Global and Planetary Change 111 (2013) 118–126

Contents lists available at ScienceDirect

Global and Planetary Change

journal homepage: www.elsevier.com/locate/gloplacha

Review paper

Crop response to climate change in southern Africa: A comprehensive review

Nkulumo Zinyengere [a,*], Olivier Crespo [a], Sepo Hachigonta [b]

[a] Climate System Analysis Group, Department of Geography and Environmental Science, University of Cape Town, Private Bag X3, Rondebosch, 7701 Cape Town, South Africa
[b] Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN), 141 Cresswell Street, Weavind Park, 0184 Pretoria, South Africa

ARTICLE INFO

Article history:
Received 2 August 2012
Revised 30 July 2013
Accepted 15 August 2013
Available online 24 August 2013

Keywords:
crops
climate change
southern Africa
modelling
adaptation

ABSTRACT

Concern over future food security in southern Africa has led to various studies that assess the impact of climate change on crops in the region. The results vary according to applied methods and tools. This study reviewed and consolidated results from 19 recent studies which quantitatively project the impact of climate change on crops for the 21st century in southern Africa. Results were assessed according to crop modelling techniques, which included process-based, statistical and economic (Ricardian) modelling. Studies were assessed for their reporting and recommendations concerning adaptation and CO_2 fertilisation. Results suggest that the aggregate impact of climate change on crops in southern Africa will be negative. Maize yields are projected to decline on average by 18%. The collective impact of climate change on all crop yields shows a median decline of −11% and −14% respectively under process-based and statistical methodologies. Median impacts show declining crop yields through the 21st century. No significant change in the near future, −18% for the mid century and −30% for late century. GCM driven Ricardian projections are highly variable. However, uniform climate scenarios project a median revenue decline. Notwithstanding the challenges of such a review; lack of data, bias towards reported methods and tools, uncertainty, scale etc., results indicate that climate change may impact southern African crops in important ways thereby making adaptation essential. Adaptation and CO_2 fertilisation could potentially moderate the negative impacts of climate change. This implies a need for studies into future adaptation that consider CO_2 fertilisation.

Contents

* Corresponding author. Tel.: +27 21 6505774, +27 84 2553826; fax: +27 21 650 5773.
E-mail address: nkulumo@csag.uct.ac.za (N. Zinyengere).

0921-8181/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.gloplacha.2013.08.010

1. Introduction

Southern Africa (SA) is one region that has been shown to be highly vulnerable to climate related risk due to the region's low coping and adaptation capacity (IPCC, 2007). Over 60% of the region's livelihoods depend on agriculture in one way or the other (Cooper et al., 2008). Agriculture is mostly practised under rain fed conditions (Twomlow et al., 2008), thereby making crop production in SA particularly prone to climate change and variability (Ziervogel et al., 2008). This has led to a lot of research on the potential impact of climate change on crop production in SA (Chipanshi et al., 2003; Fischer et al., 2005; Gbetibouo and Hassan, 2005; Abraha and Savage, 2006; Liu et al., 2008; Thornton et al., 2011).

Climate change impact studies make use of simulation models to project how crops will respond to future climate. Considering the inherent complexity of systems being simulated, numerous uncertainties arise during the simulation process. These uncertainties emanate from incomplete data, limited knowledge of systems being modelled, methods and tools. Scientists however make use of available data, tools and methods in the best possible way to attempt to make informed projections. The last decade has a substantial body of work on climate change impacts on crops whose results vary considerably across regions and within SA (Jones and Thornton, 2003; Rosenzweig and Iglesias, 2003; Parry et al., 2004; Walker and Schulze, 2006; Jain, 2007; Lobell et al., 2008; Thornton et al., 2009; Nelson et al., 2010; Roudier et al., 2011). These studies suggest that the production of major crops is under threat from climate change and that efforts to adapt food crop production systems to climate change should be explored in order to promote future food security.

Impact studies in SA produce different results based on applied methodologies, tools and location of study within the region. While these studies are useful individually, a collective assessment would allow consistent information to be extracted. It would increase confidence in study results, especially towards adaptation planning. This study attempts to provide a collective insight of climate change impacts on crops in SA by reviewing and analysing recent literature. A review of local, regional and global studies which quantitatively assess the impact of climate change on various food crops in SA is done. Results from these studies are consolidated and presented according to the tools and methods used in order to describe the magnitude and direction of climate change impacts on crops. Tools and methods used in reviewed studies are described thereby placing projected climate change impacts within the context of their strengths and weaknesses. Results are discussed and linked to adaptation strategies suggested in literature. Despite the limitations of this review, this study can help to better understand the range of impacts projected by various studies, point out more or less confident projections and what the implications are for the adaptation of vulnerable crop production systems in SA.

