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Smallholder farmer perceived effects of climate change on agricultural productivity and adaptation strategies

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ABSTRACT

The agriculture sector is sensitive to climate change and the capacity of smallholder farmers in developing countries to adapt is limited. Similar to adoption of any development-oriented strategies, perception is prerequisite to successful adaptation of agricultural strategies against climate change effects. This study was conducted in the semi-arid Lower Gweru Communal area of Central Zimbabwe to sensitize smallholder farmers on climate change and to establish their perceptions of the projected climate of Zimbabwe by 2050. Data were collected during 2011 from a total of 60 farmers drawn from six villages in Mdubiwa and Nyama Wards. Farmers were selected using systematic random sampling from a households list and grouped into three wealth groups: resource rich; resource poor and intermediate. Focus Group Discussions were conducted with each group to investigate their perceptions of the projected climate by 2050 and their proposed adaptive strategies. Farmers perceived the projected climate to have negative effects on their livelihoods and there were no outstanding differences in the nature of responses across the three categories of farmers. Farmers' responses showed that they were concerned about crop and livestock productivity as well as availability of water resources, food and nutrition security and about their general well-being. The intermediate wealth group, which had more than half of its members above 70 years of age provided the least number of ideas for adaptations. Farmers also suggested how they could possibly counteract some of the predicted negative effects or maximize on positive effects. Strategies that were suggested by the farmers were largely concerned with cropping and tended to address water shortages. It was concluded that almost all strategies suggested by farmers were self-directed, rather than directed at authorities like government or donors to do something for them thus showing that farmers had the will power to deal with climate change themselves.

1. Introduction

Climate change is a topical subject worldwide and there is evidence that this phenomenon is taking place (Solomon et al., 2007). Agriculture is one of the sectors most affected by climate change. Several research work has been conducted to try to establish the effects of climate change on agriculture. Climate change may be beneficial to agriculture, depending on geographical region. However, for the lower latitude areas, climate change is projected to result in increased temperature, reduced rainfall and increased frequency of extreme weather events such as floods and droughts. Thus, rainfed agriculture will be negatively impacted. In Africa, crop yields have been projected to decrease (e.g. Parry et al., 2007; Schlenker and Lobell, 2010). In this region, the majority of the population are smallholder farmers who rely on rainfed agriculture for their livelihoods. Rainfed agriculture is the predominant farming system in Sub-Saharan Africa where approximately 90% of cereal production is from rainfed agriculture (Rosegrant et al., 2002).

Due to their heavy reliance on rainfed agriculture, climate change will increase vulnerability of the rural populations due to food and nutrition insecurity. Communities in most developing countries, particularly those in Africa have been identified as being the most vulnerable to climate change because of multiple stressors and reduced adaptive capacity (Parry et al., 2007; Gandure et al., 2013). It is

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therefore imperative that farmers adapt to climate change and variability to reduce its negative impacts on their livelihoods. Maddison (2007) reckons that perception is pre-requisite to adaptation, implying that before communities can effectively embark on climate change adaptation strategies, they must be aware and appreciative of the potential effects that this phenomenon may have on their livelihoods. Profound community perceptions on climate variability and change have been established across Africa including in Southern Africa (Mubaya et al., 2012; Gandure et al., 2013) and in East and North Africa (Maddison, 2007). However, not all farmers perceive such changes and not all perceptions are true or match climate records. Thus, it is essential to inform community stakeholders such as farmers, of projected climate change.

In Zimbabwe approximately 90% of land cultivated by smallholder farmers is located in already marginal rural areas (Natural Regions III–V) (FAO, 2006), with respect to rainfall amount and distribution as well as soil fertility. Hence, climate change will most likely worsen their situation. The objectives of this study were to i) conscientise smallholder farmers in Lower Gweru Communal area of Zimbabwe on climate change and its potential effects on crop productivity ii) establish farmers' perceived effects of the projected climate by 2050 and iii) capture their proposed strategies to reduce possible negative impacts or maximize on possible positive impacts of climate change.

2. Materials and methods

2.1. Study area

Lower Gweru is a developed communal settlement in the Midlands province of Zimbabwe. It is located about 40 km north west of the City of Gweru, and stretches a further 50 km to the West. Two Wards namely Mdubiwa and Nyama in Lower Gweru communal area (Fig. 1) were selected for the study. The communal area falls in Natural Region (Agro-ecological Zone) IV of Zimbabwe, which is generally described as semi-arid to arid and receives rainfall from October to April ranging from 450 mm to 600 mm annually, with frequent droughts. The rainfall season is characterized by periodic seasonal droughts and severe dry spells (Vincent and Thomas, 1978 as cited in Masere and Worth, 2015). Temperatures are generally high, with annual mean maximum temperatures ranging from 32 to 35 °C. The high temperatures render rainfall received less effective due to high evaporative losses. Soils in Lower Gweru Communal area are generally shallow, coarse-grained sands, which have a low production potential (Thompson and Purves, 1978 as cited in Makuvaro et al., 2014).

