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Effects of Climate Variability and Change on Agricultural Production: The Case of Small-scale Farmers in Kenya

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Policy Brief

SUMMARY

Agriculture is the mainstay of the Kenyan economy and remains an important contributor to employment and food security of rural populations. Climate variability and change have adversely affected this sector and is expected to worsen in the future. We estimate the effect of climate variability and change on crop production and on maize and tea separately. Findings show that crop revenue including that from tea and maize are significantly affected by persistent climate variability and change. However, long-term effects of climate change on crop yields are larger than short-term effects, thus farmers need to adapt effectively to reduce the latter effects and build their resilience. Temperature has negative effect on crop and maize revenues but positive one on tea revenue while rainfall has negative effect on tea incomes. Tea production in sensitive to rainfall and temperature but doesn't for all crops combined and maize. Climate change will adversely affect agriculture in 2020, 2030 and 2040 with greater effects in tea sector if nothing is done. Therefore, rethinking about the likely harmful effects of rising temperature and increasing rainfall uncertainty should be a priority in Kenya. It is important to invest in adaptation measures at national, county and farm level as well as implementing policies that prevent destruction of the natural environment in order to address the challenges posed by climate change.

BACKGROUND

Climate change has significantly affected global agriculture in the 21st century and the Intergovernmental Panel on Climate Change (IPCC) assessment report indicates that most countries will experience an increase in average temperature, more frequent heat waves, stressed water resources, desertification, and periods of heavy precipitation (IPCC, 2014). In Kenya, agriculture continues to be the mainstay of the economy with an estimated GDP share of 27 per cent (ROK, 2015) making it an important contributor to employment and food security of rural households. Climatic variability and change directly affect agricultural production and food security given that most of the population in Kenya live in the rural areas and relies on agriculture for their livelihoods. For example, since the early 1990s, Kenya has been affected by the droughts of 1991-2, 1992-3, 1995-6, 1998-2000 and 2004, the El-Niño rains that resulted into floods of 1997-1998 and the drought of 2008-9. Climate change directly impacts on agricultural incomes as Kenya relies on rain-fed crop production. The effect will be worse due to the fact that there is still limited investment on irrigation since out of total land under agricultural production only about 1.5 percent is irrigated (NIB, 2014). In response to the challenges posed by climate change and variability, the government has put in place a National Climate Change Response Strategy (NCCRS) and in January, 2014 launched the Galana Kulalu food security project in Tana River area in the Coastal region. Mixed results have been reported on the impact of climate change on food production in Kenya with some reporting positive and others negative effects which vary by region. Farmers have been adopting different adaptation measures in terms of micro-level farm adaptations, market responses, new technological developments and institutional changes to reduce extreme adverse effects of climate variability and change. With the declining crop output for example maize declined by 4.2 percent in 2014 (ROK, 2015) and dwindling tea sector, there is need to understand whether climate variability and change has some role. To do this, we use Tegemeo Agricultural Policy Research and Analysis (TAPRA) 2000-2010 panel data set, which takes into account changes in household incomes, rainfall and temperature across both space and time, and thus enabling the assessment of any variability across these key indicators over time.

OBJECTIVES

The objective of this policy brief is to analyze the effect of climate change and variability on all crops grown by farmers, maize and tea production. Disaggregation by crop types sheds more light on the effects of climate variability and change on maize which is an important staple crop and tea, the leading foreign exchange earner contributing about 20% of the total foreign exchange earnings in Kenya.

DATA AND METHODS

We use a balanced four rounds household data (2000, 2004, 2007 and 2010) comprising of 1,243 households across ecological zones in Kenya. The panel data had been collected through rural household surveys covering 24 administrative districts, 39 divisions and 120 villages using structured questionnaires. The data collected over the years is quite broad, covering several aspects of household livelihoods including crop yields, input use and revenues. The data contains other socio-economic variables such as gender, education level of household head and asset endowment used as controls.

This study relies on the climate data (rainfall and temperature) from Kenya Metrological Services (KMS) weather stations across the country. The data obtained from KMS include temperature (0^C) and rainfall (mm) from 1980 to 2010 for different regions in Kenya. We use temperature and rainfall for respective data collection years and their long term values. Finally the relationship between the production and climate variables is estimated using fixed effect model.

KEY FINDINGS

Climate trends 2000-2010

The results show that over the last 10 years (from 2000 to 2010), Kenya has experienced relatively constant temperatures (minimal variations) with the maximum values ranging from 24.8 0^C in Central highlands to 30.3 0^C in Coastal lowlands. While rainfall shows an increasing trend between 1980 and 2010 and also across different agro-ecological zones. The lowest amount of rainfall was received between 2000 and 2005 (119mm and 127mm monthly respectively). Kenya experienced heavy rainfall around 1997-1998 of 200 mm due to *Elnino* rains followed by a sharp decline in the subsequent years up to 2009 and then a sharp rise in 2010 (206mm).

Smallholder crop revenue (2000-2010)

The income from all crops increased from Ksh 40,806 in 2000 to 70, 777 per acre in 2010 at nominal price. A similar increasing trend is observed in maize and tea sectors (Table 1). Tea and maize revenue grew by 98% and 75% respectively between the year 2000 and 2010. Agricultural revenues from all crops, maize and tea in the country also declined in 2004. RoK, (2005) indicates that maize production declined by 15 per cent in 2003 to 23.8 million bags in 2004. The decline in tea production in the same year is attributed to adverse weather conditions that led to frost attack in some tea growing regions while the sharp increase in 2007 and 2010 is partly due to better prices for maize and tea (RoK, 2013).

