The 2015-16 El Niño-induced drought crisis in Southern Africa

LESSONS FROM HISTORICAL DATA AND POLICY IMPLICATIONS

AGRA
Growing Africa's Agriculture

Correct citation: John Herbert Ainembabazi, Joseph Rusike and Boaz Keizire (2018). The 2015-16 El Niño-induced drought crisis in Southern Africa: Lessons from Historical Data and Policy Implications

Alliance for a Green Revolution in Africa (AGRA), West End Towers, 4th Floor, Kanjata Road, off Muthangari Drive, Off Waiyaki Way, PO Box 66773, Westlands 00800, Nairobi, Kenya.

The 2015-16 El Niño-induced drought crisis in Southern Africa:

Lessons from Historical Data and Policy Implications

John Herbert Ainembabazi, Joseph Rusike and Boaz Keizire

March 2018

ABSTRACT

Food crop production declined by up to 66% in various Southern African countries as a result of the El Niño induced drought during the 2015-2016 cropping seasons, leading to the emergence of a food crisis throughout the region. This paper analyses the current drought impacts and their links to historical droughts in order to draw lessons for building sustainable resilience mechanisms. The analysis uses both national and household level data. Evidence shows that up to the early 1990s, drought shocks in Southern Africa were less frequent. During this period, the yields for major crops were generally low and stagnant. However, at the beginning of the early 2000s the frequency of drought occurrence increased considerably. There was a corresponding increase in yields of roots, tubers and vegetables in some countries, while yields for cereals and pulses remained more or less stagnant. Findings further show that in countries where there are considerable increases in yields of either roots, tubers or vegetables, there is a substantial decline in the prevalence of undernourishment and food inadequacy. Overall, the promotion of non-traditional high value crops emerges as one of the key policy implications for resilience-improving interventions and food security improvements.

1 Introduction

During the 2015-2016 agricultural season, El Niño weather patterns resulted in a late start to planting and low and erratic rainfall throughout Southern Africa[1]. This resulted in higher-than-normal temperatures and a longer drought season than in the past 35 years across Angola, Botswana, Lesotho, Malawi, Madagascar, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe (FAO, 2016a). Historically, droughts have always occurred and are projected to continue hitting farmers in the region. When drought shocks hit, they result in crop yield failure and water shortages which ultimately affect social and economic outcomes. Among the outcomes of El Niño-induced drought are unfavorable crop growing conditions, reduced yields, crop failure and a decline in local food and agricultural production (Benson and Clay, 1994). This has a knock-on effect, driving households into food and nutrition insecurity, which in turn results in draining national food reserves leading to high food imports, rising prices and exacerbating the unemployment rates.

In response to these adverse impacts, farm households and national governments with support from development and technical partners seek both reactive and proactive solutions. Reactive solutions come in form of food aid and/or assistance as a short-term measure, while proactive solutions involve building resilience mechanisms at household, food system and national levels. The resilience mechanisms include development and/or deployment of adaptation and mitigation technologies such as developing productivity improving technologies, and formulating relevant policies to create an enabling environment for sustainable and smart resilient mechanisms (Fan et al., 2014). Despite these efforts to build resilience, the impact of climatic shocks has worsened over time and it is expected to become much more disastrous in the future. This is because immediate responses to such shocks are often reactive rather than proactive (Fan et al., 2014). Reactive responses provide short-term solutions of escaping hunger but not building resilience for the future. There is growing evidence that reactive solutions, especially unconditional transfers of food assistance, do not promote the adoption of sustainable and adaptive technologies (Adimassu and Kessler, 2015; Alem and Broussard, 2016). Robust and sustainable resilient solutions are urgently needed. This paper contributes to identifying some of these solutions at two levels: country and household levels respectively.

At country level, the paper assess how current drought impacts are linked to historical droughts in order to suggest conditions for building strong and sustainable resilience solutions. We use national level data from 11 Southern African countries to analyze how drought occurrence is associated with food security, crop productivity and country resilience capacity. At household level, we investigate how household resilience capacity-building affects food security and the indicators that constitute food security. Growing literature underscores food security (nutrition) as an input to and an outcome of resilience (Dufour et al., 2014; FAO, 2014), and empirical evidence emphasizes that the stronger the resilience capacity the farm household has, the lower the likelihood of having malnourished children in such a household (d'Errico and Pietrelli, 2017). The latter evidence underlines the linear correlation between malnutrition and resilience. However, the literature remains unclear about how resilience-building shapes food security and the mechanisms (pathways) through which food security is attained. Essentially, as farm households embark on building or strengthening their resilience, there is a possibility of trading-off consumption smoothing in the short-run for long-term investment in resilience building. That this, the household is likely to forego some level of consumption in order to invest in building resilience implying a decline in food security, but as the household attains strong resilience capacity, food security improves and so does consumption. This paper tests the hypothesis that there is a non-linear relationship between resilience capacity and food security. Similar relationships exist with indicators that constitute food security.

The rest of the paper is organized as follows: The next section, Section Two, reports the impacts of recent drought in Southern African countries. This is followed by Section Three with a climate change framework that provides a theoretical and conceptual foundation of climate change and its possible impact. Section Four presents analytical strategy. Section Five reports results at national level, while Section Six reports results at household level. Section Seven concludes with policy implications.

[1] El Niño is a climate cycle in the Pacific Ocean with a global impact on weather patterns. The cycle begins when warm water in the western tropical Pacific Ocean shifts eastward along the equator toward the coast of South America. www.livescience.com/3650-el-nino.html

2 Effects of El Niño-induced drought in Southern Africa

2.1 Crop production failure and food deficit

The immediate impact of drought in Southern Africa was crop failure. Low yields of major food staples such as maize were often observed, leading to food insecurity and economic stresses especially among smallholder farmers whose livelihoods depend on rain-fed agriculture. Due to data limitations, the results reported below focus on maize production. Maize is the main staple food crop throughout the Southern African countries, supplying more than 50 percent of calories in the diet. Maize production is therefore, a major source of livelihood and a determinant of vulnerability and resilience. The crop is also a wage good in urban areas. Thus, achieving household and national food security is equivalent to achieving maize self-sufficiency.

Figure 1 reports the effect of drought on maize production and compares changes in maize production during the drought hit cropping seasons of 2014/15 and 2015/16. The upper panel of Figure 1 reports average maize production of five cropping seasons preceding the drought period (2014/15 – 2015/16). Even before the occurrence of drought, poor maize production was observed in Botswana, Lesotho, Namibia and Swaziland. Correspondingly, these countries registered major reductions in maize production following the occurrence of drought especially in the 2015/16 cropping season. Botswana reported the highest reduction in maize production (78%) followed by Lesotho (67%), Swaziland (63%) and Zimbabwe (56%). With the exception of Mozambique, all other Southern African countries experienced reduction in maize production following the occurrence of El Niño-induced drought. The impact is greater in the 2015/16 cropping season than the 2014/15 season.

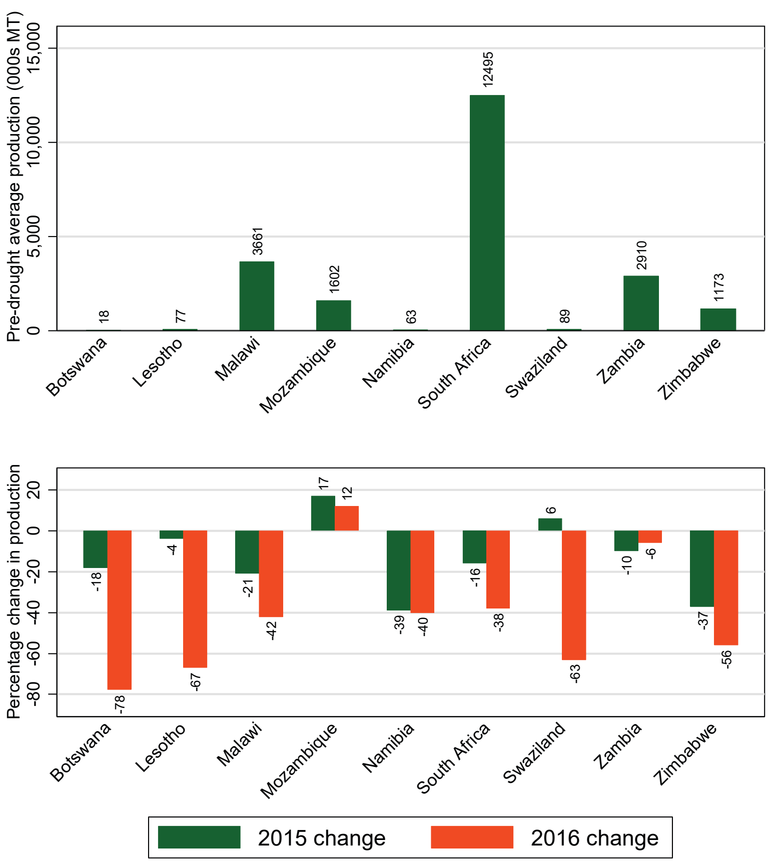
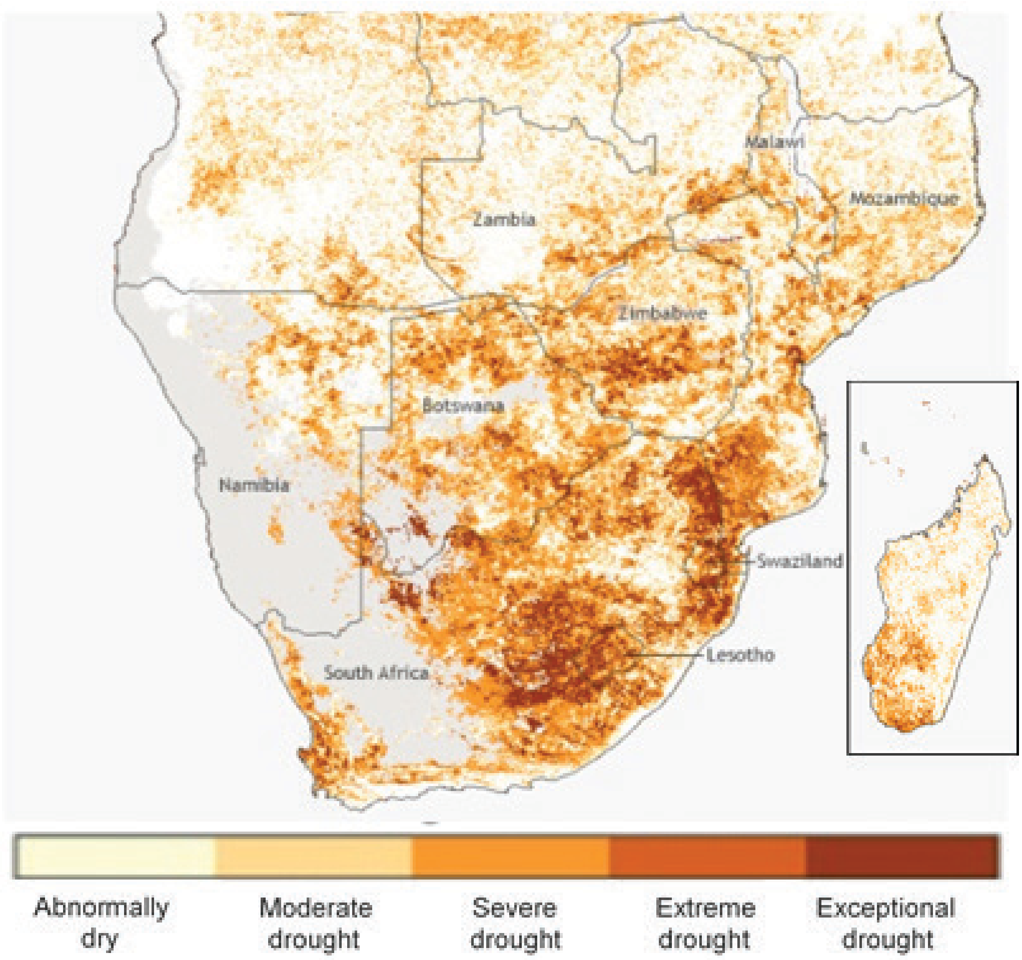


