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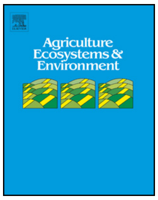

Local impacts of climate change and agronomic practices on dry land crops in Southern Africa

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ABSTRACT

Climate change impact assessments on agriculture in Southern Africa are mostly carried out at large spatial scales, risking missing out on local impacts and adaptation potential that reflect the range of multiple and unique bio-physical and agronomic conditions under which farmers in the region operate. This study investigated how climate change may affect yields of various major food crops in specific locations in the region; maize and sorghum (Mohale's Hoek – Lesotho and Big Bend – Swaziland), maize and groundnut (Lilongwe – Malawi). Using statistically downscaled climate projections from nine GCMs and the DSSAT crop model and simulating selected agronomic strategies practiced in each location, the study confirmed that impacts of climate change on crop yields in Southern Africa vary across locations and crops. Despite various uncertainties associated with such assessments, the results showed that crop yields were predominantly projected to decline in Big Bend (maize (−20%); sorghum (−16%)) and Lilongwe (maize (−5%); groundnut (−33%)). However, crop yields in Mohale's Hoek, located in a high altitude region historically prone to cold related crop yield losses were on average projected to increase (maize (+8%) and sorghum (+51%)). The geographical variation of yield projections highlights the importance of location specific climate change impact assessments. The exploration of local agronomic management alternatives revealed prospects for identifying locally relevant adaptation strategies, which cannot easily be captured at larger scales.

1. Introduction

Agriculture is one of the most climate dependent of human activities (Hansen, 2002), particularly in Sub-Saharan Africa (SSA) where close to 70% of the population depends on small scale agriculture (Cooper et al., 2008). This makes SSA extremely prone to the effects of climate change and variability. The Intergovernmental Panel on Climate Change (IPCC) (2007) states that by 2050, crop yield losses could reach up to 50% in some countries in SSA. Compounded by increased population and low adaptive capacity, the crop yield losses will severely compromise food security in Africa. In a review study of projected climate change impacts in the 21st century, Zinyengere et al. (2013) show that while there is significant uncertainty about the impact of climate change in the early 21st century (2020s), projected impacts further into the 21st century are robust, showing that climate change will negatively impact crops in Southern Africa. Recent studies in Africa concur and suggest similar negative impacts on crops (Knox et al., 2012; Berg et al., 2013; Liu et al., 2013; Waha et al., 2013; Muller, 2013). Clearly, food security and livelihoods on the continent are at risk.

The majority of studies on climate change impacts on agriculture in SSA are commonly performed at large spatial scales, aggregated over entire countries, the region or the continent as a whole (Zinyengere et al., 2013). This kind of assessment leads to generalised and broad conclusions about the impact of climate change on crop production, which are not reflective of impacts at farm or community level. While these types of studies might be useful for national and regional planning, they run the risk of missing out on local peculiarities, where impacts vary considerably in both space and time. At coarse scales, it is difficult to sensibly identify useful on-farm adaptive measures. Large scale studies usually make broad-brush recommendation of adaptation strategies over large areas, which may not speak to local small holder dry

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land farmers. These farmers operate under peculiar conditions and practices more often emanating from personal/community experience, culture, financial and physical resources, and varying over short spatial scales. In order to understand how climate change may affect crop production in the systems and conditions that small holder dry land farmers operate and to identify adaptation strategies suited to those conditions, climate change impact studies need to be performed at high spatial resolutions (Thornton et al., 2011; Lobell et al., 2008). The few studies that have carried out such assessments in Southern Africa were limited in the number of crops studied e.g., maize alone (Walker and Schulze, 2008; Abraha and Savage, 2006) and focused on one location thereby lacking a simultaneous analysis of impacts in the region. Furthermore, studies do not attempt to explicitly assess the impacts of climate change with agronomic scenarios representative of local farming practices.

This study presents a location specific climate change impact assessment for dry land crop production in Southern Africa. Three districts located in Southern Africa (Mohale's Hoek – Lesotho, Big Bend – Swaziland and, Lilongwe – Malawi) with unique agro-ecological conditions and cropping practices were selected for the study. Climate projections were downscaled from nine Global Circulation Models (GCMs) for the three locations and used to drive a crop model to simulate impacts on three major southern African crops (maize, sorghum, and groundnut). Projected baseline (1961–2000) and future (2046–2065) climate scenarios for two contrasting special report on emission scenarios (SRES) representing low (B1) and high (A2) future carbon dioxide (CO_2) emissions were used (Nakicenovic et al., 2000). Scenarios representing some agronomic strategies practiced by dry land farmers in each location were also simulated to provide insight into their potential for adaptation.