Table 1: Average crop, maize and tea revenue by year

Years	Crop revenue *(Ksh/acre)*	Maize revenue *(Ksh/acre)*	Tea revenue *(Ksh/acre)*
2000	40806.9	13117.1	83950.4
2004	33147.7	12105.9	65904.9
2007	48052.1	11503.5	99155.2
2010	70776.7	19456.3	165883.4
Pooled sample	23046.4	23145.3	103806.7

Note: Crops- Include revenue from all crops grown by farm household.

Effect of climate variability and change on production

To assess the effect of climate change on agricultural production, we estimated fixed effects model for crop, maize and tea revenues. Findings show that the coefficients associated with the temperature are much larger than those of rainfall, confirming the previous findings that contribution of temperature to global warming is much more important than rainfall in Kenya. Long-term effects of climate change (in relation to temperature) on crop production are larger than short-term effects, an indication that farmers need to adapt effectively to reduce extreme effects of weather variability.

The interaction term between rainfall and temperature have a negative and significant correlation with crop and maize revenues implying that there is an effect without a strong interaction between rainfall and temperature (Table 2). On the other hand, climate effect on tea exhibit strong positive interaction between rainfall and temperature because tea production significantly depends on stable temperatures and consistent rainfall patterns. High temperature causes drying of the soils resulting to limited water content available for tea, decrease yields and negative impacts on quality while low temperature causes severe frost leading to scorching of tea plant to death.

We also controlled for household fixed effects by adding socio economic variables on crop, tea and maize revenue regression. The results show that education, land owned, increase in use of chemical fertilizers and agricultural assets has a significant role in improving agricultural revenues. Agricultural assets are significantly important for attaining higher crop and maize revenues and being closer to fertilizer shop and motorable road significantly helps farmers to reduce transaction costs and increase crop incomes.

Predicted effect of climate change

Projections from KMS data indicate that annual rainfall will increase by 11.2%, 26.3% and 29.8% in 2020, 2030 and 2040, respectively-which are similar to predictions by CIAT (2011). Based on previous studies that temperature in Kenya is likely to increase between 1^0C to 2.5^0C on average (CIAT 2011), we assumed that the annual temperature will increase by 1^0C in 2020 and 2^0C and 2.5^0C in 2030 and 2040, respectively. Simulation results in Table 3 show that increasing rainfall will have positive significant effect on crop revenue but will negatively affect tea revenue by 2020, 2030 and 2040. Holding all other factors constant, an increase in rainfall by 26% in 2030 and 30% in 2040 would significantly decrease tea revenue by 6% and 9%, respectively (Table 3). Tea as a crop is very sensitive to both rainfall and temperature and any excess would negatively affect production patterns.

Table 2: Effect of climate change parameter estimates

Variables	Crop revenue		Tea Revenue		Maize revenue	
Rainfall	0.007***	(0.001)	-0.0223***	(0.005)	0.0043***	(0.001)
Rainfall sq.	-0.000***	(0.000)	0.0001***	(0.000)	-0.000***	(0.000)
Long term rainfall	0.033	(0.085)	-0.1277	(0.290)	0.0905	(0.098)
Long term rainfall sq.	0.0002	(0.000)	0.0006	(0.001)	0.0000	(0.000)
Mean temperatures	-0.5740***	(0.160)	1.0372**	(0.505)	0.0411	(0.208)
Mean temperatures sq.	0.0164***	(0.004)	-0.0249*	(0.015)	0.0031	(0.005)
Long term mean temperature	-8.2395***	(2.493)	8.8997*	(4.730)	-9.800***	(3.232)
Long term mean temperature sq.	0.1525**	(0.062)	-0.1536	(0.124)	0.2858***	(0.078)
Rainfall*temperature	-0.0055	(0.003)	0.0008	(0.011)	-0.0060	(0.004)
Household FE	Yes		Yes		Yes	
Yearly FE	Yes		Yes		Yes	

Notes: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Household FE comprise of socioeconomic characteristics not presented here.

Table 3: Predicted effect of climate change on agricultural production

Year	Increase level (%/ ^{0}C)	Climate variable	Rainfall and temperature increase effect (in %)		
			Crop revenue	Maize revenue	Tea revenue
2020	11%	Rainfall	0.8	0.6	-2.5
	1^{0}C	Temperature	-14.2	1.1	2.3
2030	26%	Rainfall	0.9	1.2	-5.5
	2 ^{0}C	Temperature	-14.8	2.2	2.4
2040	30%	Rainfall	1.0	1.9	-8.8
	2.5^{0}C	Temperature	-15.2	3.3	2.5

Source: Author's estimates

CONCLUSION

Based on the analysis, we find that climate change has potential to significantly affect small-scale farmers' livelihoods by either decreasing or increasing the farm revenues. Temperature has negative effect on crop and maize revenues but positive one on tea while rainfall has negative effect on tea incomes. Long-term effects of climate change on crop production are larger than short-term effects. Findings also show that temperature as a contributor to global warming is much more important than rainfall in Kenya. Climate change effect on tea production strongly depends on stable rainfall and temperature but does not for all crops and maize. Thus crop production and also tea as the main foreign exchange earner in Kenya will be adversely affected by climate variability and change if nothing is done.

RECOMMENDATIONS

There is need to rethink about the likely harmful effect of climate variability and change in the future and integrate it into agricultural and environmental policy formulation processes. Much effort should be made in consolidating and implementing policies particularly those that prevent destruction of natural environment and ensure that crop insurance as a risk coping mechanism has a solid framework to enhance its uptake by farmers. Given that the human activities are the major drivers of climate change; it is necessary to invest in adaptation measures at national, county and farm level especially in the tea growing regions as a way of building farmers' resilience. In this regard, farmers should adopt an integrated approach comprising of adaptation measures.

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