Figure 1. **Maize production in 2014/15 and 2015/16 cropping seasons compared to pre-drought seasons**

(source of data: Various online reports from: http://www.wfp.org/countries, accessed October, 2016)

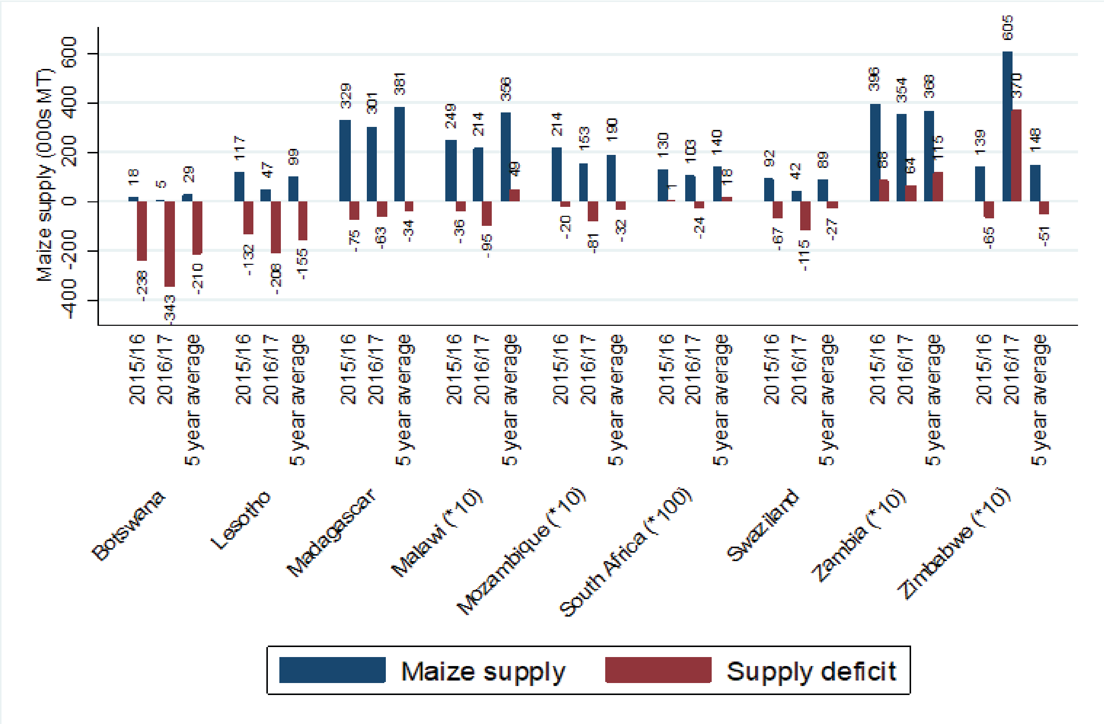
As a consequence of what is reported in Figure 1, Figure 2 illustrates the market-related impacts of drought during 2016-2017 on the domestic supply of maize, requirements (deficit) and self-sufficiency ratios. With the exception of Zambia, all countries had a national maize deficit in the 2016-2017 marketing year. Possibly, this is because a large part of Zambia did not experience extreme drought (Map 1) and it is farther north towards the equator. Also as indicated in Figure 1, Zambia registered a low reduction in maize production in the 2015/16 cropping season. As shown in Map 1, most of the countries in Southern Africa experienced severe to extreme drought episodes that resulted in reduced crop plantings and yields, causing shortfalls in food production in the face of growing demand. Consequently, countries experienced large production deficits leading to reduced options for in-country food supply and increased demand for food imports. This resulted in high maize prices above the five-year average; escalating by 17% to 30% in Lesotho, 156% in Malawi, 177% in Mozambique, 22% in South Africa, 66% in Swaziland, 35% in Zambia and 29% in Zimbabwe[2].



Map 1: **The 2015/2016 Southern Africa Drought**

(Source: OCHA, 2016)

[2] Beyond immediate and easily observable impacts, the El Niño-induced drought led to unfavorable behavior of some of the economic indicators such as loss of on- and off-farm employment, high food and input prices among others, all necessary for a thriving rural economy. In its assessment to determine the availability of seeds and other inputs in the formal agricultural input system in the drought-affected countries, FAO found that significant gaps exist for seed of staple food crops in Lesotho, Madagascar, Malawi, and Mozambique, while Zambia and Zimbabwe have maize seed surpluses (USAID, 2016).



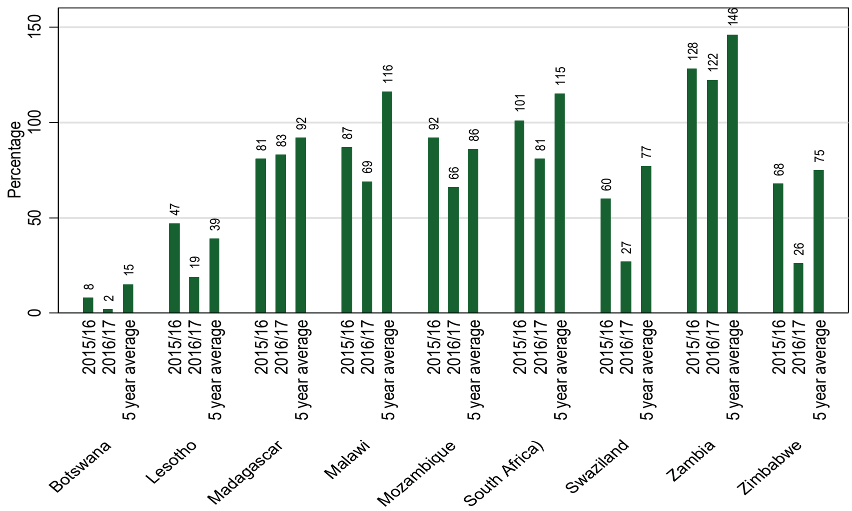


Figure 2: **Impact of drought on maize supply projections for marketing year 2016-2017**

(source of data: Various reports from: http://www.fews.net/ and http://www.wfp.org/countries, accessed October, 2016).

*Note: For countries with (*10) and (*100) means that values are multiplied by 10 and 100, respectively. For example, Malawi had 249,000 MT of maize supply and 360,000 MT of supply deficit in 2015/16 cropping season.*

2.2 People affected and food insecurity

According to information available in various online reports from the WFP website and the Southern African Development Community report (SADC, 2016), the overall impact of the 2015-16 droughts in Southern Africa showed that at least 18 million people were worst-hit by drought. About 7 million of these were targeted for assistance by WFP, and by end of September 2016, only 1.7 million people had received food assistance (Figure 3, left panel). However, due to data limitations, it was difficult to estimate the number of people receiving assistance from government disaster programs and other non-governmental organizations (NGOs). The combined impacts of drought caused severe food insecurity and hunger in

Southern Africa, but to a varying degree across countries. By end of September 2016, more than a half of the national population (58%) in Swaziland was experiencing food insecurity resulting from drought impacts, as well as 38% in Malawi, 34% in Lesotho and 29% in Zimbabwe (Figure 3, right panel).

From the results reported in Figures 1 and 2, it is apparent that some of the countries recording poor production and low levels of food self-sufficiency had a large of share of their population affected by drought. At the same time, countries that had relatively high food production and self-sufficiency levels - *Malawi* and *Zimbabwe* - had a large share of their population also affected by drought. Whereas countries like Madagascar, Mozambique and Zambia that were moderately food self-sufficient had a small proportion of their populations affected by drought. Given that drought hit the Southern Africa countries at the same time and to a large extent with the same intensity, the observed variation in the number of people affected suggests that countries have varying degrees of resilience to climate change and related shocks. This implies that there are opportunities to be exploited in order to absorb climate change shocks in the future. The following section explains how variations in resilience emerges, while the section further below reports empirical evidence from a historical perspective.