2. Methodology

2.1. Study location

Study locations were selected to represent a diversity of agro-ecological and agronomic conditions in Southern Africa while crops were selected depending on local and regional importance to food security as follows; maize and sorghum in Big Bend; maize and sorghum in Mohale's Hoek; maize and groundnut in Lilongwe. Big Bend (−26.82°, 31.93°) is found in the low veld of Swaziland, a region considered marginal for maize and more suited to small grains. Temperatures are high with a monthly average of 30 °C during the cropping season (Manyatsi et al., 2013). Mohale's Hoek (−30.15°, 27.47°) is located in the low veld, the main agricultural region of Lesotho, a high altitude country prone to cold related crop yield losses. Average annual minimum temperatures are below 10 °C (Gwimbi et al., 2013). Lilongwe (−13.98°, 33.78°) is located in a mid-altitude region that is considered one of the most productive for cereals in Malawi (Saka et al., 2013). Temperatures are moderate. All three locations experience uni-modal summer rainfall between October and April, averaging 507 mm, 602 mm, and 810 mm during the cropping season for Big Bend, Mohale's Hoek, and Lilongwe, respectively. Agriculture in all locations is dominated by dry land small holder production on old sandy clay loam soils.

2.2. Scenario based impact assessment

In this study, the decision support system for agro- technology transfer (DSSAT) deals with the crop growth (Jones et al., 2003). To assess the impacts of climate change on crops at a fine level scale (farm/community), local climate variables (e.g., maximum temperature, minimum temperature, solar radiation, and precipitation), crop and soil parameters, and management practices were crucial inputs.

2.2.1. Climate data and scenarios

The study used nine comprehensive model intercomparison project 3 (CMIP3) GCMs data (Meehl et al., 2007) as summarized in Table 1. The data was downscaled to a climate station in each study district to represent climate projections in each location for a baseline (1961–2000) and future period (2046–2065). The statistical downscaling was done using the self-organising maps (SOMs) approach by Hewitson and Crane (2006). Daily weather records (minimum and maximum temperatures and rainfall) were obtained from national meteorological institutions in each study country. Solar radiation was estimated with a routine based on daily minimum and maximum temperatures, latitude and elevation using the methods of Allen et al. (1998) and Ball et al. (2004) which were shown to be efficient over Southern Africa (Hachigonta, 2011). For each of the nine GCMs, contrasting scenarios, namely the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios (IPCC SRES) carbon dioxide (CO_2) emissions were used, respectively designated for B1 (low emission) and A2 (high emission).

Table 1
Comprehensive model intercomparison project 3 (CMIP3) Global Circulation Models (GCMs) from which climate scenarios were obtained.

Name used	Originating group(s)	Country	Model full name	Primary reference
CCMA	Canadian Centre for Climate Modeling & Analysis	Canada	CGCM3.1 (T47)	Flato and Boer (2001)
CNRM	Météo-France/Centre National de Recherches Météorologiques	France	CNRM-CM3	Salas-Mélia et al. (2005)
CSIRO	Australia's Commonweath Scientific and Industrial Research Organisation	Australia	CSIRO_MK3.5	Gordon et al. 2002
GFDL	US Dept. of Commerce/NOAA/Geophysical Fluid Dynamics Laboratory	USA	GFDL-CM2.1	Delworth et al. (2006)
GISS	NASA/Goddard Institute for Space Studies	USA	GISS-ER	Russell et al. 2000
IPSL	Institute Pierre Simon Laplace	France	IPSL-CM4	Dufresne et al. 2005
MIUB	Meteorological Institute of the University of Bonn, Meteorological Research Institute of KMA, Model and Data group at MPI-M	Germany/ Korea	ECHO-G	Legutke and Voss (1999)
MPI	Max Planck Institute for Meteorology	Germany	ECHAM5/ MPI-OM	Jungclaus et al. 2006
MRI	Meteorological Research Institute	Japan	MRI-CGCM2.3.2	Yukimoto et al. 2001