The impact of climate change on net revenue and food adequacy of subsistence farming households in South Africa

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ONLINE APPENDIX

The climate change and food security nexus

According to the IPPC, Africa is the most vulnerable region to climate change and climate variability (IPCC, 2007). This is because the majority of the population in Africa depend on agriculture (Kurukulasuriya *et al.*, 2006; Kempe, 2009; Kotir, 2011) both through direct livelihood and national gross domestic product (IPPC, 2007). In addition the region already faces ecosystem degradation, warm baseline temperatures, low precipitations and limited adaptation capabilities making the region even more vulnerable (Kurukulasuriya *et al.*, 2006; IPCC, 2007; Kotir, 2011). Furthermore, almost 70 per cent of sub-Saharan African households obtain their livelihoods from small-scale subsistence farming (Ellis and Freeman, 2004). Climate variability and change is therefore a potential threat to food security in this region, greatly dampening the achievement of the Millennium Development Goals. This is further exacerbated by the fact that the population in sub-Saharan Africa region is already the most undernourished, with approximately 32 per cent of the population currently being deprived of access to food (Kotir, 2011). Thus the strongest impact of climate change will likely occur among the poorest and already most food insecure population (IPCC, 2007), that is, smallholder subsistence farming households in sub-Saharan Africa (Reilly *et al.*, 1996; Kates, 2000; Kotir, 2011). This is mainly because poor households typically have limited opportunities and consequently are likely to be disproportionately affected by the negative impacts of climate change (IPCC, 2007).

The effects of climate change are expected to affect all dimensions of food security both directly and indirectly.[1] Directly, by reducing food availability as it affects the basic requirements of agriculture – temperature, water availability and biodiversity. Indirectly through dimensioned economic growth, labour market and income distribution (IPCC, 2007;

[1] Nelson *et al.* (2010) used a comprehensive global partial equilibrium model to assess the costs of climate change and adaptation for agriculture and by extension for human wellbeing. They found that irrespective of the climate model that is used, climate change will result in losses in agricultural productivity and that rising food prices will lead to reduced food availability and increases in malnourished children.

Kotir, 2011). This study is concerned with the former as we investigate the impact climate change will likely have on poor households who participate in agriculture to supplement household income and dietary requirements. As previously mentioned there is a growing body of literature on impact assessment in sub-Saharan Africa,[2] for example the GEF funded project and other independent research.[3] For instance, in a comprehensive study covering Africa, Kurukulasuriya *et al*. (2006) analysed the response of net farm revenue from crop agriculture and livestock production based on the GEF survey of 9000 farmers in 11 African countries (Burkina Faso, Egypt, Ethiopia, Ghana, Niger, Senegal, South Africa, Zambia, Cameroon, Kenya and Zimbabwe). Along similar lines, Kurukulasuriya and Mendelsohn (2006), using the same data as Kurukulasuriya *et al*. (2006), measured the response of net farm revenue from crop agriculture only. In parallel to Kurukulasuriya *et al*.'s (2006) comprehensive continental study, Seo and Mendelsohn (2006) conducted a further study using the same 11 country data but focussing only on livestock or animal husbandry. They found the possibility to substitute towards livestock farming to be an important cushioning effect against climate change. In a separate analysis, Seo *et al*. (2009) used the same dataset and assessed crop and livestock cultivation in different agro-ecological zones in Africa. The results from their study indicate that livestock may be a good substitute for crops.

In another study Mano and Nhemachena (2006) found the net effect of climate change on agriculture to be significant in the net revenues of Zimbabwean farmers. Similarly, Molua and Lambi (2006) observed that climate change would have a negative effect for the Cameroon economy. In Bukina Faso, Ouedraogo *et al*. (2006) found increases in temperature and decrease in precipitation to reduce net farming revenue. The same observation was made by Deressa (2006) using data of Ethiopian farmers. For Zambia, Jain (2006) concluded that