Most of the Lower Gweru communal farmers own very small farms ranging from 0.5 ha to 2.4 ha (Masere, 2014). However, most farmers were cultivating only portions or few of their fields due to lack of adequate inputs (fertilizers and hybrid seeds), high frequency of below-normal rainfall seasons, poor soils and labour constraints (Makuvaro et al., 2014; Masere, 2014). Main crops grown include cereals (maize [*Zea mays*], sorghum [*Sorghum bicolor*], Finger millet [*Eleusine coracana*]), legumes (groundnuts [*Arachis hypogea*], sugar beans [*Phaseolus vulgaris*], cowpeas [*Vigna unguculata*], Bambara groundnuts [*Vigna subterranea*]), tuber crops (Irish potatoes [*Solanum tuberosum*], sweet potatoes [*Ipomoea batatus*]), fruits and vegetables (Makuvaro et al., 2014; Masere, 2015). The two main purposes of growing crops are household consumption and income generation. The other reason is stock (cattle and poultry) feeding. Legumes are also grown for improving the soil nutrient status due to their ability to fix atmospheric nitrogen into the soil (Masere, 2015).

Lower Gweru farmers have limited livestock with the majority (about 70%) owning between one to five cattle (Masere, 2015). Similar ownership patterns were also reported for small livestock (goats and poultry). Cattle are very useful as a source of draft power for various field operations and for food. Conversely, goats are usually used as a form of insurance for income and can be disposed of quickly in the

