Climate Variability and Change in Africa – *Perspectives, Experiences and Sustainability*

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CHAPTER 14

Climate Change Adaptation Research and Policy for Agriculture in Southern Africa (CCARPASA) – Evidence from Rain-fed Systems

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Abstract: Sustainability of rain-fed farming systems under climate variability and change conditions is a key concern for policy and adaptation planning processes to improve food and nutrition security. The challenge is to improve farming and tillage practices to enhance soil moisture availability and harvest excess runoff thereby making the farming systems more reliable and resilient to unpredictable risks of climate change and variability. In this short manuscript, an assessment of climate change impact on the agricultural water availability for rainfed systems in southern Africa is discussed through a pilot project conducted recently as part of climate change adaptation integrated modeling of crop-climate-soil systems. We consider the Pandamatenga plains in north-eastern Botswana, which was undertaken with the main indicators of crop yield impact with respect to soil water availability and excess runoff harvesting potential, for the current climatology (1971-2000) and projected over the coming decades up to the 2050s. The indicators of rainfed practices of growing maize, sorghum and sunflower are discussed, which are likely influenced not only by climate, but also the response requiring local and regional adaptation investments for improved food security and increase productivity. The manuscript recommends technical and policy interventions for incorporating climate change adaptation practices, with the view to outscale to national and possibly regional agricultural development planning processes.

Key words: CCARDESA; CCARPASA Project; Climate Smart Agriculture; SADC; CAADP; food security; rainfed agriculture; farming system

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1.1 Introduction

The role of rain-fed agriculture and its importance for household food security and contribution to the overall agricultural productivity in the maize growing and mixed maize agrosystems in the southern African region is well acknowledged, and well documented. The challenge is to provide evidence on the impact of climate change and advice policy on sustainable adaptation investment plans (Ainsworth and Long 2005).

The SADC region needs to develop and implement sustainable agricultural and food systems that improve soil fertility, ensure efficient land and water use that are resilient to climate change and protect biodiversity. There is a growing technical and political will in Africa and recognition of the significance of and need to address issues of climate change. One of the strategies adopted under Pillar I of the Comprehensive Africa Agriculture Development Programme (CAADP) is the adoption of sustainable land and water use practices in order to contribute to CAADP's 6% annual growth of agriculture. To achieve this, a combination of policy, technology and financing mechanism is required for sustainable agricultural development under varying and changing climatic conditions.

CCARDESA considers Climate Smart Agriculture (CSA) through a modular approach will allow incorporating climate change adaptation and mitigation measures into agricultural development planning and investment, in which countries can sustainably increase agricultural productivity and reduce food insecurity. The concept of climate smart agriculture is well articulated in FAO (2010). A strategic CSA implementation framework is presented for driving actions that require local and regional adaptation research and investments in the SADC region. This paper presents a model which demonstrates how climate smart adaptation strategy can improve the outcomes on research and development in selected and diverse rainfed-dependent farming systems in southern Africa.

In this study, using a modelling approach, it is attempted to pursue three objectives:

☐ to determine the availability of daily and dekadal soil moisture in the root zones of crops in a rainfed conditions to sustain healthy crop development and to determine the runoff harvesting potential of the croplands.

☐ to demonstrate how the different human and climate factors influence the availability and sustainability of rainfed crop systems considering sorghum, maize and sunflower in a typical rainfed farming system in southern Africa.

☐ To recommend policy recommendations on the efforts to improve rainwater productivity as an adaptation capacity through promotion of Climate Smart Agriculture

A case study site in the north eastern Botswana has been used to demonstrate the possible outcome scenarios. Using the integrated systems approach of crop-climate impact modelling, it was found that the agricultural yield reduction in sunflower is higher than maize and sorghum. This calls for targeted adaptation strategies in order to grow these crops under limited rainfall conditions as a result of possible climate change. Tillage practices and other technologies that enhance soil moisture availability and in-situ and ex-situ excess rainwater harvesting could be promoted for similar agro-ecological conditions.

1.2 Climate Change Scenarios and Agricultural Impacts

Assessments of climate change impacts are especially challenging because they are subject to considerable uncertainties of climate predictions and the feedback mechanisms. Several studies highlighted the importance of precipitation, temperatures, soil moisture, and atmospheric CO2 concentrations in crop-soil-atmospheric interactions (Iglesias *et al.* 2011, Ainsworth 2008, Ainsworth and Long 2005). These components are projected to change significantly in the coming decades (Meehl *et al.* 2007). The knowledge gained in such experimental studies can be formalized in models, helping to structure the complex interactions, which can be purely conceptual, or quantitative (Hillel and Rosenzweig 2010).

