Impact of climate change on smallholder farming in Zimbabwe, using a modelling approach

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Abstract

Agriculture is pivotal to the development of most countries in southern Africa, including Zimbabwe, with the sector contributing significantly to the Gross Domestic Product of these countries. The sector also provides labour to the majority of people and most rural populations in these countries derive their livelihoods from agriculture. The relative contribution of agriculture to national economies and to food security is, however, being reduced by climate variability and change. Smallholder farmers in semi-arid areas of Africa are particularly vulnerable to climate variability and change. The overall objective of this study was to establish the extent to which maize yield in the smallholder farming sector of semi-arid Zimbabwe could be affected by climate change, by 2050. The study also sought to establish trends in extreme temperature and rainfall indices, current farmer cropping practices and their current coping/adaptation strategies to climate variability and to assess the likelihood that farmers would adopt selected strategies of adapting to climate change. The study areas, Lower Gweru and Lupane communal areas are located in agricultural regions with low potential, being in Natural Regions III and IV, and lie in the central and western parts of the Zimbabwe, respectively. Extreme temperature and rainfall indices for Bulawayo Airport meteorological station which is in western Zimbabwe and equidistant from the two study areas, Lower Gweru and Lupane, were computed and their linear trends were calculated for the period 1978-2007 using the Statistical and Regional dynamic Downscaling of Extremes for European regions (STARDEX) software. Significance of the trends was tested using the Kendall-Tau's test. It was found that for the period 1978 to 2007, cold extremes represented by frequency of cold days, coldest day-time and night-time temperatures did not show evidence ($p>0.05$) of warming or cooling for Bulawayo. Warm extremes, however showed significant warming ($p<0.05$), particularly during winter and spring as well as for the year. The greatest signal for warming was shown by trends in hottest day-time temperature and frequency of hot days. Trends in mean diurnal temperature range were positive, but only significant ($p=0.05$) during the winter season, while trends in extreme low (10th percentile) and extreme high (90th percentile) diurnal temperature range were also positive but insignificant ($p>0.05$) across all seasons. Increasing trends in diurnal temperature are not consistent with climate change, suggesting that warming evidenced by warm extremes are probably not due to climate change per se. Only three indices, two of which are less commonly used indices, namely mean dry spell length during the dry season (April, May and June), the longest dry spell during the first half of the rainfall season and the correlation for spell lengths during the second half of the rainfall season (January, February and March) season, show significant trends ($p<0.05$). Both quantitative and qualitative methods were used to establish agronomic practices of farmers, constraints they faced and their coping strategies to climate variability. Methods used to collect data included structured interviews with farmers, semi-structured interviews with key informants, focus group discussions and a desktop study. Farmers commonly have coping strategies to address some of the general constraints they

encounter in agricultural production as well as strategies to cope and adapt to current climate variability. The study has identified a number of research and extension interventions which may enhance crop productivity in the smallholder farming sector in semi-arid western central Zimbabwe. Effects of climate change on days to physiological maturity, maize yield and soil water balance components were simulated using the Agricultural Production Systems sIMulator (APSIM) model version 7.3, for maize grown in Lower Gweru, on a sandy soil. Simulated yields and water balance components were compared across three climate scenarios, the current climate (representing no change in temperature and rainfall, and a CO2 concentration of 370 ppm); Future climate 1 (representing a temperature increase of 3o C, rainfall decrease of 10% and CO2 concentration of 532 ppm) and Future climate 2 representing a temperature increase of 3o C and a rainfall decrease of 15% and CO2 concentration of 532 ppm. The reference period for future climate is the year 2050 under the A2 Intergovernmental Panel on Climate Change (IPCC) CO2 emission scenario. The climate change scenarios were created by perturbing the observed climate data for Gweru Thornhill meteorological station near Lower Gweru. A sensitivity test was done using a range of temperature changes (+0.5 to 3.5o C) and rainfall changes (+5 to -20%) as well as under a range of CO2 concentration (420 to 700 ppm) and all under nitrogen non-limiting conditions. Results of this test showed that CO2 offsets the negative effects of both high temperature increases and rainfall reductions with temperature increases in the low range of 0.5 to 1.5 o C, increasing maize grain yield at higher CO2 concentrations of 580 and 700 ppm. Thus the greatest yield reductions due to either increased temperature or reduced rainfall amounts occurs at lower rather than higher atmospheric CO2 concentrations. The results of this test also show that maize grain yield increased with increased CO2 concentration and suggest that temperature and rainfall changes contribute relatively equally to the overall effect of climate change on maize yield in central Zimbabwe. Significant differences among treatment (different climate scenarios) means were tested using non-parametric tests, namely the Kruskal-Wallis and Mann-Whitney tests for independent samples, for simulated data that were not normally distributed, while for normally distributed data, t-test for independent samples was used. Climate change significantly ($p<0.05$) reduced the number of days taken by both early and late maturing maize varieties to reach physiological maturity, with the late and early maturing varieties taking 29 and 23 days less, respectively, to mature under climate change compared to under the current climate. Under climate change days to maturity of the SC709 late maturing maize variety are reduced to a duration similar to that of the current early maturing variety SC403, grown under current climate. Therefore maize yields could be maintained by shifting from early maturing to late maturing varieties, in the face of climate change. Climate change reduced maize yield, with slightly greater reductions obtained under the drier climate change scenario of 15% reduction in rainfall. Grain, biomass and stover yields were reduced by 13% for the early maturing variety SC403 while for the late maturing variety SC709, these yields were reduced by 16, 18 and 20% respectively. However, the only significant ($p<0.05$) yield reduction was that for stover of the late maturing variety. Climate change reduced the amount of water available at sowing by 8-10%, seasonal soil evaporation by about 10% and transpiration by 5-8%. It also reduced the amount of runoff and drainage by about 26-38%, with greater reductions occurring under the drier future climate. However, the reductions were not significant ($p>0.05$) for any of the components except for runoff. Significant reductions in seasonal runoff due to climate change results in reduced water availability from surface water resources and this calls for efficient use of water. Lower Gweru farmers' opinions on climate change effects on agricultural productivity and their possibility of