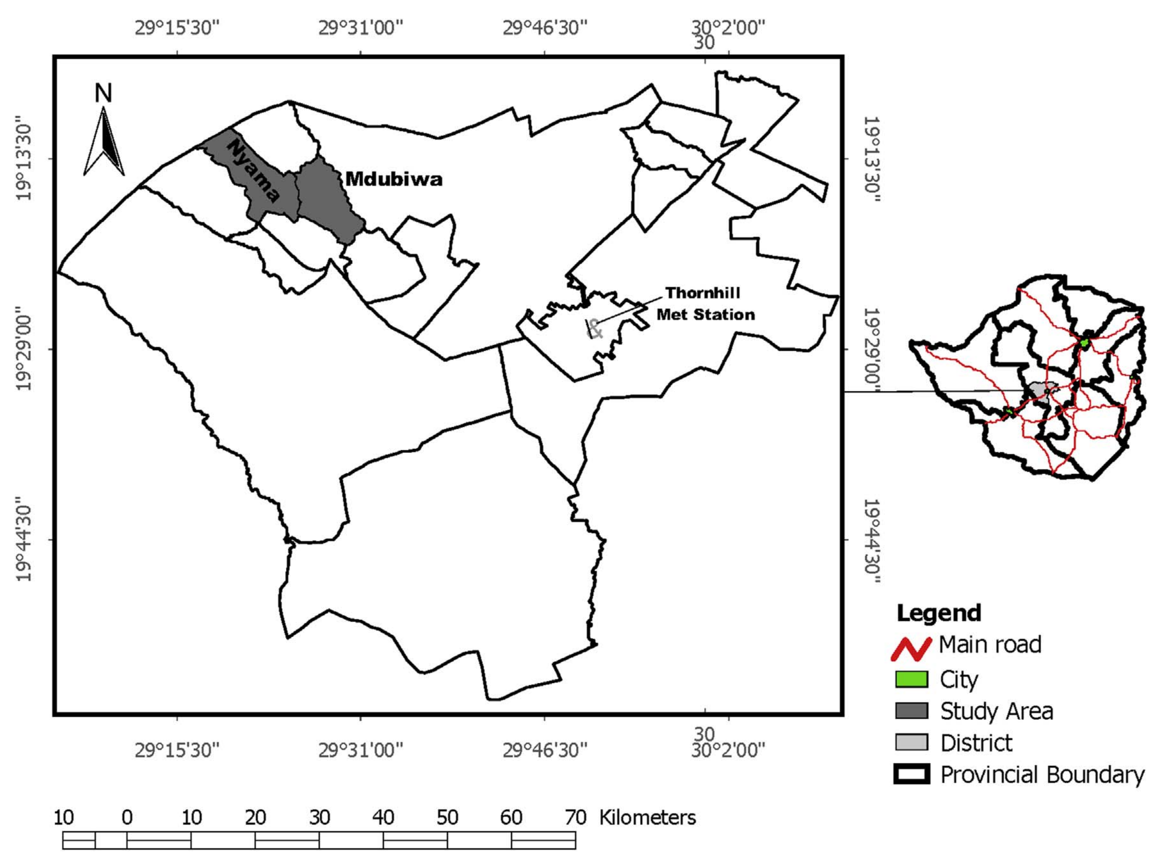

Fig. 1. Map showing location of study area and Thornhill meteorological station whose data were used in simulating climate change effects on maize growth and yield.

Table 1
List of wards and villages in Lower Gweru Communal area, from which farmers were selected for the focus group discussions.

Ward	Village	Number of participants	Number of Men	Number of Women
Mdubiwa	Mxotshwa	10	7	3
	Nsukunenji	10	5	5
	Madinga	10	7	3
Nyama	Matonsi	10	6	4
	Guduza	10	5	5
	Siyabalandela	10	8	2

event that farmers need income (Masere, 2015). Poultry is kept for household consumption (eggs and meat) as well as for income generation.

2.2. Selection of participant farmers

A total of 60 participant farmers (household heads) drawn from six villages in two Lower Gweru Wards; Mdubiwa and Nyama (Table 1), were selected using systematic random sampling from households lists that were obtained from the village heads. Each village list had 100 households, from which 10 farmers were selected. Mdubiwa and Nyama Wards were chosen from eight wards in Lower Gweru based on their representativeness and easy accessibility. Mdubiwa and Nyama had a population of approximately 800 each. Of the 22 female household heads, 13 were female *de facto* (either widowed, divorced or had never married) and 9 female *de jure* (household heads by virtue of their husbands being away in urban areas either locally or in the diaspora, mostly in neighbouring countries).

The selected 60 farmers were then grouped into three wealth groups (Loader and Amartya, 1999; SwathiLekshmi et al., 2008) as it was hypothesized that farmers' responses to climate change issues would vary depending on their economic and social status. The objective of forming groups was explained to the farmers after which they were asked to suggest the criteria for classifying one as "rich", "intermediate" or "poor". The criteria were decided at ward level after which consensus was sought among farmers in both wards. The major criteria that farmers agreed to use in categorizing themselves into the three wealth groups were livestock ownership (cattle ownership in particular), the type of homestead one possessed, farm implements owned and access to labour (Table 2). These criteria have also been used in wealth ranking by other farming communities including Namakkal district of Tamil Nadu, India (SwathiLekshmi et al., 2008) and in Tsholotshlo, western Zimbabwe (Ncube et al., 2009).

After agreeing on the criteria, farmers were then asked to self-categorize themselves at village level. Farmers belonging to the same category were then grouped together and the resultant groups were named group A (for the rich), group B (for the intermediate) and group C (for the poor). The number of "rich" (18) and "intermediate" farmers (17) was almost the same, while the "poor" constituted the largest group of 25. Women constituted 27.7, 23.5 and 52% of the rich, intermediate and poor farmers, respectively. Relatively younger farmers, in the 45–60 years age group, dominated the "rich" group. Conversely, the poor and intermediate groups had more than 50% of its members aged 70 years and above.

Consistent with Masere (2014), poor farmers were also often characterized by late planting of crops due to a combination of lack of draft animals and implements and poor access to other production resources such as improved seed and fertilizers thus leading to low yields. This notion was supported and verified by agricultural extension supervisors of both Mdubiwa and Nyama Wards. In light of this, yields attainment may be loosely used to indicate the wealth status of a farmer.

2.3. Data collection

The data used in the study can be divided into two categories, namely primary and secondary data. The primary data were in the form of farmers' responses during focus group discussions (FGDs). These responses provided information necessary for evaluating the views of the community in terms of their farming systems, impact of climate change on production systems, and their knowledge, attitudes and practices related to climate change. FGDs were conducted with the selected 60 farmers in their respective wealth categories in Lower Gweru Communal area, using a guided list of key topics to establish farmer opinions on projected climate for Southern Africa, with more emphasis on Zimbabwe, by 2050. Secondary data included climate projections information from the Intergovernmental Panel on Climate Change (IPCC) as presented by Christensen et al. (2007); reports on APSIM applications presented by various authors for example, Masere and Worth (2015); Makuvaro (2014) and Dimes et al. (2008) as well as climate data for Thornhill Meteorological Station.