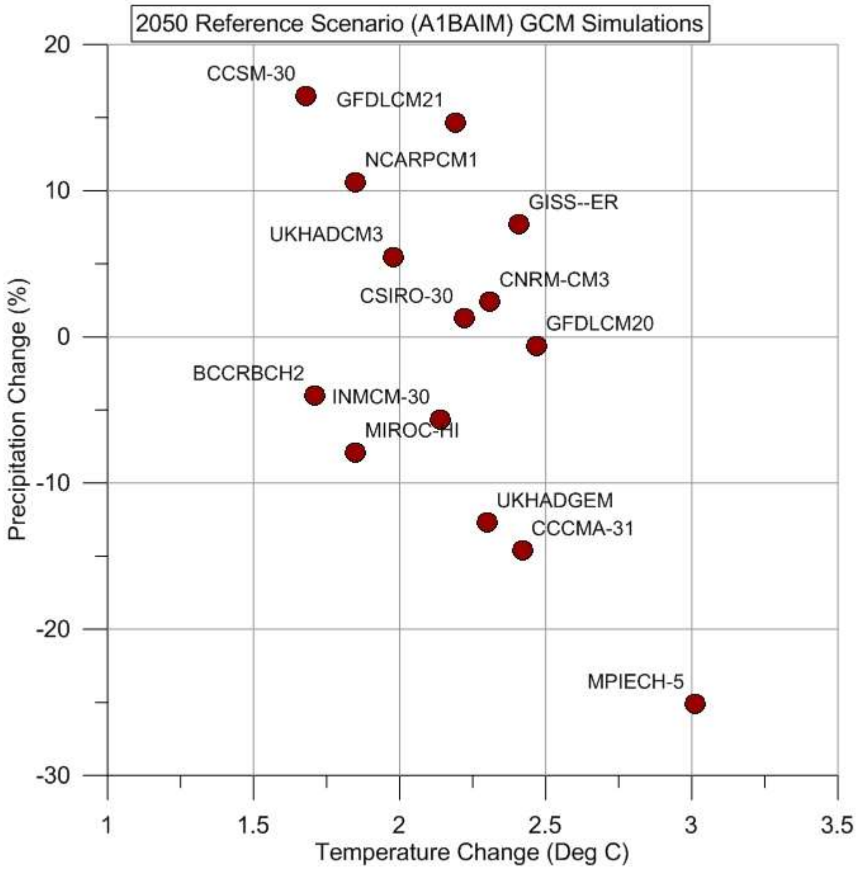
One such approach is to apply crop models with simulation results of atmospheric general circulation models (GCMs). In the this study, MAGICC/SCENGEN climate predictions were adopted to study the regional and local climate and also analyse the wider variations among various GCM predictions embedded in MAGICC/SCENGEN (Wigley 2008) and to consider the crop yield sensitivity by the various SRES and GCM scenarios as presented in detail and noted by Alemaw and Simalenga (2015). It was applied in the context of the local climate conditions of the Pandamatenga plains located in northern Botswana considering a square grid with a spatial resolution of 2.5°, and this has been a basis for this discussion in this short manuscript.

Wider variations among GCM predictions are generally common among climate predictions obtained from the various researches conducted by different organizations and researchers due to possible different in model assumptions, the mathematical model boundaries, climate forcing, etc. However, GCMs provide the most plausible regional climate change scenarios.

It was attempted to determine the climate change scenarios over the study area from various GCM simulations. The coordinates of a square area covering the study area were identified. Fig. 14-1 shows changes in temperature in °C and changes in precipitation in percentage form as given by the model for a 2.5° square grid located with center at Latitude 21.25°E, Longitude 28.75°S around the center of the study area based on the SRES scenarios of A1B-A1M (Wigley 2008), which is the illustrative scenario adopted.

Of the 14 GCM and SRES climate prediction scenarios, the temperature and precipitation changes of three scenarios is summarized in Table 14-1, which repreent simulated changes for the 2050s at a 2.5^{o} square pixel centered at the Pilot area (around the center of the Pandamatenga Plains). These three selected GCM scenarios were adopted as they typically represent dry, moderate and wet conditions as summarized in Table 14-1 and described as:

- Warm and wet conditions (Scenario 1). This is typically represented by GFDLCM21.
- Warm and dry conditions (Scenario 2). This is a typical condition of CCCMA-31.
- Moderate conditions (Scenario 3). This is typical of the UKHADCM3 model.