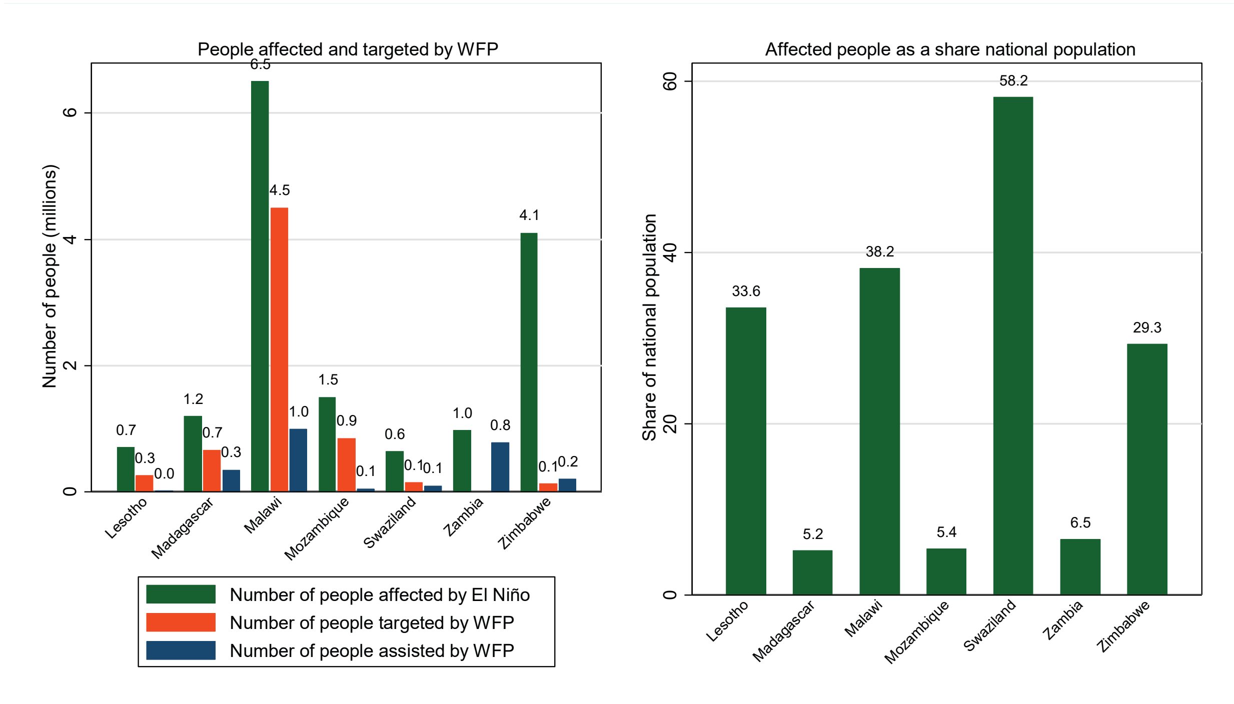


Figure 3. **The extent of impact of drought on Southern population and food assistance.**

(Source of data: Various reports from: http://www.wfp.org/countries*, accessed October, 2016)*

3 Climate change framework for analysis

There is an increasing frequency and intensity of drought and extreme weather events in Southern Africa (IPCC, 2013), particularly due to climate change. Therefore, the impact of drought and lessons learned of experiences to build resilience to future shocks and stresses are best understood in a framework for analyzing climatic change and the role of agriculture to mitigate and adapt to climate change and climate variability. Most climate models predict decreases in annual precipitation for Southern Africa by as much as 20% by the 2080s (Conway et. al., 2015). Impact models suggest that these changes are responsible for increased temperatures and reduced rainfall and moisture in certain areas and excess rainfall in other areas during critical stages of crop growth and livestock production. This reduces crop harvests and pasture availability resulting in food insecurity. Climate change further increases the prevalence and incidence of invasive pathogens and species in the form of insects, plant and animal diseases (Armbruster, 2008).

The impact of climatic change on smallholder households is adverse, and since they derive their livelihoods from staple food production, including the consumption of their own produced food, an El Niño-induced drought has a direct impact on household consumption gaps. At the local level, smallholder households meet their food requirements through purchases from markets thus food deficits at local and national levels increases the likelihood of food imports. When food prices increase due to of lack of supply of locally grown food and the presence of imported food, households are denied access to nutritious food. In these circumstances, they respond by expanding existing livelihood strategies. These include the sale of labor to off-farm activity markets, engagement in petty trade, extraction of forest products and involvement in artisan activities. However, income levels from these activities are lower than normal due to the reduced demand for labor. This reduces household capacity to meet its consumption needs and leads to failure to purchase agricultural inputs required for subsequent planting seasons - resulting in low incomes and inability to build sustainable resilience mechanisms necessary for coping with climate change shocks.

Relief assistance for households becomes necessary in order for them to meet their consumption gaps, in addition to receiving social protection to build resilience for future drought and other related shocks. In agriculture, resilience is achieved mostly through building capacity to adapt to the changing conditions. As a result of institutional inertia, there is a need to learn from the experiences of ongoing responses to the current situation in order to identify practical and effective opportunities in order to build the resilience against future shocks.

Following Hoddinott (2014), Figure 4 maps food security outcome levels for six different countries (or households) during three different periods: the pre-shock period represented by orange squares, the shock period represented by dark gray hexagons, and the recovery period represented by the green disks. The horizontal lines represent the range within which a country can operate to absorb a shock given its resource endowments. During the pre-shock period, countries to the right (A, C, E and F) of the minimum food security indicator score (FSI) are food secure, while B and D are food insecure. Given the range of FSI values, only country F is not vulnerable to becoming food insecure in the event that a shock occurs. In the event that the shock occurs, causing the initial food security values to shift to the left to a new position (the dark gray hexagon), all countries, with the exception of F, become food insecure.

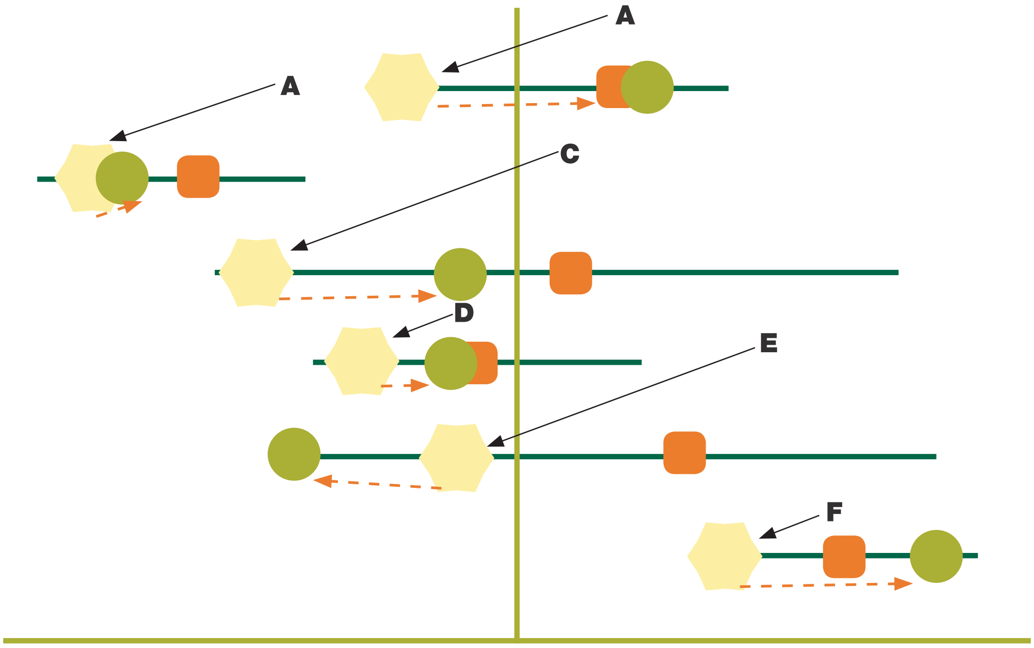


Figure 4. **Food security outcomes for countries following drought occurrence**
(Adapted from Hoddinott, 2014)

However, differences in the magnitude of shifts reveal the intensity of the shock and countries' readiness to absorb the shock. The country's readiness is not only necessary during the shock period, but also in the aftermath. During the recovery period, only countries A and F are fully resilient because they are able to recover and return to their pre-shock or even higher levels of food security. Country D is partially resilient, but due to limited capacity the food security levels remain below the minimum FSI. Countries B and C are partially resilient, while country E is non-resilient. This theoretical framework reflects the picture painted in Figures 1 through 3 and forms the basis for the analytical framework in Section 4. The analysis assesses the resilience of the countries to drought shocks in order to identify the opportunities for building household resilience, production as well as national systems.

4 Analytical strategy

The variation in the impact of drought across countries discussed in Section 2 is in part explained by the countries' resilience capacity to absorb drought shocks. However, quantitative measurement of reliance capacity is a challenge because resilience is a dynamic, multidimensional and unobservable variable (Levin et al., 1998; Batabyal, 2003; Barrett et al., 2014). There are, nonetheless, attempts to measure resilience indicators as unobserved variables as explained below. We measure resilience and assess its variation over time at the country level analysis complemented by household level analysis.

4.1 Country level assessment

The country level assessment uses simple descriptive and rolling window regression analyses. Descriptive analysis uses historical data on crop yields and food security indicators to assess the variation in trends associated with past occurrence of drought shocks. Food security was measured using the prevalence of undernourishment and food inadequacy. According to the statistics division of the Food and Agriculture Organization (FAO, http://faostat3.fao.org, accessed October, 2016) the prevalence of undernourishment expresses the probability that an individual from the population that consumes an amount of calories that is insufficient to cover her/his energy requirement for an active and healthy life. This is the traditional FAO hunger indicator. Whereas the prevalence of food inadequacy measures the percentage of the population that is at risk of not covering the food requirements including those who, even though cannot be considered chronically undernourished, are likely being conditioned in their economic activity by insufficient food.