adopting selected adaptation strategies against climate change were established during focus group discussions with a total of 36 farmers. Pre-requisite exercises for capturing farmers' reactions to climate change included presentation of the outcome of a survey on farmer perceptions on climate variability and change that had been conducted during 2008 and presentation of the projected climate for Zimbabwe, by 2050. To facilitate discussions on farmers' likelihood of adopting long season maize varieties, use of mulch and planting basins, in the face of climate change, simulated maize grain yield and soil water balance under different climate and agronomic scenarios were presented to the farmers in simple graphical form. Annual simulated yields and water balance were presented for the latest 10 seasons, 1998/99 to 2007/08 seasons. Farmers provided their responses in three groups that were formed based on wealth ranking. All farmers irrespective of wealth category, envisaged negative impacts of climate change on agricultural productivity. They also expressed concern on the likelihood of reduced water availability; reduced food and nutrition security, increased number of school drop-outs and a decline in their general wellbeing. Farmers did not provide alternative strategies (to deal with climate change effects) to those they use to cope with current climate variability. Also most of their responses were biased towards crops and these ranged from crop choice, reduced input levels and use of water conservation techniques. Farmers also recommended an expansion in irrigation development by the government. The resource rich farmers suggested supplementary pen feeding of livestock as an adaptation strategy against climate change. Smallholder livestock producers can employ other adaptation strategies, which include shifting towards small livestock and browsers rather than the current cattle and grazers. Although use of mulch and planting basins clearly improved soil water balance in terms of reducing the amount of soil evaporation and runoff, this did not translate into an overall increase in maize yield. However, in relatively poor rainfall years both mulch and planting basins gave higher yields than conventional ploughing without mulch. Thus, use of reliable seasonal rainfall forecasts can help farmers to decide on when to use mulch and/or basins. Farmers showed that it was relatively easy to shift from growing early maturing maize varieties to late maturing varieties, but indicated that the cost of hybrid seed and its availability have always been prohibiting factors. They are unlikely to adopt the use of mulch and planting basins due to high labour requirements and limited access to "extra" fertilizer required when mulch is used. Mulch availability is also limited as its main source, stover, has other uses that compete with use as mulch. It appears planting basins are a more important alternative for land preparation and crop establishment for farmers who do not have draft power than for those with draft animals. It can be concluded that warming is taking place for the station (Bulawayo Airport) considered in this study and this is particularly evident from warm extremes. There is, however, limited evidence of changes in rainfall extremes. Similar analyses as those done for Bulawayo Airport station should be done for more stations and for longer periods. Climate change was found to significantly reduce the number of days taken by maize to reach maturity, with the long-season variety taking about the same number of days to mature under climate change as the short season variety, under current climate. Maize yields are also negatively affected by climate change. Results from the study also indicate that there is a significant reduction in runoff due to climate change. These effects have implications on food and water availability, hence the need to put appropriate adaptation strategies and policies in place. It was encouraging to note that, generally, smallholder farmers in the study area had a sound inference of the likely impact of climate change on agriculture and their well-being. They were also able to suggest possible strategies to deal with climate change, given the expected rainfall and

temperature projections for Zimbabwe by 2050. Smallholder farmers in the study area use several strategies to cope and / or adapt to the numerous constraints they face in crop production. Strengthening farmers' capacity to employ these strategies will improve crop productivity. Based on the current farmer practices in the study areas, the study has identified both research and extension interventions that could be used to increase productivity in the study area and in similar biophysical and economic environments.