2.4. Presentation of future climate scenarios to farmers and seeking their reactions

Projected temperatures and rainfall for Zimbabwe by 2050 were presented to the farmers. The presented projections, were based on the A2 CO_2 emission scenario, where an increase in temperature of 2.3–4.5 °C, a decrease in rainfall of about 10–15% and a CO_2 concentration of 532 ppm (Christensen et al., 2007) are expected. Farmers were then asked to give their opinion as to what they thought would be the impact of such changes (in rainfall and temperature) on agricultural productivity. Farmers wrote responses to these questions on manila charts and presented their findings to the whole group. Due to its relatively big size, the "poor" group was divided into two groups of 12 and 13 farmers for better interaction among the farmers for this particular exercise. The sub-groups had a balance of female and male farmers. However, responses from the sub-groups were then put

Table 2
Criteria used by farmers in Mdubiwa and Nyama Wards to categorize themselves into wealth classes.

Criteria	Rich	Intermediate	Poor
Number of cattle owned.	More than 5 cattle.	2-5 cattle.	0-1 cattle.
Possession of farm implements.	Normally have a plough and cart plus other implements e.g. harrow and cultivator.	Have at least a plough. May need to team up with others to prepare land for planting.	No farming implements except a hoe. Rely on others for land preparation or dig their fields using hoes.
Type of homestead.	Nicely built and clean homestead. Brick under asbestos or iron sheets houses. Have toilet and protected well or borehole.	Decent homestead. May have a toilet and a protected well.	Homestead with one (most cases a hut) or two small buildings used by whole family. No toilet nor protected well.
Access to labour.	Labour not a major constraint. Normally hire labour	Normally use family labour, but sometimes hire labour.	Work in "rich" farmer fields and in return, rich farmers plough their fields.

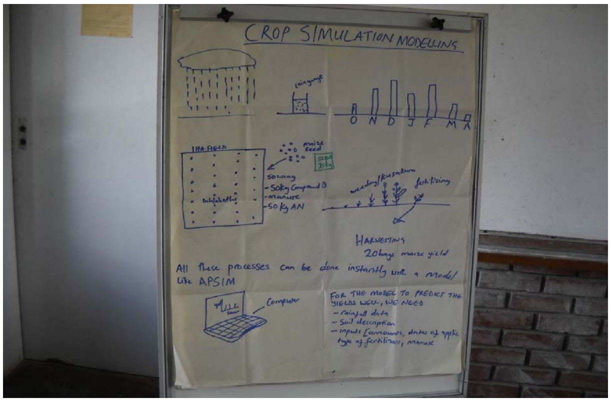

Fig. 2. Sketch diagram used to show farmers some of the input data required to run a crop model.

together for purposes of reporting, in this paper.

2.5. *Presentation of simulated climate change effects on maize yield to farmers*

The session on presentation of simulated climate change effects on maize yields started with researchers explaining the concept of a crop model (Fig. 2).

It was also explained to farmers that while crop models attempt to mimic most of the processes involved in crop production from sowing up to physiological maturity (Fig. 2), there are often some inconsistencies and variabilities because it is impossible for reality to be modelled with certainty. As such, users of these models and/or their outputs must understand the uncertainties and possible variations of the model outputs from reality, particularly on a larger scope (time/space/ensemble) forecast. Farmers understood that crop models are developed as decision support guides and may not always be 100% accurate. Farmers emphasized their understanding of model consistency and variability issues by giving their own experience of using seasonal climate forecasts, which for example may be pointing to a good rainfall season yet sometimes the season, may turn out to be a very dry one.

To recap the session, farmers were then asked what they understood about crop models and how they can use them. Their responses are shown in Box 1.

Box 1

Lower Gweru farmers' excerpts to illustrate their understanding of use of a crop model.

- "A model can help us in preparing for the season, that is, the inputs we can use and the area we can plant."
- "It helps to make budgets and to save money."
- "A model can be very close to what we do in our fields and the results can be close to those obtained in the model."

