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Agriculture and Future Climate Dynamics in Africa: Impacts and Adaptation Options

by

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Submitted in partial fulfilment of the requirements for the degree of

PhD Environmental Economics

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Dedication

To my wife Charity and son Blessings

Declaration

I declare that this thesis I hereby submit for the degree of PhD in Environmental Economics at the University of Pretoria is entirely my own work and has not been submitted anywhere else for the award of a degree or otherwise.

Parts of the thesis have been published and submitted for publication in journals.

Any errors in thinking and omissions are entirely my own responsibility.

Signed: ……

Name: Charles Nhemachena

January 2009

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Degree: PhD Environmental Economics
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Abstract

This study had two main objectives. One objective was to measure the aggregate impact of climate change on income from all agricultural production systems (crop, livestock and mixed) in Africa and to predict future impacts under various climate scenarios. In addition to measuring economic impacts, the study analysed determinants of farmers' choices between alternative adaptation measures available to African farmers. The study is based on a cross-section survey of over 8000 farming households from 11 countries in east, west, north and southern Africa.

To achieve the first objective, the cross-section (Ricardian) approach was used to measure the impact of climate change attributes (rainfall and temperature levels) on income from all agricultural production systems (crop, livestock and mixed) in Africa, controlling for other production factors. Based on empirical estimates from the Ricardian model, the study predicts future impacts under various climate scenarios. In addition to estimating impacts on mixed crop–livestock farms, the study also measures and compares impacts on specialised crop and livestock farms. Responses of different production systems are analysed under irrigation and dryland conditions. The response of net revenue from crop and livestock agriculture across various farm types and systems in

Africa, to changes in climate variables (i.e. mean rainfall and temperature) is analysed. The analysis controlled for effects of key socio-economic, technology, soil and hydrological factors influencing agricultural production. In addition to measuring impacts on aggregate revenue, the study examined variations in the response of three distinct production systems characterising African agriculture: specialised crop; specialised livestock and mixed crop and livestock systems. Differential impacts of climate change on the studied systems were measured under irrigation and dryland conditions.

Results show that net farm revenues are in general negatively affected by warmer and dryer climates. The mixed crop and livestock system predominant in Africa is the most tolerant, whereas specialised crop production is the most vulnerable to warming and lower rainfall. These results have important policy implications, especially in terms of the suitability of the increasing tendency toward mono-cropping strategies for agricultural development in Africa and other parts of the developing world, in the light of expected climate changes. Mixed crop and livestock farming and irrigation offered better adaptation options for farmers against further warming and drying predicted under various future climate scenarios.

For the second objective, the study employed a multinomial choice model to analyse determinants of farm-level climate adaptation measures in Africa. Results indicate that specialised crop cultivation (mono-cropping) is the most vulnerable agricultural practice in Africa in the face of climate change. Warming, especially in summer, poses the highest climate risk which tends to indicate switching away from mono-cropping towards the use of irrigation, multiple cropping and integration of livestock activities. Increased precipitation reduces the need for irrigation and will be beneficial to most African farming systems, especially in drier areas. Better access to markets, agricultural extension and credit services, technology and farm assets (such as labour, land and capital) are critical enabling factors to enhance the capacity of African farmers to adapt to climate change. Government policies and investment strategies that support the provision of and access to education, markets, credit, and information on climate and adaptation measures, including suitable technological and institutional mechanisms that facilitate climate

adaptation, are therefore required for coping with climate change, particularly among poor resource farmers in the dry areas of Africa.

Key words: climate change, impacts, adaptation, agriculture, Africa, Ricardian approach, multinomial choice models

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ACRONYMS AND ABBREVIATIONS

AEZ	Agro Ecological Zone
AGRIM	Agriculture, Growth and Redistribution of Income Model
AOGCMs	Atmospheric-Oceanic Global Circulation Models
APN	Asia-Pacific Network for Global Change Research
ARTES	Africa Rainfall and Temperature Evaluation System
CCC	Canadian Climate Centre
CEEPA	Centre for Environmental Economics and Policy in Africa
CERES	Crop Estimation through Resources and Environmental Synthesis
CGE	Computable General Equilibrium
CO_2	Carbon Dioxide
CROPWAT	Crop Water
DES	Dietary Needs Supply
EASM	Egyptian Agricultural Sector Model
EPIC	Erosion Productivity Impact Calculator
FAO	Food and Agriculture Organization
FARM	Future Agricultural Resources Model
GEF	Global Environmental Facility
GCM	Global Circulation Model
GDP	Gross Domestic Product
GIS	Geographic Information System
LUT	Land Utilisation Types
IAC	InterAcademy Council
IPCC	Intergovernmental Panel on Climate Change
MINK	Missouri-Iowa-Nebraska-Kansas
MLCRDRY	Multiple crops under dryland
MLCRIRRG	Multiple crops under irrigation
MLCRLSIR	Multiple crop-livestock under irrigation
MLCRLSDR	Multiple crop-livestock under dryland

MOCRLSDR	Mono crop-livestock under dryland
MOCRLSIR	Mono crop-livestock under irrigation
MNL	Multinomial Logit
MNP	Multinomial Probit
PCM	Parallel Climate Model
SNM	Standard National Model
SRES	Special Report on Emissions Scenarios
SSA	Sub-Saharan Africa
SSMI	Special Sensor Microwave Imager
TAR	Third Assessment Report
UNEP	United Nations Environmental Programme
US	United States of America
VIF	Variance Inflation Factor
WB	World Bank