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[2] The Ricardian model has also been applied elsewhere, for example, Kumar and Parikh (2001) analysed Indian farms; Mendelsohn *et al*. (2009) study Mexican farmers; Seo and Mendelsohn (2008) assessed South American farms; while Liu *et al*. (2004) and Wang *et al*., (2009) analysed Chinese farmers.
[3] See Hassan (2010) for a comprehensive review of the GEF/WB studies.

climate change will have adverse effects on Zambian farmers. Kabubo-Mariara and Karanja's (2007) assessment revealed that agricultural productivity will be affected by climate change in Kenya. Molua (2009) in analysing the effects of changes in climatic averages on agriculture production in Cameroon found that a simultaneous increase in temperature and decrease in precipitation would have a detrimental effect on net agriculture revenue. In a follow up paper, Deressa and Hassan (2009) examined the effects of climate change on Ethiopian crop farmers using the Ricardian model. They observed the climate variables to have a significant effect on net revenue. Nhemachena *et al*. (2010) also examined mixed crop-livestock strategies as a coping mechanism for farms from three Southern African countries (South Africa, Zambia and Zimbabwe). Their analyses controlled for effects of key socioeconomic, technological, soil and hydrological factors influencing agricultural production. They found that specialised crop cultivation was more sensitive to warmer and drier climates whereas small-scale mixed crop and livestock farming predominant in large parts of Southern Africa is better adapted to such climates. Along similar lines, Di Falco *et al*. (2012) estimated the impact of climate change on cereal crops in the Nile Basin region of Ethiopia. The authors also investigated the determinants of adaptation and found that extension services as well as access to credit and information were important drivers.

The observations made in sub-Saharan Africa regarding climate change and food security are also evident in South Africa. South African agriculture is characterised by large-scale commercial farming and small-scale/homestead farming mainly of subsistence nature (DEA, 2011). It is estimated that 1.5 million children in South Africa are malnourished, 14 million are likely to be food insecure and that 43 per cent of households suffer from food poverty (DEA, 2011). Given that an approximately 3 million primary food producers meet their family needs through subsistence farming,[4] this could be worsened by climate change.[5] Small-scale farming is mainly practiced in rural areas. It is estimated that 70 per cent of the poorest households live in these rural areas of South Africa and remain food self-reliant through small-scale farming. These small-scale farmers are particularly vulnerable to climatic variability due to limited capital to invest in mitigation strategies (Schulze, 2010; DEA, 2011). To date one of the government's major concerns is 'food security and the environment – climate change risk of increased hunger' (DEA, 2011) and this continues to remain amongst the national policy concerns (Schulze, 2010).

According to our literature review, few studies have assessed the impacts of climate change on agriculture in South Africa. Gbetibouo and Hassan (2005) undertook a study of seven field crops (maize, wheat, sorghum, sugarcane, groundnut, sunflower and soybean) and found that both seasons and location were important in determining the potential impacts of climate change on crop production in South Africa. As with many other studies, they found that increases in temperature had a negative effect while increases in precipitation had a positive effect on net revenue. They further showed that irrigation presented a viable form of adaptation in the face of climate change to the extent that the negative impacts of climate change can be harnessed to achieve positive changes in net revenue. The potential to use this as an adaptive mechanism would be limited, however. Deressa *et al*. (2005) used the Ricardian model to assess the impact of climate change on net revenue of sugarcane farmers in South Africa. They found that climate change would negatively affect the revenues of these farmers. They also observed that irrigation was not an effective mitigation strategy among these sugarcane farmers. In addition, the comprehensive eleven African countries

[4] Subsistence farming forms a livelihood strategy where the main output is consumed directly, where there are few if any purchased inputs and where only a minor proportion of output is marketed.

[5] Not only will climate change affect food security for South Africa but also the Southern African region because the country is a net exporter of food. For instance, South Africa produces 50 per cent of maize (the main staple) in the Southern African Development Community (SADC) region (Kurukulasuriya and Rosenthal, 2003; Durand, 2006). Adverse effects of climate variability and extreme weather conditions in South Africa could therefore destabilize the whole region.