"As farmers, where can we get these computers to enable us to use these models?"Once the farmers had shown basic understanding of crop models and some of their applications, the researchers proceeded to inform farmers on how a crop model could be used to establish the possible impacts of projected climate change on crop productivity in their area. A crop model, Agricultural Productions Systems Simulator (APSIM) (Keating et al., 2003), was chosen and used in this study for three main reasons. Firstly, because of its capability to simulate simultaneously, the effect of climate, soil and management variables on crop growth processes and yield on a daily time step thus matching reality (Dimes et al., 2003; Carberry et al., 2004; Probert and Dimes, 2004; Makuvaro, 2014; Masere and Duffy, 2014). Secondly, APSIM has been validated in many farming systems of the world including Africa (Dimes et al., 2003; Carberry et al., 2004; Duffy and Masere, 2015). Thirdly, some of the participant Lower Gweru farmers had prior experience of interacting with APSIM and its outputs as they had already been introduced to APSIM including how it operates and its input data requirements (daily climate data, soil description data and crop management data) in an earlier study by Masere and Worth (2015).

In the study by Masere and Worth (2015) farmers supplied their crop management data on resource allocation maps detailing their

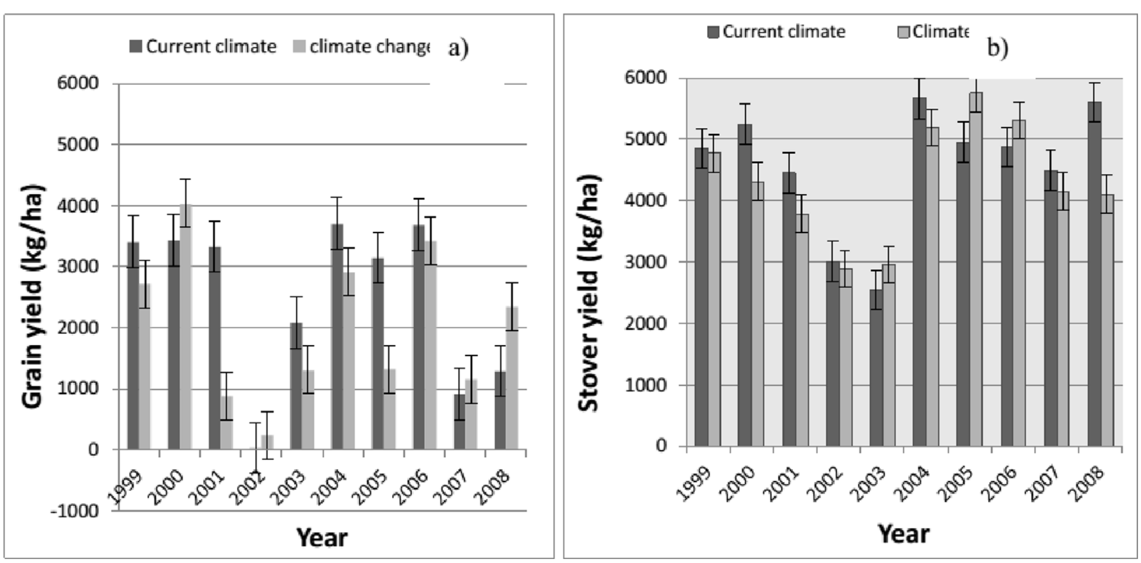

Fig. 3. Difference in a) grain yield and b) stover yield of SC403 maize variety grown on a sandy soil at Lower Gweru, between current climate and climate in 2050s (climate change).

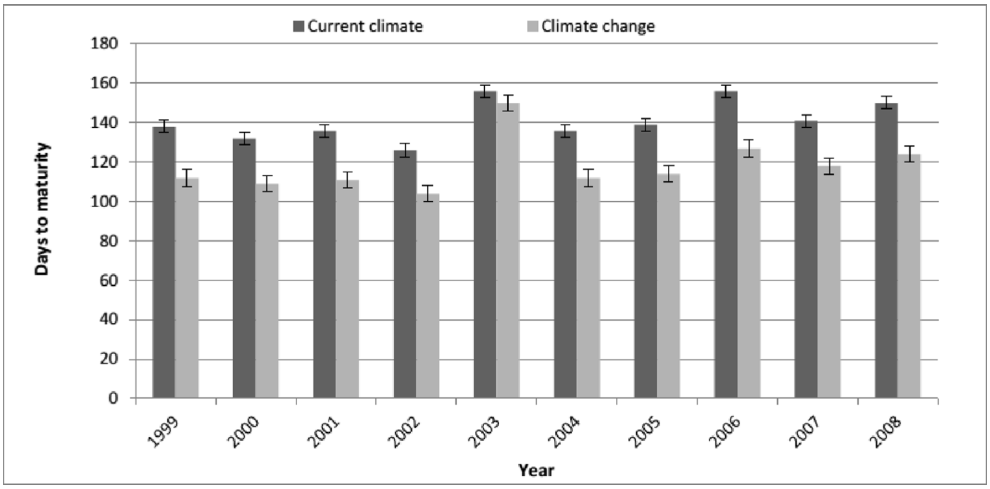

Fig. 4. Difference in days to physiological maturity of an early maturing maize variety, SC403 grown on a sandy soil in Lower Gweru Communal area, between current climate and climate in the 2050s (climate change).