(*Adopted from* CCARDESA 2014, Fig. 3-1)

Figure 1-1 Comparison of GCM projections at *a 2.5^{o} square GCM grid Centered at Pandamatenga/Mid-Zambezi Basin (between 17.5-20 ^{o}S and 25-27.5 ^{o}E).*

Table 1-1 Projected changes in temperature and precipitation during the baseline period in the study area

GCM	Temperature change (°C)	Précipitation change (%)	Remark
CCCMA-31	2.42	-14.60	warm/ dry
GFDLCM21	2.19	14.70	warm/wet
UKHADCM3	1.98	5.50	Moderate

(Source: CCARDESA 2014)

1.3 Results of Climate-Agricultural Modelling System

Against the baseline 1971-2000 climatology, three specific GCM model projections (Hulme et al. 2007; Wigley 2008) for 2050s, namely GFDLCM21, UKHDCM3 and CCCMA-31, which respectively represent warm/wet, moderate and warm/dry scenarios in the region, were considered. The corresponding soil-water balances of simulated moisture, actual evapotranspiration and excess surface runoff in Pandamatenga Plains of Botswana, which is a vast plain dominated with vertisols extending to parts of eastern Namibia, southern Zambia and western Zimbabwe.

The soil water balances for 2050s and the baseline period were simulated using a coupled GCM and daily soil-moisture accounting crop-specific (SMACS) model (Alemaw et al. 2006). For the simulated periods, SMACS considers crop calendars and crop coefficients for the specific crop, which were studied. The yield reductions were also computed as illustrated in Table 14-2, in which the decline in yield under the wet/dry and moderate scenarios present more series challenge than the warm/wet scenario, which is more or less similar to the baseline climate situation.

The potential for harvesting excess storm runoff in the rainfed agricultural fields of the study site is investigated. It is presented in Table 14-3 for the baseline period, and Table 14-4 for the three GCM scenarios considered. It can be emphasized that, despite reduction of yield due to dry spells and shortfalls of moisture that occur frequently, there are also some days with excess storm that can be utilized for mitigating risk and potentially promote excess rainwater harvesting practices.

Table 1-2 Projected percentage yield reductions for the various scenarios

Crop		Moderate		Warm/Wet		Warm/Dry	
	Baseline	UKHDCM3	UKHDCM3	GFDLCM21	GFDLCM21	CCCMA-31	CCCMA-31
	1971-2000	2001-2030	2031-2050	2001-2030	2031-2050	2001-2030	2031-2050

Maize	55	66	65	62	55	68	72
Sorghum	40	50	49	46	42	51	53
Sunflower	49	52	50	50	47	54	58

(Source: CCARDESA 2014)

Table 1-3 Direct runoff that can be harvested for the baseline climatology

Indicator: % No of days exceeding	**1971-2000**				**1971-2000**			
	Baseline [mm]				**Baseline** [$m^3\ ha^{-1}d^{-1}$]			
	Maize	**Sorghum**	**Sunflower**	**Average**	**Maize**	**Sorghum**	**Sunflower**	**Average**
10%	2.79	4.39	2.95	3.56	28	44	29	36
15%	1.70	2.32	2.03	2.25	17	23	20	22
20%	0.69	1.31	1.04	1.29	7	13	10	13

(Source: CCARDESA 2014)

Table 1-4 Direct runoff that can be harvested under the three climate change scenarios in the 2050s for three rainfed cropping systems simulated using a coupled-GCM-crop-water balance model.

Indicator: % No of days exceeding	**GCM Scenario**								
	GFDLCM21 [Warm/Wet]			**UKHDCM3 [Moderate]**			**CCCMA-31 [Warm/Dry]**		
	Maize	**Sunflower**	**Sorghum**	**Maize**	**Sunflower**	**Sorghum**	**Maize**	**Sunflower**	**Sorghum**
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
10%	2.27	2.83	2.49	2.53	2.91	2.86	3.27	3.81	3.62
15%	1.41	1.95	1.66	1.51	1.88	1.84	2.29	2.92	2.75
20%	0.49	1.22	0.93	0.55	1.10	1.08	0.94	1.84	1.49

(Source: CCARDESA 2014)

1.4 Conclusion

With or without climate change, through this study, it is shown that there is an opportunity to improve moisture availability and excess rainwater harvesting. In the study area, the researchers have gathered secondary information in Pandamatenga plains of Botswana and northern part in

Southern Zambia that local farmers use a number of practices for rainwater harvesting, soil moisture enhancement, and related conservation practices, with huge potential to outscale in various areas.