GEF research by Kurukulasuriya and Mendelsohn (2006), Kurukulasuriya *et al*. (2006) and Seo *et al*. (2009) previously mentioned also included South Africa. In another study, Benhin (2008) assessed the impact of climate change on 416 crop farmers, while controlling for livestock and mixed farming practices in South Africa. The findings indicated that dryland farming is more vulnerable than irrigated farming. In addition the results show that small-scale farmers are much more affected by climate change than large-scale farmers. The study by Nhemachena *et al*. (2010) was a regional study that included three Southern Africa countries - South Africa, Zambia and Zimbabwe using the GEF data. In this study it was observed that crop farming was more sensitive to warming than mixed crop-livestock farming.

Given the existence of these studies, we see the current study as complementary research to the existing literature as we continue to provide further evidence of the impact of climate change on poor households that participate in agriculture to supplement household food and income requirements. As already noted, in the current study we follow from Nhemachena *et al*. (2010) who simultaneously assessed the impact of climate change among 121 South African farmers along with 833 Zambian and 377 Zimbabwean farmers. Using the GEF data, their assessment used separate Ricardian regressions for specialised crop farmers and mixed crop-livestock farmers only because of insufficient observations on specialised livestock farmers among the Southern Africa sample. We expand the analysis to a countrywide sample of 1,121 poor farming household using the 2008 National Income Dynamics Study and separate our Ricardian analysis by specialised crop, livestock and mixed farmers. Going a step further we use an objective and subjective outcome measure which includes net farm revenue and self-reported household food adequacy, the latter being a broader measure that captures household's food availability in general, while the former is more reflective of household income and food generated from farming activities. Our presupposition that self-reported food adequacy is likely to be directly affected by farming activity and therefore by climate change is based on the following two key observations. First, our dataset reveals that 58 per cent of crop production and 27 per cent of livestock products are retained for household's own consumption. Second, we obtain a positive and significant correlation between net farm revenue and the self-reported food adequacy measure. The findings from this study, which complements previous Ricardian models, will provide policy makers with the necessary additional scientific evidence to evoke the needed policy changes.

Table A1: *Descriptive statistics*

Variable	Mean	Std. Dev.
All farmers		
Net Revenue	367.39	3,425.00
Type of soil	4.9	3
Average precipitation - yearly	60.5	10.1
Average precipitation - winter	27.9	7.0
Average precipitation - summer	93.2	16.4
Average temperature- yearly	17.4	0.9
Average temperature - winter	14.3	1.2
Average temperature - summer	20.4	0.8
Mixed crop-livestock farmers		
Net Revenue	413.81	3,832.92
Type of soil	5.1	3
Average precipitation - yearly	62.1	10.1
Average precipitation - winter	29.2	7.2
Average precipitation - summer	94.9	16.1
Average temperature - yearly	17.5	0.7
Average temperature - winter	14.5	1.0
Average temperature - summer	20.4	0.7
Crop farmers		
Net Revenue	97.15	684.80
Type of soil	4.5	3
Average precipitation - yearly	61.2	10.6
Average precipitation - winter	27.5	7.7
Average precipitation - summer	94.8	16.8
Average temperature - yearly	17.6	1.0
Average temperature - winter	14.5	1.3
Average temperature - summer	20.6	0.9
Livestock farmers		
Net Revenue	677.21	4,788.53
Type of soil	5.3	2
Average precipitation - yearly	57.9	8.8
Average precipitation - winter	26.5	4.7
Average precipitation - summer	89.4	15.3
Average temperature - yearly	17.0	0.9
Average temperature - winter	13.9	1.1
Average temperature - summer	20.1	0.8

Table A2: *Distribution of total gross revenue by household needs*

Type of farming activity	Percentage of total gross revenue
Crops	
Crops sold	30.1
Crops given away as gift	12.0
Crops retained for own consumption	57.8
Livestock	
Livestock sold	48.9
Livestock given away as gift	24.3
Livestock retained for own consumption	26.7