agronomic practices regarding maize production. This information coupled with historical daily climate data obtained from the nearby Thornhill Meteorological Station and soil description data were input data used for running and validating APSIM to establish credibility (Masere and Worth, 2015). In the absence of actual soil description data, the soil descriptions used were modified from the in-built soil descriptions in the model, based on the experience of the extension agents and the lead researcher. The resultant simulated maize yields were in most cases found to be closely matching the observed yields. Thus credibility of APSIM as a decision support tool was established with the farmers, who went further to successfully utilize the model and its outputs to decide on management strategies (treatments) to explore in the on-farm trials that followed later that season (2009/10 season). The on-farm trials offered farmers an opportunity to test the accuracy and reliability of APSIM on their fields. They called the on-farm trial maize yields "tangible evidence" which they needed before they could fully trust the model and its outputs enough to utilize them as a decision support tool (Masere and Worth, 2015).

Following discussions with farmers on the concept of a crop model, researchers then presented APSIM simulated maize grain and stover yields (Fig. 3a and b) as well as number of days taken to reach physiological maturity by the maize crop (Fig. 4). The average Lower Gweru farmers' maize production strategies on a sandy soil modified to suit Lower Gweru soil conditions were used in the simulations. These included a fertilizer application of 30 kg N/ha, planting density of 44 444 plants/ha, three weeding times, an early maturing variety SC403 and a sowing window of 15 October to 15 December, for which sowing was set to occur at the first opportunity of a cumulative 20 mm of rain received over 5 days. Daily climate data from 1999 to 2008 were obtained from the nearby Thornhill Meteorological Station. The simulated projected climate change conditions were taken to be an increase in temperature of 2.3–4.5 °C and a decrease in rainfall of about 10–15% (Christensen et al., 2007) of the current climate. A CO_2 concentration of 370 ppm was inputted for the current climate while for the future climate 532 ppm was used (Christensen et al., 2007). Presentation of these model outputs offered a platform for informing farmers about how the projected climate change could affect maize yield and growing season duration at their locality, by 2050. The message given to the farmers was that higher grain yields were obtained under current climate than projected climate change conditions for six out of 10 years (Fig. 3a). However, on average, climate change decreased maize grain yield by about 16%. Climate change reduced stover yield by 13% compared to the past 10 years (1999–2008). Six out of the 10 years had higher yield under current climate than under climate change (Fig. 3b). Thus, under the projected climate change the risk of getting lower yields was higher than under the current climate.

Climate change significantly reduced ($p < 0.05$) the number of days taken by a relatively early maturing maize variety SC403 to reach physiological maturity by approximately 23 days (Fig. 4). The most possible reason for this reduction is that the total degree days required by the maize crop from planting to physiological maturity would accumulate relatively quicker under the projected climate change temperatures than current climate conditions. Increased temperature advances the onset and reduces duration of phenological stages such as unfolding of leaves, flowering and fruiting stages (Gordo and Sanz, 2010). This shortens the crop growing season (Wang et al., 2011) and the resultant effect is less time available for CO_2 assimilation resulting in less total CO_2 assimilated during the growing season and reduced dry matter accumulation and, thus, reduced crop yield. Other researchers (e.g. Dimes et al., 2008; Gordo and Sanz, 2010; Ma et al., 2012) also obtained a reduction in number of days to physiological maturity, under climate change. The reduction in number of days to maturity for the short season maize variety SC403 obtained in this modelling exercise, is comparable with the estimated reduction in days to maturity for a similar maize variety grown at Bulawayo (south west of Zimbabwe) by 2050 (Dimes et al., 2008).

Farmers were then asked to suggest how they could reduce any possible negative impacts or maximize on any positive impacts climate change could have on rainfed agriculture. These suggestions were based on their perceived effects of climate change as well as on the effects of projected climate change on maize that had been shown to them.

3. Results and discussion

3.1. Farmer perceptions of possible effects of projected climate change on agricultural productivity and on farmers' well-being

Farmers' responses to possible effects of projected climate change showed that they were concerned about crop and livestock productivity as well as availability of water resources, food and nutrition security and about their general well-being (Box. 2).

Box 2

Farmers' perceived climate change effects on agricultural production.