To estimate a country's resilience to drought shocks, the standard deviation (SD) of prevalence of undernourishment and food inadequacy-based rolling regression is used (Zivot and Wang, 2006). Pace et al. (2017) used the same indicator to measure the resilience of ecosystems to early warning. The rolling regression has the ability to compute the resilience indicator for each regression. The computed resilience indicator is then plotted over time along with 95% confidence interval band to assess its changes associated with occurrence of droughts. The question of interest, however, is how a set of country specific factors are related to its resilience capacity. This question is presented in the form of a general equation as:

$$Resilience_{ct} = ð + wCtryfact_{ct} + e_{ct} \qquad (1)$$

where Resilience_{ct} denotes resilience capacity at time t of country c, is the intercept, *ð* is a vector of slope coefficients, *Ctryfact* denotes a vector of country specific factors, and e_{ct} is the error term. To estimate equation (1), we use ordinary least squares with panel corrected standard errors (OLS-PCSE), which controls for the contemporaneous correlation of the errors and perforce heteroschedasticity (Beck and Katz, 1995).

4.2 Household level assessment

To complement the country level analysis and test the robustness of findings obtained at country level, we also measure resilience at farm household level. For this level, we utilize the framework for modeling resilience as an unobservable variable based on observable characteristics (Alinovi et al., 2008 and 2010; FAO 2016). This framework assumes that in anticipation or presence of shock occurrence household resilience capacity building is th function of wellbeing indicators including: access to basic services (ABS), assets (AS), social safety nets (SSN) and adaptive capacity (AC):

$$RC_{it} = f(\mathbf{ABS}_{it}, \mathbf{AS}_{it}, \mathbf{SSN}_{it}, \mathbf{AC}_{it}) + \Sigma_{it} \qquad (2)$$

where RC_{it} is the household resilience capacity of household i time t, Σ_{it} is the unobserved error and the rest of the elements are as defined above.

The framework estimates resilience capacity as an index generated as an aggregate of elements in equation (2) in a two-step procedure. The first step estimates the resilience elements as separate variables through factor analysis from an observed set of variables. The variables used to estimate each element in equation (2) are listed below. The second step utilizes the structural equation model (SEM) (Acock, 2013) to predict the latent household resilience using the predicted elements from the first step. The details of

[2] Beyond immediate and easily observable impacts, the El Niño-induced drought led to unfavorable behavior of some of the economic indicators such as loss of on- and off-farm employment, high food and input prices among others, all necessary for a thriving rural economy. In its assessment to determine the availability of seeds and other inputs in the formal agricultural input system in the drought-affected countries, FAO found that significant gaps exist for seed of staple food crops in Lesotho, Madagascar, Malawi, and Mozambique, while Zambia and Zimbabwe have maize seed surpluses (USAID, 2016).

this estimation procedure and discussion of its advantages and disadvantages can be found in d'Errico and Pietrelli (2017) and d'Errico and Di Giuseppe (2018). For easy interpretation, the household resilience capacity index (RCI) value is transformed into a standardized index, ranging between 0 (minimum RCI) and 1 (maximum RCI), using a min-max scaling approach (FAO, 2016) as $RCI_i^{*} = (RCI - RCI_{min}) / (RCImax - RCI_{min})$.

In this paper, the following variables were considered in factor analysis to predict each element in equation (2). ABS includes distances (km) from community to the nearest bus stop, daily market, weekly market, public telephone, primary school, secondary school, drug shop, clinic; and number of months of inadequate food supply in at least past 1.5 years preceding the survey. AS comprises of number of different farm related assets; value (Malawian Kwacha (MK)) of transport related assets (bicycles, cars and motor cycles); value of communication related assets (radio, television, computer, phones, among others) (MK); value of other assets (furniture, generator, and so on) (MK); number of household members employed in off-farm activities; household owns a house (dummy); household size; tropical livestock units[3]; area of land operated (hectares); and remittances (cash and in-kind) received from children (MK). The components of SSN include: distances (km) from community to the nearest commercial bank and micro-finance; amount of credit received in past 12 months (MK) preceding the survey; accumulated number of months a household received assistance in past 12 months preceding the survey; free maize distribution (kg); free food distribution other than maize (MK); food or cash assistance for work (MK); direct cash transfer from government or non-governmental organization (MK); income from savings, pension investments and rentals; amount of scholarships (MK); cash or food or non-food transfers from individuals other than household members; and frequency of development project introduction in 5 years before and since 2010. Finally, AC is comprised of: household used own savings in response to shock (dummy); household received unconditional help from government, relatives and friends (dummy); household changed eating habits (dummy); household engaged (more) in off-farm work in response to shock (dummy); household members migrated or sent children somewhere in response to shock (dummy); household reduced expenditure on health/education in response to shock (dummy); household obtained credit in response to shock (dummy); household sold assets, land, crop and livestock in response to shock (dummy); number of different crops grown; number of different income generating activities; dependence ratio (number of household members aged up to 15 years plus those aged above 65 years divided by the number of members aged above 15 years up to 65 years); education of household head (years in school) and education of spouse (years in school).

4.2.1 Identification procedure

Our aim is to identify the correlation between food security, its indicators and household resilience capacity. The indicators of food security considered are crop productivity and adoption of crop productivity-improving practices. As aforementioned, food security is an input to and an output of resilience. This implies that direct estimation of food security and its indicators on resilience may yield biased estimates due to endogeneity problems. To control for the potential endogeneity bias in estimation of outcomes of interest (food security and its indicators) associated with the inclusion of RCI as a regressor, we use the control function approach (Papke and Wooldridge, 2008) in a two-step procedure. The first step regresses RCI on exclusion restriction variables and other covariates as shown below.

$$RCI_{itv} = HX_{ivt}\beta_h + VX_{it}\beta_v + \beta_r R_{it} + \sum_{it} \qquad (3)$$

Where RCI_{itv} is the RCI for household i living in village v at time t. HX_{ivt} and VX_{it} are vectors of household and community level characteristics, respectively. R_{it} is exclusion restriction variable. $\beta_h \beta_v \beta_r$ are parameters to be estimated and $\sum_{it}$ is the error term.

We use as an exclusion restriction for RCI at community level, the community's ability to prioritize its needs before taking action or mobilizing resources (dummy). The community's ability to identify and prioritize investments for overcoming pressing communal needs creates an enabling environment that prepares community members for any covariate shocks, but such investments may not have a direct effect on food security of individual households except through an enabling environment. We estimate equation (3) using pooled ordinary least squares. Although the exclusion restriction variable might be weak, the falsification test (Pizer, 2016) showed that the restriction had significant correlation with RCI, but not food security and its indicators. Table A1 reports first stage estimates. In the second stage, food security and its indicators () are estimated with the residuals generated from first stage as an additional covariate as follows:

[3] Tropical livestock units were generated using weights adapted from Njuki et al. (2011).

$$FI_{itv} = \alpha_{rci} RCI_{ivt} + HX_{ivt}\alpha_h + VX_{ivt}\alpha_V + \rho_\Sigma \Sigma_{it} + E_{it} \quad (4)$$

Where α_{rci} α_h ρ_Σ are parameters to be estimated, Σ_{it} is the residuals variable estimated from first stage, E_{it} is the error term. The rest of the terms are as defined above.

The test for endogeneity is obtained as a t-test on residuals generated from the first step. A significant coefficient on the residuals () suggests the presence of endogeneity, otherwise RCI is considered exogenous and the first step estimation is ignored. In presence of endogeneity, standard errors are corrected for the first step estimation by bootstrapping (Wooldridge, 2010).

We estimate equation (4) using two specifications: panel data models and weighted least squares model. The selection of the specifications is based on the variation of the outcome variables over time. We utilize the random effects model to determine how the variation in food security, crop productivity, amount of inorganic fertilizer use, and amount of organic manure use are correlated with RCI in the presence of adverse shocks. Random effects estimation is preferred to fixed effects model because of the limited variation within clusters and slow changing variables over time (Wooldridge 2010) in our sample data. In the same line, we use the random effects logit to estimate binary decision of adopting soil and water conservation practices. The weighted least squares (WLS) estimation is used to examine how past resilience capacity varies with food security and its indicators. The WLS is particularly useful when running a model that includes a large number of dummy variables (Wooldridge, 2010), which is a case in our data. A probit model was used to estimate binary decision of adopting soil and water conservation practices.

4.3 The Data

The country level data used in analysis is from available online databases of the World Bank (2016), FAOSTAT (2016) and Center for Research on Epidemiology of Disasters (2016). The variables obtained at country level included crop yields, prevalence of undernourishment and food inadequacy, occurrence of drought shocks, and other variables are reported in Figure 9. The household data were also obtained from publicly available online data of the World Bank (http://microdata.worldbank.org) under the umbrella of the Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA). We use household data collected from farmers in Malawi. The World Bank conducted several panel farm household surveys in Malawi. We use the panel household data for 2010 and 2013. The LSMS-ISA has rich household level information that we exploit to construct household level Resilience Capacity Index (RCI) as a measure of resilience to climate change and Food Self-Sufficiency Ratio (FSSR) as a measure of food security. The FSSR was estimated as the total energy available in on-farm produce divided by total energy requirements for the household (Rufino et al., 2013). FSSR greater than one means that the households has a surplus of energy from on-farm production. Table A2 reports descriptive statistics of key household and community level characteristics.