Table A3: *Correlation between food adequacy and agriculture revenue*

Type of Revenue	Polychoric rho
Household income per capita (including revenue from agriculture)	0.21416039***
	(0.03620008)
Agriculture revenue	0.07855172*
	(0.03629089)
Agriculture revenue from retained crop farming	0.08411777*
	(0.04155679)
Agriculture revenue from sale of crop farming	0.04673899
	(0.07003469)
Agriculture revenue given as gift from crop farming	0.05359972
	(0.05778999)
Agriculture revenue from retained livestock farming	-0.03415902
	(0.06351433)
Agriculture revenue from sale of livestock farming	0.03810544
	(0.0585823)
Agriculture revenue given as gift from livestock farming	-0.01428345
	(0.10347726)

Notes:
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.
All income/revenue variables have been changed to quartiles.
The correlation analysis is based on the total sample size of 1128.

Table A4: *Ricardian regressions using OLS and OPROBIT*

	OLS				OPROBIT			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable: Food Adequacy	All Farmers	Mixed Farmers	Crop Farmers	Livestock Farmers	All Farmers	Mixed Farmers	Crop Farmers	Livestock Farmers
Precipitation- winter	-0.00122	-0.0727	0.00524	-0.0248	-0.0118	-0.155	0.00468	-0.0922
	(0.0246)	(0.0462)	(0.0492)	(0.0607)	(0.0492)	(0.0959)	(0.105)	(0.130)
Precipitation - winter^2	-0.000300	0.00108	-0.000279	-8.80e-05	-0.000449	0.00236	-0.000234	0.000339
	(0.000352)	(0.000715)	(0.000697)	(0.000897)	(0.000700)	(0.00148)	(0.00150)	(0.00186)
Precipitation - summer	-0.0332**	0.0387	-0.000112	-0.0614**	-0.0636**	0.0848	0.00733	-0.134**
	(0.0145)	(0.0354)	(0.0315)	(0.0263)	(0.0286)	(0.0735)	(0.0671)	(0.0552)
Precipitation - summer^2	0.000224***	-0.000153	1.80e-05	0.000422***	0.000433***	-0.000340	-2.03e-05	0.000917***
	(8.05e-05)	(0.000191)	(0.000177)	(0.000152)	(0.000159)	(0.000396)	(0.000378)	(0.000322)
Temperature- winter	-0.224	1.151	-2.317**	1.364	-0.262	2.560	-5.109***	3.263
	(0.527)	(1.118)	(0.919)	(1.391)	(1.051)	(2.332)	(1.900)	(3.032)
Temperature- winter^2	0.00831	-0.0447	0.0854***	-0.0472	0.0101	-0.100	0.187***	-0.113
	(0.0189)	(0.0391)	(0.0330)	(0.0500)	(0.0380)	(0.0819)	(0.0678)	(0.110)
Temperature- summer	0.264	-6.864*	12.72***	3.842	-0.624	-16.81**	30.14***	7.356
	(1.675)	(3.501)	(3.299)	(6.352)	(3.464)	(7.639)	(7.600)	(14.67)
Temperature- summer^2	-0.00724	0.174**	-0.313***	-0.101	0.0137	0.425**	-0.737***	-0.196
	(0.0416)	(0.0867)	(0.0814)	(0.160)	(0.0861)	(0.189)	(0.186)	(0.369)
Constant	3.091	63.45*	-110.2***	-41.00				
	(15.55)	(33.42)	(31.17)	(66.33)				
cut1 constant					-13.32	-156.5	270.1***	83.59
					(32.21)	(253.5)	(72.36)	(151.7)
cut2 constant					-11.80	-154.8	271.5***	85.28
					(32.21)	(253.5)	(72.37)	(151.7)
Soil type dummy	Y	Y	Y	Y	Y	Y	Y	Y
Land type dummy	Y	Y	Y	Y	Y	Y	Y	Y
Province dummy	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,127	408	397	305	1,127	408	397	305
R-squared	0.213	0.316	0.244	0.259				