Resource rich farmers (Group A)

- "We will lose livestock due to poor conception rates and death of some animals."
- "Crops will be burnt."
- "There will be hunger and starvation."
- "Drinking water will be inadequate for both livestock and human beings"
- "Diseases and malnutrition will be prevalent."

Medium resource farmers(Group B)

- "There will be waste of seed and yield."
- "If we apply fertilizers, crops will be burnt."
- "Availability of water for livestock and human consumption will be reduced."

Resource poor farmers(Group C):

- "Corps will be burnt."
- "Crops yields will be reduced."
- "Availability of water for livestock and human consumption will be reduced."
- "There will be increased cases of school drop outs."
- "Climate change will increase poverty and thieving will be more rampant."

The farmers' envisaged effects were only negative and there were no marked differences in the nature of responses across the three categories of farmers. However, it appears the rich farmers showed greater concern for livestock than the other groups by mentioning effects on livestock first and by elaborating on the nature of livestock losses. This response was expected, given that this group of farmers owned more cattle (at least five head of cattle) than members of other groups. The more elaborate response on climate change effects on livestock by this group could also be because more than half of farmers in this group were younger (between 45 and 60 years). Similarly, Masere (2015) in a study in Lower Gweru communal area, found that the majority of farmers in this age group attained higher levels of formal education than their older counterparts as such they generally possessed a relatively higher level of comprehension on modern issues.

It appears that the predicted increases in temperatures were perceived by farmers to be dramatic as they envisaged severe wilting of crops to occur (resource rich and resource poor farmers). This was probably due to a misconception of the intensity of heat associated with the projected temperature increase by 2050 or limited knowledge of crop response to such a change, on the part of farmers. However, the intermediate (medium) group suggested that wilting of crops would occur if fertilizers were applied to the crop. Farmers also mentioned that climate change would reduce crop yields (intermediate and resource poor groups) and cause seed losses (intermediate farmers).

According to the medium group farmers, planting seed was generally expensive and not readily available. Thus, if low yields are obtained due to climate change effects, when a farmer has invested much in planting seed, then this would mean a great financial loss. Farmers envisaged a reduction in availability of water resources, a factor that would negatively affect both livestock and humans due to shortage of drinking water. According to the farmers' perceptions, it is submitted that climate change would impact negatively on their well-being through increased poverty, hunger and starvation, increased prevalence of diseases and malnutrition as well as increased cases of school drop outs. Farmers in Lower Gweru expected these impacts since their livelihoods are based on agriculture (Mubaya et al., 2012; Makuvaro, 2014) which is the main source of food and income. However, the medium category farmers did not indicate concern on number of school dropouts. This is probably because most of them no longer had children of school going age. Similar to communities elsewhere in the world, and Africa in particular, responses by farmers in Lower Gweru indicated that farmers already knew that there are generally vulnerable to current climate variability and the expected climate change will worsen their situation.

3.2. Farmers' suggested strategies to deal with future climate

The medium wealth group, which had more than half of its members above 70 years of age provided the least number of ideas for adaptations (Box 3). This is contrary to the expectation that, since these elderly people have lived through many years of varied climatic conditions they should have a large wealth of experience to draw from, with suggestions for possible alternative farming interventions. It is, however, possible that these farmers were not free to share information on adaptations when other farmers within and outside their own group were around. The strategies that were suggested by the farmers were largely concerned with cropping and tended to address water shortages. The strategies hinged on soil water conservation, crop choice, fertilizer use, irrigation and soil water conservation (Box.3). Their skewed focus on cropping strategies was probably because they considered crop productivity to be more sensitive to climate variability and change, compared to livestock productivity. Other possible reasons could be that most of the participant farmers do not own much livestock and that researchers presented crop model simulated outcomes and no livestock simulated outcomes.

Box 3

Lower Gweru farmers' suggestions on how to reduce or capitalize on possible impacts of climate change.

Resource rich farmers (Group A)

- "Practise conservation agriculture."
- "Grow small grains."
- "Supplement grazing with animal feed."
- "Apply low levels of fertilizer."
- "Practise winter ploughing and deep ploughing to conserve moisture."
- "Government should embark more on irrigation development."

Medium resource famers(Group B)

- "Practise water conservation by ridging and pot-holing."
- "Grow drought tolerant crops such as sorghum, pear millet, cowpeas and maize variety SC403 which matures early."

Resource poor farmers(Group C)

- "Grow early maturing varieties."
- "Grow drought tolerant crops."
- "Practise conservation farming."
- "Apply minimal fertilizer."