5 Historical assessment results: National level analysis

5.1 Crop yields over time and drought occurrence

Results in Figure 5 show that generally up to the early 1990s, drought shocks in Southern Africa were less frequent. The frequency of occurrence increased considerably in the early 2000s. Across all countries under study, yields for cereals and pulses are generally low and stagnant over time averaging below 1 metric ton per hectare. Although there are observable drops in yields of cereals and pulses following drought shocks in some countries like Lesotho, Malawi, Mozambique and Swaziland, the other countries maintained stable and low yield levels over the years.

The trends in yields of roots and tubers and vegetables are notably variable. Up to the early 1990s, the yields of roots and tubers and vegetables were generally stagnant across the Southern African countries, but increasing trends are observable from the early 2000s. As noted above, drought shocks were less frequent up to early 1990s and more frequent starting from the early 2000s. This suggests that farmers tend to focus on producing more drought tolerant crops like cassava and early maturing crops like vegetables as an adaptation strategy to drought shocks. As evidenced in the graphs, the recovery period for roots and tubers and vegetables following drought shocks is one year, with the aftermath yields exceeding the pre-shock yield levels.

The preceding discussion points to policy implications. In Southern Africa, maize is a major crop for research and development and most public sector interventions such as input subsidy programs have always targeted mainly maize as a crop. As aforementioned, maize supplies more 50% of calories in household diets and is a source of income for many smallholder farmers in the region. However, experience shows that most public sector interventions have tended to focus less on roots and tubers and vegetables yet, according to results reported in Figure 5, it is apparent that these crops have become an adaptation strategy to drought shocks. These observations and in-country experiences call for a need to promote diversification of crop mix along with the development of high yielding, drought tolerant and early maturing varieties to withstand drought and related shocks and stresses.

We test the robustness of the preceding findings using household level analysis. As indicated in the Section 4, we use farm household data from Malawi. Figure 6 reports non-parametric relationships between the share contributed to total household food self-sufficiency by different food crop categories and the household resilience capacity. The contribution of different food crop categories to total household food self-sufficiency is measured as the share of FSSR contributed by a particular food crop category.

The household level findings support the national level findings that when households are drought- hit, they invest in producing more roots and tubers that are fairly drought tolerant as they build or strengthen their resilient capacity. Correspondingly, during early stages of resilience-building or strengthening, households tend to rely more on roots and tubers and less on cereals for food self-sufficiency. However, as households gain strong resilience capacity, the contribution of roots and tubers to household food self-sufficiency reduces, while it increases for cereals and so is the corresponding reduction and increase in investment in production of these crops.

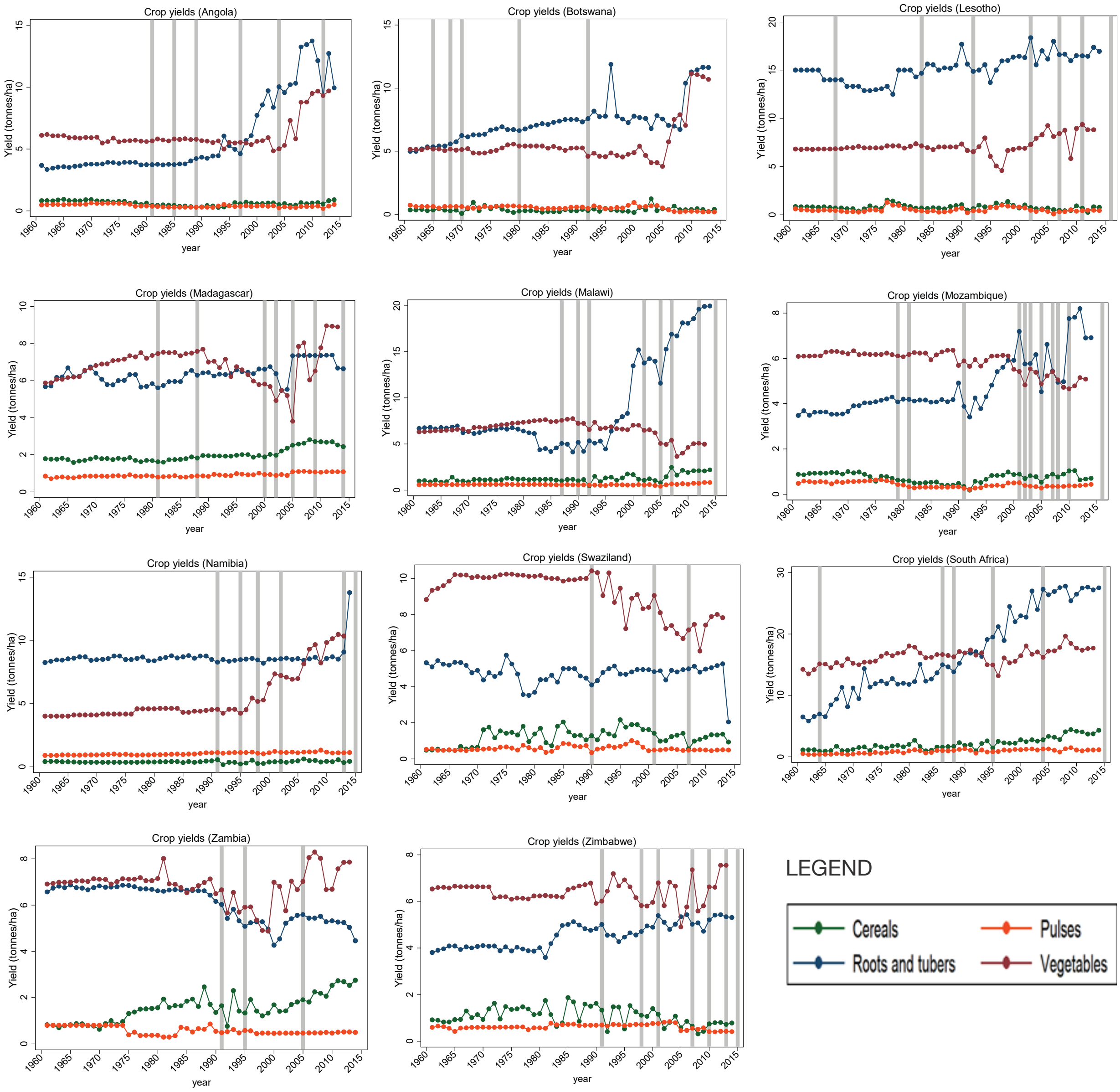


Figure 5. **Drought occurrence and crop yield trends**

Figure 6 further shows that when a household is drought hit in two consecutive periods, the contribution of cereals to food self-sufficiency, generally, declines as the household strengthens its resilience capacity. Somewhat similar results are observed when a household is not drought hit in either period. However, when a household is drought hit in only one period, it exhibits an inverse relationship between the share contributed by cereals to the food self-sufficiency and household resilience capacity. That is, when the household is drought hit in one period, the contribution of cereals to food self-sufficiency first declines to a certain level before increasing as the household builds its resilience capacity. Irrespective of whether the household experienced drought shock or not, there is a consistent inverted U-shaped relationship between the share contributed by roots and tubers to food self-sufficiency and household resilience capacity. A fairly comparable relationship is observed between the contribution of pulses to food self-sufficiency and household resilience capacity when a household is drought hit in one period. The contribution of vegetables to food self-sufficiency during resilience building is not definite.

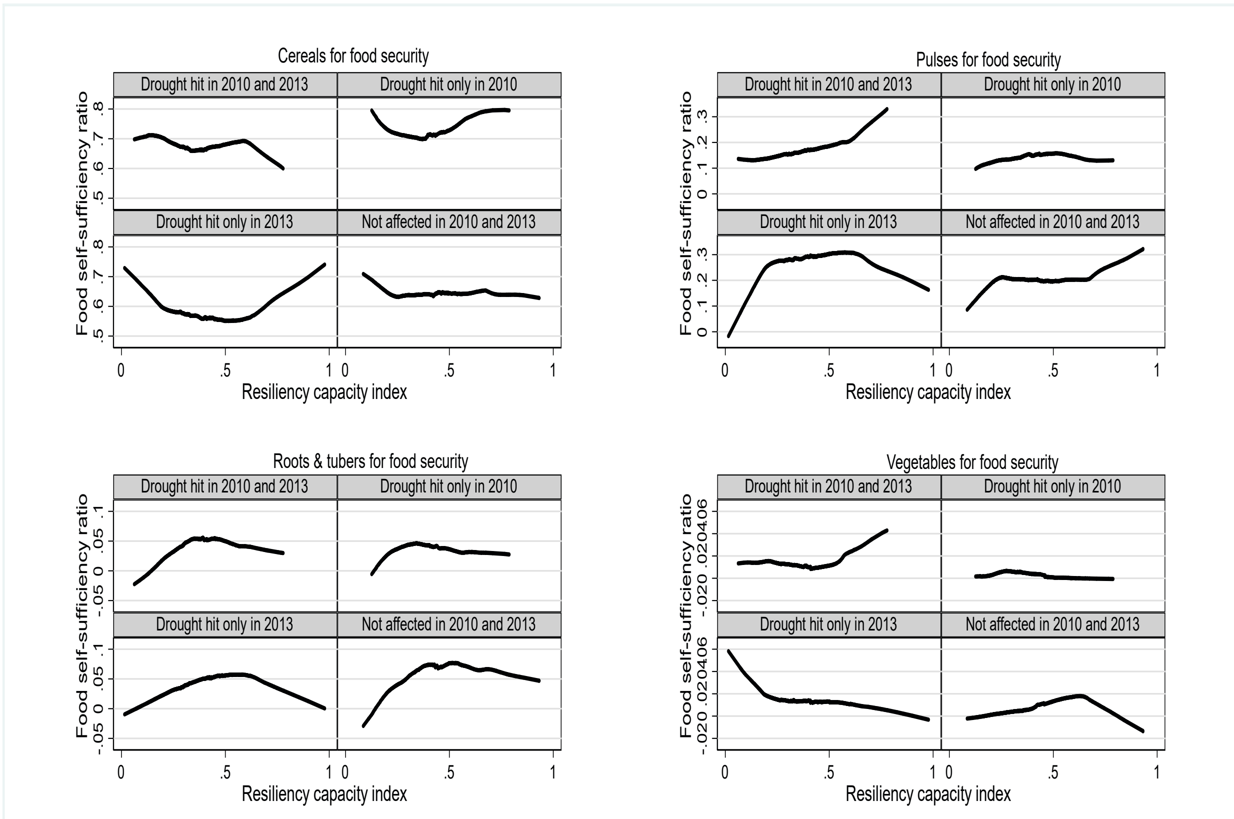


Figure 6. **The contribution of crop categories to food self-sufficiency and resilience**

5.2 Food security and drought occurrence

Food security measurement is a complex and multidimensional concept and it is difficult to report strong correlations with a single variable. With this caveat in mind, the interpretation of results below should be considered with care.