The study further suggests that there is a need to develop a comprehensive intervention not only on the physical interventions but also on the overall adaptation practices. The practice of CSA (FAO 2010) could be a holistic approach to promote future adaptive responses to improve the productivity of rainfed systems.

The approach could be to look at cross-cutting social, market, and investments that consider at least one or a combination of the following issues, which would ensure outscaling to various localities and environments:

- Strengthening of conservation agriculture practices is key element in climate change adaptation. This calls various media and fora for expanded and scaled-up adoption of conservation agriculture practices especially among the smallholder farming systems and related industry in Africa (CCARDESA 2016). Mixed crop-tree farming practices also offer encouraging results as noted by Phiri et al. (2003).
- Improved rainwater harvesting and moisture enhancement techniques (Alemaw *et al.* 2006). Depending on rainfall patterns and local soil characteristics, appropriate application of in situ and micro-catchment techniques could improve the soil water content of the rooting zone by up to 30% (Biazin *et al.* 2012).
- Consideration of fodder-crop systems could be potential intervention besides measures that focus directly on animal productivity, feed and manure management, since there are a range of grassland management practices that can address mitigation and improve resilience. As noted by FAO (2010), grasslands, including rangelands, shrub lands, pasture lands, and croplands sown with pasture, trees and fodder crops, represent 70 percent of the world's agricultural area while the soils under grasslands contain about 20 percent of the world's soil carbon stocks.
- Improved varieties of dry land crops (maize, sorghum, sunflower, etc). Sangakkara et al. (2002) noted the impact of the Cropping Systems of a Minor Dry Season on the Growth, Yields and Nitrogen Uptake of Maize, which recorded varied changes of yield and productivity under various moisture regimes.
- More detailed research on climate change & variability shocks and impact study (Alemaw, and Chaoka 2006b; Alemaw 2017). This is so relevant as most agricultural water scarcity in the predominantly rainfed agricultural system of sub-Saharan Africa (SSA) is more

related to the variability of rainfall and excessive non-productive losses, than the total annual precipitation in the growing season (Biazin et al. 2012).

- ☐ Strengthened capacity development at various levels for enhancing response actions and build community resilience (Alemaw 2017). As noted in (Biazin *et al*. 2012), the much needed adaptation to climate change in SSA should blend rainwater harvesting ideals with agronomic principles. The need to improve the indigenous practices, and to disseminate best practices on a wider scale is also noted in the scientific and research community.

The above interventions should be built in a consultative national adaption and development planning process considering the role of multi-institutional actions related to agriculture, environment and natural resources.

Outscaling to local scale depending on a given agroecological setting suitability can be achived using integrated soil-water management strategies which could include: 1) strengthening of conservation tillage to improve soil-water productivity and land fertility; 2) improving near real-time weather forecasting and advisory services to support farmers to adjust cropping pattern and planting dates of cultivars; 3) encouragement and incentive measures for effectively use available rainwater and harvest excess runoff; and 4) strengthening contribution to awareness and public policy processes in an effort demonstrate the potential benefits of developing adaptation strategies in terms of the socio-economic, economic diversification benefits and ultimately improvement of food security of a nation or the region at large.

Outscaling could be also be achieved through conservation farming and related climate adaptation practices. Survey was conducted in the study area including farming communities in three districts in southern Zambia (Chogwe, Chisamda and Chipembi Districts). It was established from the survey that a mix of various Conservation Farming and Climate Adaptation Practices are being adopted at various levels (CCARDESA 2014; Alemaw and Simalenga 2015). It is noted that the farmers have developed local and indigenous knowledge systems and they also appreciate how improvements in conservation farming, water harvesting, water access and climate resiliency could help them protect their deteriorating agricultural and livestock yields in their community. These practices should be outscaled in this region for similar environments including: 1) Dry-season land preparation using minimum tillage; 2) Crop residue retention; 3) Seeding and input application in fixed planting stations; 4) Nitrogen-fixing crop rotation; 5) Infield water conservation; 6) Crop-livestock system for soil fertility and income generation; and 7) Mixed farming of maize with soybeans, groundnuts, etc. These practices are there for possible adoption by other communities in similar agro-ecological conditions, if they are given the means and support them in agricultural productivity and household food security enhancement.

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