The suggested strategies are similar to those that the farmers in this study area use to deal with current rainfall variability (Makuvaro et al., 2017; Mubaya et al., 2012). However these strategies (to deal with current rainfall variability) are in limited use for example, only about 10% of the farmers in Mdubiwa Ward, benefit from the two existing irrigation schemes, in the Ward and adoption rates for soil water conservation techniques in the area are also low (Makuvaro, 2014).

The use of early maturing maize varieties, nominated by farmers as an adaptive strategy to help reduce impact of climate change on yield, were simulated to test whether it will be viable under projected climate change. The late maturing variety SC709 (which was only simulated as a control for comparison purposes and whose results are not shown here, as it was not suggested as an adaptive strategy by farmers), took similar days to reach maturity under projected climate change as SC403 the short season variety, under current climate. Thus the late maturing variety behaved like the early maturing variety under climate change. An earlier study by Dimes et al. (2008) indicated that temperature (whose negative effect is through reduction in number of days to maturity) had the greater effect on crop yield than reduced rainfall amount, under climate change for Western Zimbabwe. Makuvaro (2014), however established approximately the same contribution to yield reduction from increased temperature and reduced rainfall amounts under climate change, for Central Zimbabwe. Model outputs from the simulation exercise in this study indicated a greater yield reduction for early maturing varieties than late maturing varieties, under climate change. Thus under climate change, smallholder farmers in the study area and other semi-arid areas could improve crop productivity, particularly where irrigation is employed, by shifting to the current late maturing varieties. Such varieties have more days in the critical flowering and grain-filling growth stages than early maturing varieties thus are more resilient to the increased temperature.

Resource-rich farmers proposed supplementing natural grazing with animal feed – this being the only strategy to deal with the likely reduction in livestock productivity, that the farmers suggested. Supplementary feeding with stock feed has its own challenges since the current source of feed is mostly grain from crop production, an enterprise which is also negatively affected by climate change. It, thus, appears that the farmers did not quite integrate livestock and cropping systems in their thinking. Other strategies that farmers could employ include increasing numbers of small livestock and reducing those of cattle as small livestock could be better suited to a warming and drying climate (Nhemachena et al., 2010b). They could also shift towards keeping more browsers than grazers since climate change favours growth and development of browse tree species, in semi-arid rangelands (Morgan et al., 2007). Farmers could also resort to keeping indigenous animal breeds rather than exotic breeds (e.g. Brahman) or cross breeds of indigenous and exotic breeds, since indigenous breeds are more tolerant to higher temperatures expected under climate change conditions (Thornton et al., 2007). Most farmers in the study area and other semi-arid communities in Southern Africa practise mixed crop-livestock systems and these systems are more suitable under climate change compared to specialized systems based on cropping or livestock production alone (Nhemachena et al., 2010a).

4. Conclusion

In this interactive study between researchers and farmers, it emerged that smallholder farmers in Lower Gweru's perceived effects of climate change included reduction in crop and livestock productivity as well on water availability. The nature of effects outlined by the farmers confirmed that they were vulnerable to climate change with respect to food and nutrition insecurity, reduced water availability and their general well-being. The fact that the farmers perceive effects of climate change on their livelihoods is a positive aspect towards adaptation to the phenomenon. It should be noted however, that not all of the farmers' aforementioned woes could be attributed to climate change alone. Other non-climate factors are also responsible for these woes including, but not limited to, bad governance and the economic challenges that have been prevalent in Zimbabwe since the new millennium. Farmers suggested several adaptation strategies most of which they are already using to cope with current climate variability. With the exception of irrigation development, all the strategies suggested by farmers are self-directed, as opposed to being pointed at government or donors to deliver solutions. This shows that farmers have the will power to deal with the challenges posed by climate change.

The willingness by farmers to confront issues affecting their livelihoods is a step in the right direction. Whether they have sufficient tools or the capacity is another question, but for now they proved they would not shy away from the climate change challenges or simply wait for solutions from authorities. However, it is important to re-enforce these strategies by improving farmers' adaptive capacity and to test effectiveness of these and other strategies under future climate. There is a limited range of strategies that farmers suggested for sustainable livestock production in the face of climate variability and change. This indicates that farmers' suggested adaptive strategies may not be sufficient to deal with the impacts of climate change on their agricultural productivity. The onus thus falls on the relevant authorities and stakeholders (researchers, extension agencies, seed houses, livestock departments and NGOs) to chip in preferably as equal partners with farmers and together identify aspects of adaptation farmers require assistance (capacity building). In this way, farmers are capacitated to develop resilient agricultural systems that can withstand current and future climate change effects.

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