Table 1. **Correlation coefficients between undernourishment scores and crop yields**

Country	Cereals	Pulses	Roots & tubers	Vegetable
Angola	-0.595**	0.154	-0.905***	-0.813***
Botswana	0.219	0.510**	-0.482**	-0.419**
Lesotho	0.555**	0.483**	-0.709***	-0.754***
Madagascar	-0.010	-0.116	-0.268	-0.580**
Malawi	-0.635***	-0.562**	-0.962***	0.731***
Mozambique	-0.555**	-0.421**	-0.803***	0.701***
Namibia	-0.295	-0.285	0.307	-0.140
Swaziland	0.187	0.137	-0.154	-0.125
South Africa	-0.371*	-0.170	-0.333	-0.643**
Zambia	0.603**	-0.401**	-0.109	0.713***
Zimbabwe	0.492**	0.826***	-0.689***	-0.214

*Note: ***, ** and * denote statistical significance at 1%, 5% and 10% respectively. Data source: FAO, 2016.*

Results in Figure 7 show the prevalence of undernourishment and food inadequacy had been declining over time in some countries and increasing in other countries. On the one hand, in countries like Lesotho, Madagascar, Malawi, Namibia and Swaziland there is a noticeable increase in the prevalence of food insecurity following the occurrence of drought shocks. On the other hand, there is evidence that in countries where there are considerable increases in yields of either roots and tubers or vegetables, there is a substantial decline in the prevalence of undernourishment and food inadequacy. To understand this correlation more intuitively, consider the yield curves in Figure 7 and correlations in Table 1 for Malawi and Mozambique. In these two countries, there are strong and negative correlations between prevalence of undernourishment and yield levels of roots and tubers - 96% for Malawi and 80% for Mozambique (Table 1). Correspondingly, there are significant and positive correlations between prevalence of undernourishment and yield levels of vegetables, 73% and 70%. Turning to Figure 7, it is apparent that in both Malawi and Mozambique, between 2000 and 2010 there was high frequency of droughts and the yields of roots and tubers - albeit fluctuating - exhibited a positive trend, while the yields of vegetables were declining. These findings give an indication of how non-priority crops - in this case roots and tubers and vegetables compared to maize which is commonly prioritized in a number of Southern African countries - can be a successful adaptation strategy in the event that a climate change shock occurs. Reconsidering and reprioritizing non-traditional high value crops (activities) can form successful strategies for resilience and policy implications.

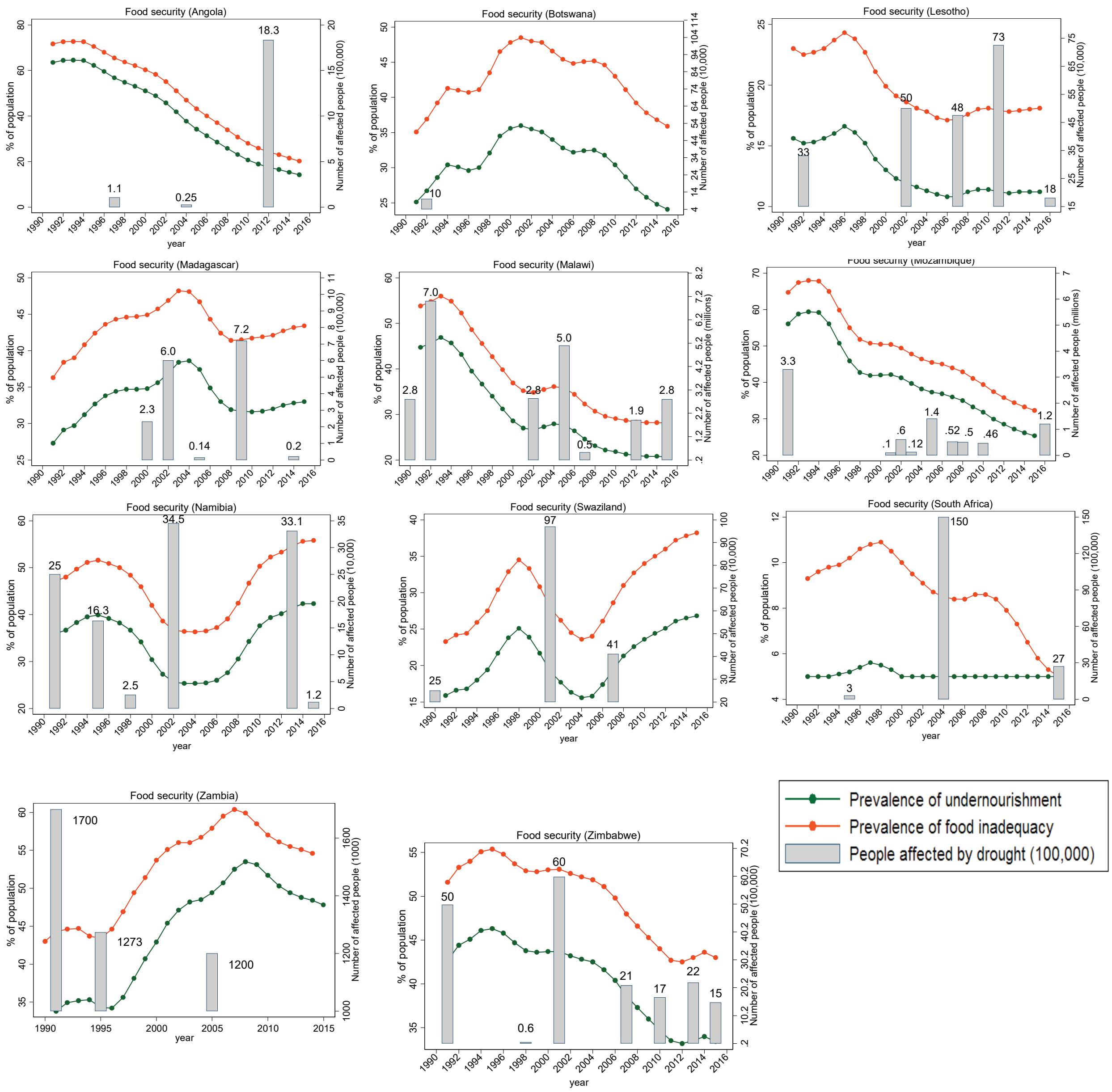


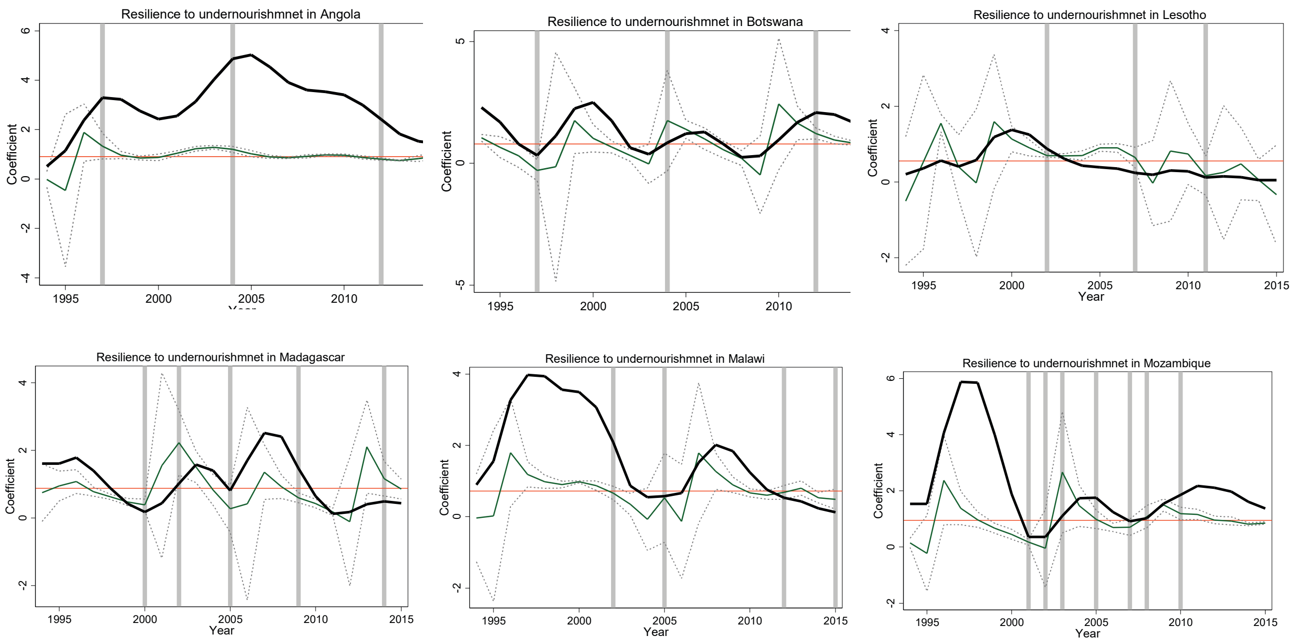
Figure 7. **Drought occurrence and trends of food security indicators**

5.3 Resilience to drought occurrence in Southern Africa

Building resilience is a dynamic process. Therefore, important insights into understanding resilience can be reflected from long-run data spanning a number of periods of drought shocks and subsequent variation in food security indicators. As such, countries (or households) that have in place strong mechanisms to absorb shocks, after being exposed to a drought shock, such countries (or households) are expected to experience inconsequential declines in food security and recover relatively in a short time. Conversely, countries (or households) that have weak mechanisms for overcoming drought shocks experience large declines in their food security levels and recover relatively slowly over time. That is, weak mechanisms may not enable countries to fully recover from one drought shock and a subsequent shock will move them onto a worsening trajectory, while countries with strong resilience mechanisms will follow a positive trajectory. We test this hypothetical scenario using both national and household level analytical approaches highlighted in section 4.