Table A5: *Marginal effects and elasticity of food adequacy*

		Marginal effects Winter	Elasticity	Marginal effects Summer	Elasticity
All farmers	*Precipitation*	-0.02	-0.0014	0.01	0.0022
		(0.0079274)		(0 .0025972)	
	Temperature	0.01	0.0005	-0.03	-0.0018
		(0.055066)		(0 .0633649)	
Mixed crop-livestock farmers	*Precipitation*	-0.01	-0.0007	0.01	0.0022
		(0.0116027)		(0.0048365)	
	Temperature	-0.14	-0.0050	0.24	0.0121
		(0.0941591)		(0.1219103)	
Crop Farmers	*Precipitation*	-0.01	-0.0029	0.005	0.0032
		(0.0178674)		(0 .0053681)	
	Temperature	0.17	0.0250	-0.19	-0.0404
		(0.1115287)		(0.1434942)	
Livestock Farmers	*Precipitation*	-0.029	-0.0012	0.014	0.0019
		(0.0203759)		(0.0055042)	
	Temperature	0.056	0.0011	-0.21	-0.0062
		(0.1130482)		(0.132143)	

Notes:
Based on an increase in temperature and a decrease in precipitation.
The predictions are based on the regression models 1-4 in table A4.

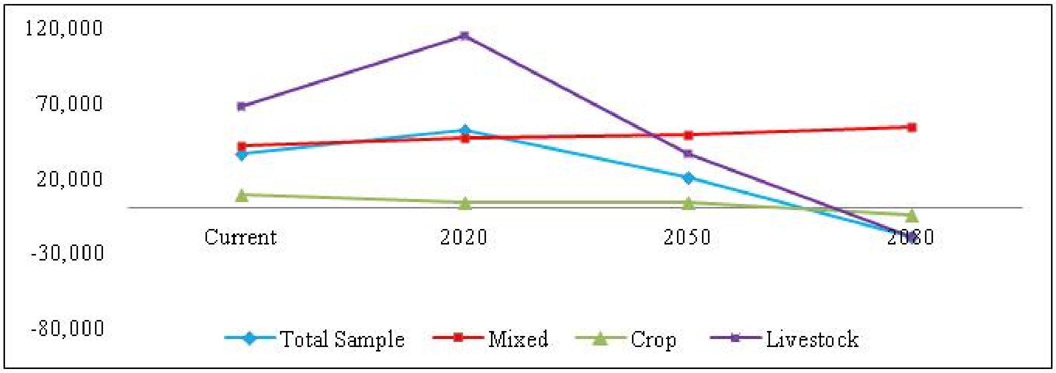

Figure A1: *Change in net revenue as a result of decrease in precipitation and increase temperature*

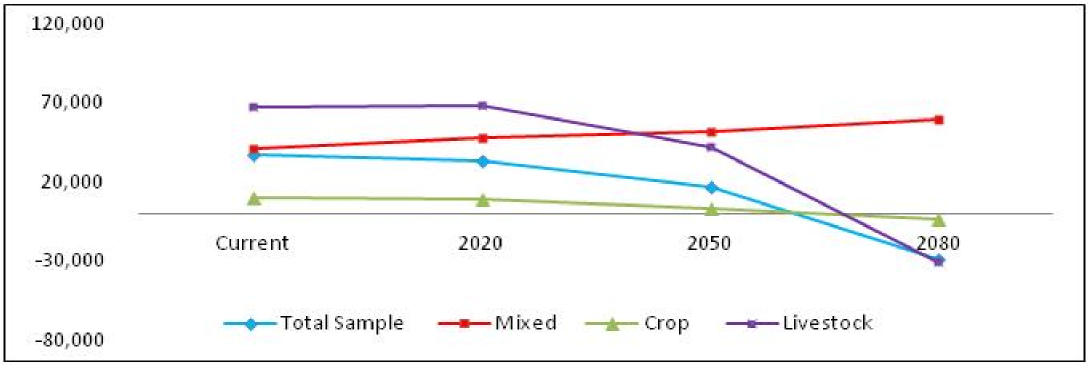

Figure A2: *Change in net revenue as a result of increase in temperature*

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