2. Background

2.1. Global climate trends and projections

The Intergovernmental Panel on Climate Change (IPCC) fourth assessment report (AR4), states that global temperatures are on the rise. Instrumental records of temperature over the period of 100 years ending 2005 clearly show an average global increase of 0.74 °C with the 2nd half of the century being twice as warm as the entire period (IPCC, 2007). Continental average temperatures over the same period also rose similarly. Notably, global and continental temperature rise is clearly attributable to human activity. The IPCC (2007) reports an 80% rise in annual carbon dioxide (CO_2) emissions since 1970. This and longer term green house gases (GHGs) emission rise are reportedly a result of fossil fuel burning and land use changes among other human activities.

While global temperature projections are consistent over time, rainfall varies temporally, spatially and across models, such that no general trend is apparent on a global scale. However, it has been noted that rainfall variability globally is quite high. There has been an increase in the parts of the world that are continuously being affected by excessive and insufficient rainfall (Porter and Semenov, 2005). Of concern in low income regions like Africa and some parts of Asia is the fact that regionally important food crop producing areas have been experiencing changes in rainfall variability and intensity.

Table. 1
Summary of projected temperature (°C) changes per SRES scenario (B1, B2, A1B, A1T, A2, A1FI) by the end of the 21st century.

	B1	B2	A1B	A1T	A2	A1FI
Temperature (°C)	+1.8 (1.1–2.9)	+2.4 (1.4–3.8)	+2.8 (1.7–4.4)	+2.4 (1.4–3.8)	+3.4 (2.0–5.4)	+4.0 (2.4–6.4)

Projecting into the future, most climate models agree on global temperature rise, albeit with varying degrees of warming (IPCC, 2007). As shown in Table 1, mean temperatures are consistently projected to rise by the end of the 21st century. Mean temperature projections range from increases of 1.8 °C to 4.0 °C, according to the different CO_2 emission scenarios defined in the special report on emission scenarios (SRES). On the other hand, future rainfall projections are not consistent. This poses a challenge when simulating the impact of climate change on crop development and devising adaptation strategies in Africa where a large portion of the population relies on rainfed crop production for food.

2.2. Future climate projections in Africa

A general warming larger than the global mean warming is predicted for all seasons across Africa. These projections are summarised in Table 2. All 21 General Circulation Models (GCMs) in the IPCC AR4 agree on warming across Africa. However, the degree of warming projected varies from one region to the other within the continent. Higher mean temperatures are projected for the Sahel compared to other regions. Projected temperature changes also vary from one season to the other within regions. Projections of future rainfall are more uncertain. Climate models do not agree on the magnitude or direction of rainfall changes. Mean annual rainfall is projected to increase in West Africa (+2%) and East Africa (+7%). Mean annual rainfall is projected to decrease in Sahel (−6%) and SA (−4%). Marked variations are projected within seasons. These variations are significant for future crop production and food security.

Table. 2
Future projections of climate in Africa by the end of the 21st century. Output from 21 GCMs (IPCC, 2007). Highlighted are changes of significance to crops in SA.

Region	Season	Temperature change			Rainfall change (%)		
		Min	Mean	Max	Min	Mean	Max
Sahel	DJF	2.4	3.2	5	-47	-18	31
	MAM	2.3	3.6	5.2	-42	-18	13
	JJA	2.6	4.1	5.8	-53	-4	74
	SON	2.8	3.7	5.4	-52	6	64
	Annual	2.6	3.6	5.4	-44	-6	57
West Africa	DJF	2.3	3	3.5	-16	6	23
	MAM	1.7	3.5	3.6	-11	-3	11
	JJA	1.5	3.3	3.7	-18	2	13
	SON	1.9	3.3	3.7	-12	1	15
	Annual	1.8	3.3	3.6	-9	2	13
East Africa	DJF	2	3.1	3.4	-3	13	33
	MAM	1.7	3.2	3.5	-9	6	20
	JJA	1.6	3.4	3.6	-18	4	16
	SON	1.9	3.1	3.6	-10	7	38
	Annual	1.8	3.2	3.4	-3	7	25
Southern Africa	DJF	1.8	3.1	3.4	-6	0	10
	MAM	1.7	3.1	3.8	-25	0	12
	JJA	1.9	3.4	3.6	-43	-23	-3
	SON	2.1	3.7	4	-43	-13	3
	Annual	1.9	3.4	3.7	-12	-4	6