5.3.1 National food security resilience and drought occurrence

Figure 8 reports resilience trends over time and the possible association with drought occurrence. The following should be noted about the interpretation of resilience curves. First, the prevalence of undernourishment and food inadequacy remains high and increasing in Madagascar, Namibia and Swaziland, while it is high but declining in Angola, Botswana, Lesotho, Malawi, Mozambique, Zambia and Zimbabwe (Figure 7). For South Africa, the prevalence food insecurity is below 5% of its population in recent years. It is therefore difficult to set a reference for prevalence below which to consider a country as being food secure. The ideal reference prevalence would be zero, but all countries apart from South Africa, are far from zero prevalence. We use the average of persistence coefficient for each country over time as the reference line, plotted as a horizontal red line. The country is considered to be recovering from the shock if the resilience curve is falling towards (and below) the reference line. Second, the resilience curve is plotted as a green curve with its confidence band plotted as dotted lines. To provide an intuitive interpretation of the persistence coefficient, we also plotted a 4-year rolling standard deviations. Rolling standard deviations are often used to measure price volatility in business cycles research studies (IMF, 2007). Third, a country that is resilient to drought shocks should have the resilience curve oscillating closely to the reference line, narrow peaks and troughs with short amplitudes, and a narrow confidence band. Fourth, the thick gray vertical lines represent years in which drought shocks occurred.



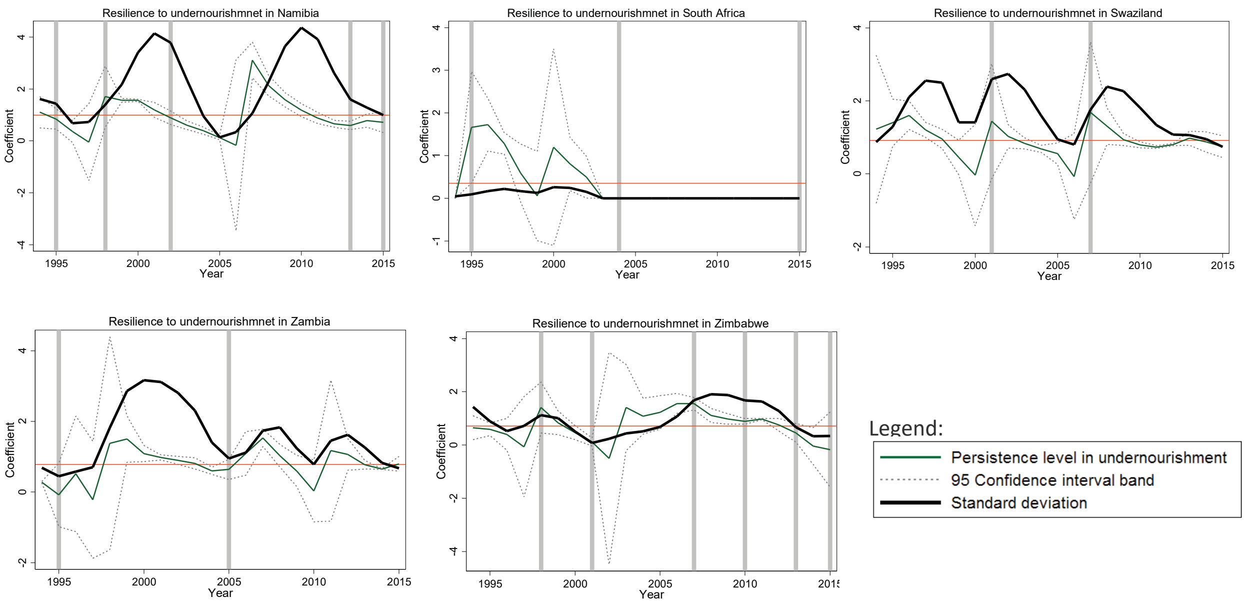


Figure 8. **Drought occurrence and trends of food security resilience.**

Note: we only report results for resilience to undernourishment and not food inadequacy. Results for food inadequacy are practically similar as the prevalence levels of undernourishment and not food inadequacy are highly correlated (see Figure 7). Rolling estimates and the 95% confidence interval of the resilience parameter for countries 1995 – 2015. Window size 4 years.

The persistent coefficient curves measured using a 4-year rolling window regression follow a similar pattern of a 4-year rolling standard deviation curves (Figure 8). This shows the validity of our choice of persistent coefficients as a reasonable measure of resilience. The resilience pattern over time varies considerably across countries suggesting greater heterogeneity in their coping mechanisms. For instance, the resilience curves for Madagascar, Malawi, Namibia and Swaziland show much higher upturn in the wake of the drought shocks, spanning more than 5 years in some cases to recover from the shock. Conversely, the resilience curves for Lesotho and South Africa portray a remarkable recovery ability following drought shocks.

Applying the theoretical picture reflected in Figure 4, South Africa and Lesotho would be considered to qualify for full resilience (F position), because they were able to recover and return to their pre-shock levels of food security outcomes as indicated by small amplitudes of the oscillations around the mean and a shift towards zero value. Botswana and Swaziland are also resilient because they have short periods between the turning points in the plots of resilience to undernourishment, and they would qualify to be in position A. The other countries exhibit weak resilience because they are able to partially recover to their levels of food security as indicated by the moderate to high amplitudes of oscillations and relatively long periods between the turning points in the plots of resilience to undernourishment. The differences in resilience can be explained by differences among countries' ability to avail profitable climate smart technologies to smallholders. However, we are constrained by the lack of appropriate data to provide these explanations. We attempt to provide some explanations using national level data on some key economic indicators relevant for agricultural transformation as reported below.

5.3.2 Drivers of resilience to drought occurrence in Southern Africa

The time series regression approach is used to identify the drivers of resilience. The dependent variable is the 4-year rolling standard deviation. The rolling standard deviations are preferred to the rolling regression coefficients because the former are easy to interpret in terms of their non-negative magnitude unlike the latter that can have both negative and positive coefficients. In addition to having limitations of accessing data on relevant variables, we were still faced with missing data for some variables. We use prevalence of undernourishment for regression analysis. There are missing data points for prevalence of food inadequacy that would significantly reduce the number of observations. The regression using prevalence of food inadequacy, however, would yield similar results to those obtained using prevalence of undernourishment since they are correlated. Figure 9 reports regression results of two models. Model 1 reports results with variables having less missing data points for some years. The estimates in this model are potentially biased due omitted variable bias. Model 2 reports results with variables having missing data for a number of years. The interpretation below is based model 2. Regression coefficients are reported with confidence intervals represented by black thick lines. A coefficient with a confidence interval band crossing the zero vertical line is insignificant. The regression results suggest the following as drivers of resilience.

