry of Finance, Government of Zimbabwe. 228pp.

De Wit, M. 2006. The economic impacts of climate change on agriculture in Zimbabwe. Climate Change and African Agriculture, Policy Note No. 11, August 2006, CEEPA.

Dennett, M.D. 1987. Variation of rainfall: the background to soil and water management in dryland regions. *Soil Use and Management* 3 (2): 47-51.

Drimie, S. and Gillespie, S. 2010. Adaptation to climate change in Southern Africa: factoring in AIDS. *Environmental Science and Policy* 13: 778-784.

FAO and ACFD. 1999. A fertiliser strategy for Zimbabwe. A FAO/African Center for Fertiliser Development Publication. Rome, Italy and Harare, Zimbabwe. 105pp.

Ferrier, N. and Haque, C.E. 2003. Hazard risk assessment methodology for emergency managers: a standardised framework for application. *Natural Hazards* 28:271-290.

Grothmann, T. and Patt, A. 2005. Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Global Environmental Change* 15:199-213.

Heathcote, R.L. 1969. Drought in Australia: A problem of perception. *Geographical Review* 59: 175-194.

Hulme, M., Doherty, R., Ngara T. and New, M. 2005. Global warming and African climate change: A re-assessment. Climate Change in Africa. pp.29-40. Low, P.S. (Ed.). Cambridge University Press.

IPCC. 2007. Climate Change 2007: Climate Impacts, Adaptation and Vulnerability. Working Group II to the Intergovernmental Panel on Climate Change Fourth Assessment Report, Geneva: Intergovernmental Panel on Climate Change.

Maddison, D. 2006. The perception of and adaptation to climate change in Africa. CEEPA Discussion Paper No. 10. Centre for Environmental Economics and Policy in Africa, University of Pretoria, South Africa. 47pp.

Mano, R. and Nhemachena, C. 2006. Assessment of the economic impacts of climate change on agriculture in Zimbabwe: A Ricardian approach. CEEPA Discussion Paper No. 11. Pretoria: Centre for Environmental Economics and Policy in Africa, University of Pretoria, South Africa. 43pp.

Martin, R.V., Washington, R. and Downing, T. 2000. Seasonal maize forecasting for South Africa and Zimbabwe derived from an agroclimatological model. *Journal of Applied Meteorolology* 39:1473-1479.

Nyanga, P.H., Johnsen, F.H., Aune, J.B. and Kalinda, T.H. 2011. Smallholder Farmers' Perceptions of Climate Change and Conservation Agriculture: Evidence from Zambia. *Journal of Sustainable Development* 4(4): 73-85.

Rao, K.P.C., Ndegwa, W.G., Kizito, K. and Oyoo, A. 2011. Climate variability and change: Farmer perceptions and understanding of intra-seasonal variability in rainfall and associated risk in semi-arid Kenya. *Experimental Agriculture* 47: 267-291.

Osbahr, H., Dorward, P., Stern, R. and Cooper, S. 2011. Supporting agricultural innovation in Uganda to climate risk: linking climate change and variability with farmer perceptions. *Experimental Agriculture* 47 (2): 293-316.

Mupangwa, W.T. 2009. Water and Nitrogen Management for Risk Mitigation in semi-arid cropping systems. PhD. Thesis. Faculty of Natural and Agricultural Sciences, Department of Soil, Crop and Climate Sciences, University of the Free State, Bloemfontein, South Africa. 350 pp.

Nyamapfene, K. 1991. Soils of Zimbabwe. Harare, Zimbabwe. Nehanda Publishers. 179 pp.

Recha, C.W., Shisanya, C. A., Makokha, G. L. and Kinuthia, R.N. 2008. Perception and Use of Climate Forecast Information Amongst Smallholder Farmers in Semi-Arid Kenya. *Asian Journal of Applied Sciences* 1 (2):123-135.

Scoones, I. 2004. Climate change and the challenge of non-equilibrium thinking. *IDS Bulletin* 35: 114-119.

Slegers, M.F.W. 2008. "If only it would rain": Farmers' perceptions of rainfall and drought in semi-arid central Tanzania. *Journal of Arid Environments* 72: 2106-2123.

Stern, R., Dennett, M.D. and Garbutt, D.J. 1981. The start of the rains in West Africa. *Journal of Climatology* 1:59-68.

Tadross, M.A., Hewiston, B.C. and Usman, M.T. 2005. The interannual variability of the onset of the maize growing season over South Africa and Zimbabwe. *Journal of Climate* 18:3356-3372.

Twomlow, S.J., Steyn, J.T. and du Preez, C.C. 2006. Dryland farming in Southern Africa. Chapter 19. pp. 769-836. In: Dryland Agriculture 2nd Edition. Agronomy Monograph No. 23. American Society of Agronomy, Madison, Wisconsin, USA.

UNEP. 2002. Global Environment Outlook 3: Past, present and future perspectives. United Nations Environment Programme. Nairobi, Kenya. Earthscan Publications Ltd.

Unganai, L.S. 2000. Application of long-range rainfall forecasts in agricultural management. A review of Africa's experiences. Proceedings of the International Forum on Climate Prediction, Agriculture and Development, International Research Institute for Climate Prediction. Rio de Janeiro. Brazil.

Washington, R., Harrison, M. and Conway, D. 2004. African Climate Report. Report commissioned by the UK Government to review African climate science, policy and options for actions. www.defra.gov.uk/environment/climate change/ccafrica-study/index.htm Accessed 31 December 2011.

Weber, E.U. 2010. What shapes perceptions of climate change. *Wiley Interdisciplinary Reviews: Climate Change* 1(3):32-342.

Vogel, C. and O'Brien, K. 2006. Who can eat information? Examining the effectiveness of seasonal climate forecasts and regional climate risk management strategies. *Climate Research* 33: 111-22.

Ziervogel, G., Bharwani, S. and Downing, T.E. 2006. Adapting to climate variability: Pumpkins, people and policy. *Natural Resources Forum* 30: 294-305.

Zimmerman, F.J. and Carter, M.R. 2003. Asset smoothing, consumption and the reproduction of inequality under risk and subsistence constraints. *Journal of Development Economics* 71 (2): 233-260.