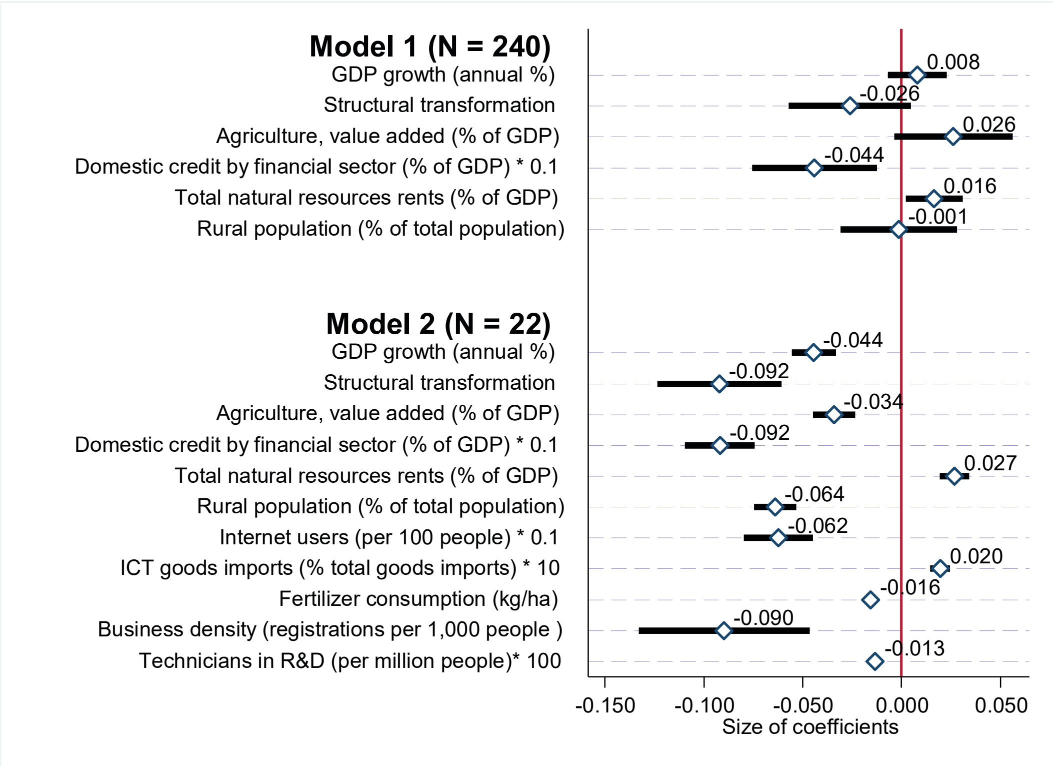


Figure 9. **Drivers of resilience in Southern Africa**

- High Gross Domestic Product (GDP) growth rate is associated with reduced volatility of prevalence of undernourishment. This implies that countries with high GDP growth rates are more resilient to drought shocks than those with low growth rates. Similarly, countries with high agricultural value-added GDP have the ability to build strong resilience to drought shocks.
- Higher levels of structural transformation correspond to lower levels of volatility of prevalence of undernourishment and hence strong resilience mechanisms. Structural transformation is ordinarily captured by the share of non-agricultural activity contributions to GDP. Here structural transformation was computed as the average of share of GDP contributed by services valued added and manufacturing value added GDP.
- Improving domestic credit provided by financial sector significantly strengthens the resilience of a country. This suggests that policies that incentivize financial institutions to provide more credit to private sector businesses can promote development and distribution of resilience-improving interventions.
- Increasing business density substantially coincides with strong resilience mechanisms. This is linked to credit provision mentioned above. Policies enabling financial institutions to provide credit to private sector encourage the development of new businesses. This in turn encourages expansion of these new business to rural areas, bringing services and inputs nearer to farmers to improve their adaptation strategies to climate change.
- Improving access to internet use reduces the prevalence of undernourishment but increasing the import of ICT goods relative to import of other goods worsens the prevalence of undernourishment. The latter finding is counterintuitive. One would have expected that availability of ICT solutions to

improve delivery of services to smallholders such as mobile marketing information systems.

- Promoting fertilizer use and increasing the number of technical personnel in Research and Development offer strong resilience to drought shocks. Using the ‘right’ fertilizer combined with ‘right’ technical knowledge provided by scientists and extension agents leads to high productivity levels during good cropping seasons that can provide buffer stocks against deficits during dry seasons.
- Countries profiting from natural resources, especially forests, are more likely to have weak resilience mechanisms to drought shocks. Deforestation and forest degradation activities have been proven to worsen climate change shocks.

To put drivers of resilience in perspective, in their to study using historical data to analyze the Integrated Agricultural System and Social Protection Strategies to Reduce Vulnerability to Climate Change in East Africa, the Alliance for a Green Revolution in Africa (AGRA) in collaboration with University of Georgia and the United States Department of Agriculture (USDA) found that smallholder households already incur high costs from exposure to droughts and variable rainfall (AGRA, 2016). These households employ integrated agricultural and non-agricultural resilience strategies to reduce the costs of rainfall variability. However, households are not able to completely buffer their welfare against drought shocks and hence require resilience building at country level, largely to provide an enabling environment that promotes the building of sustainable mechanisms.

6 Resilience and its effects: Household level analysis

This section presents household level analysis. The analysis involves a descriptive analysis to show household adaptation behavior following drought occurrence in two periods. Then non-parametric and parametric regressions are used to determine how resilience capacity of farm households shapes their food security, crop productivity performance and adoption of agricultural practices.

6.1 Drought occurrence and household behavioral association

Figure 10 shows that in general, farm households improve their resilience capacity building as time progresses regardless of whether the household experienced drought shock in the previous or current period. However, households that did not experience drought shocks in two consecutive periods have stronger resilience than those that experienced drought shock in either previous or current period, the difference is much larger when compared with households that experienced drought shocks in both periods. Similarly, the proportion of households using agricultural practices to strengthen their resilience capacity tends to increase with time. Particularly, a large share of households that experienced drought shocks in two consecutive periods appeared to adopt soil and water conservation (SWC) technologies much more than those that did or did not experience drought shocks in either period. In contrast, a small share (22%) of households hit by drought in both periods used inorganic fertilizer in 2010 but the share increased by 51 percentage points to 73% in the drought period of 2013. These findings support a priori expectation that households tend to strengthen their resilience mechanisms after being hit by a shock in anticipation of absorbing future shocks and that these mechanisms may consist of adoption of integrated practices including long-term practices such as SWC or short-term practices such as fertilizers.

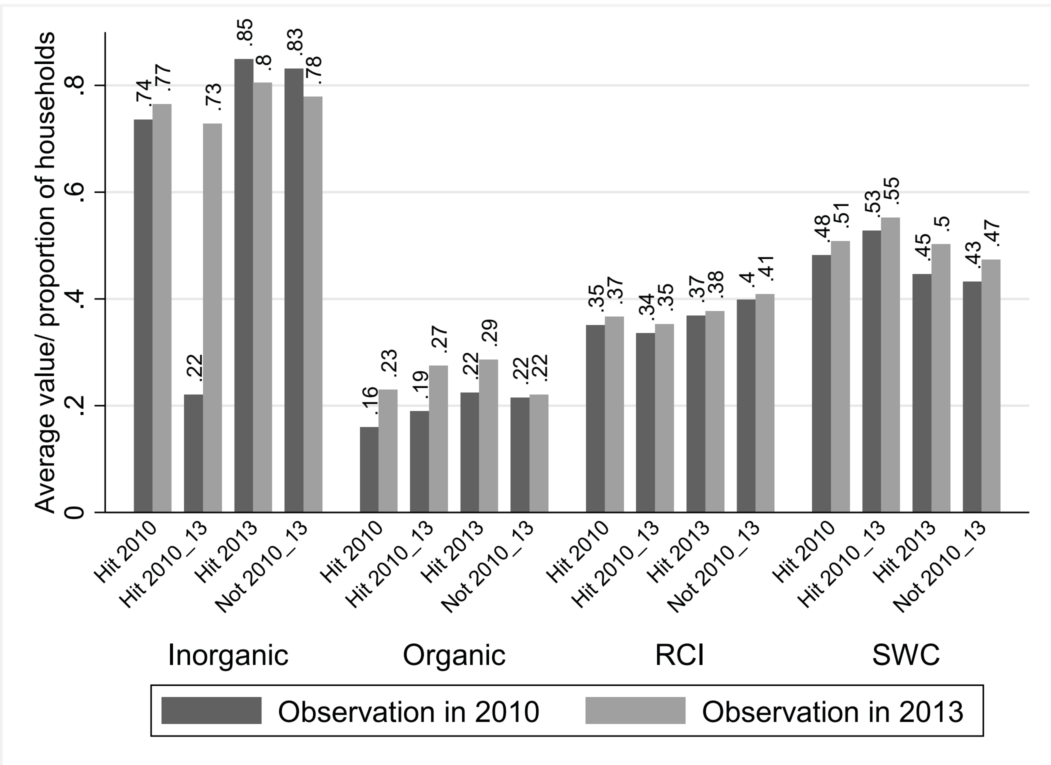


Figure 10. **The descriptive behavior of households that experienced drought in: 2010 only (Hit 2010), both 2010 and 2013 (HIT 2010_13), 2013 only (Hit 2013) and never experienced drought in both 2010 and 2013 (Not 2010_13). The y-axis reports average value for Resilience capacity index (RCI); and the proportion of households adopting inorganic fertilizer, organic manure and soil and water conservation (SWC).**

6.2 Effect of resilience on food security and crop productivity

Before reporting the main results, we first report results obtained using bivariate regression. We use non-parametric regression that allows household resilience capacity not to show a predetermined distributional form but how it is shaped according to information derived from the data. Figures 11 and 12 report the non-parametric estimates obtained using locally weighted regression of outcome variables of interest on the household resilience capacity. All Figures report how past and 'current' household resilience capacity varies with different outcome variables and whether some households experienced drought either in 2010 or 2013[4]. On the one hand, in general, the results show that past and current household resilience capacity has the same effect on food security, crop productivity and use of input or agricultural practices to improve productivity. This suggests that the household's ability to build resilience capacity matters much more than the time when to build resilience capacity. On the other hand, the results reveal a non-linear relationship between the outcome variables of interest - apart from fertilizer use - and the household resilience capacity.

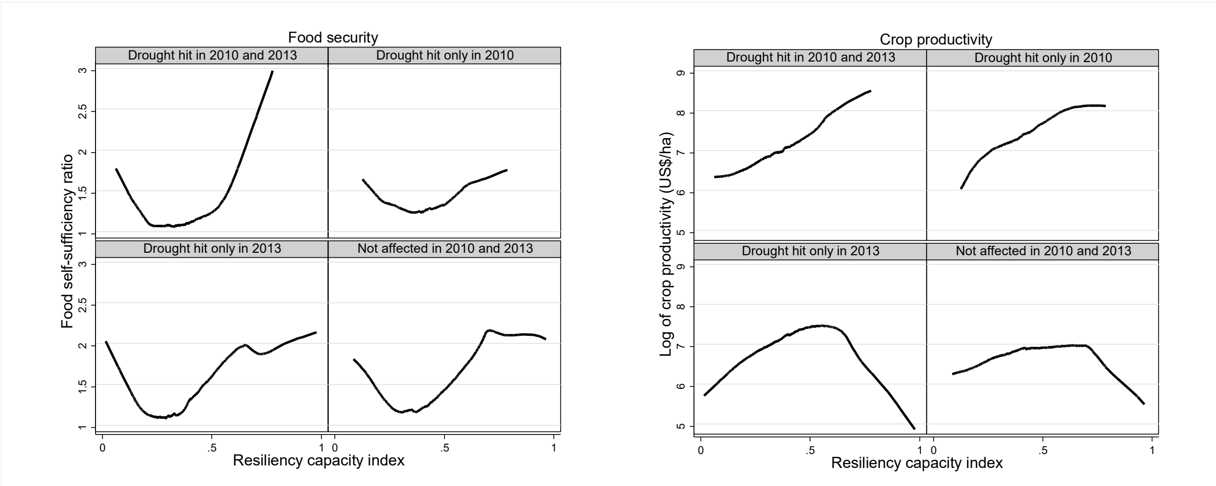


Figure 11. **Non-parametric regression of RCI on food security and crop productivity**

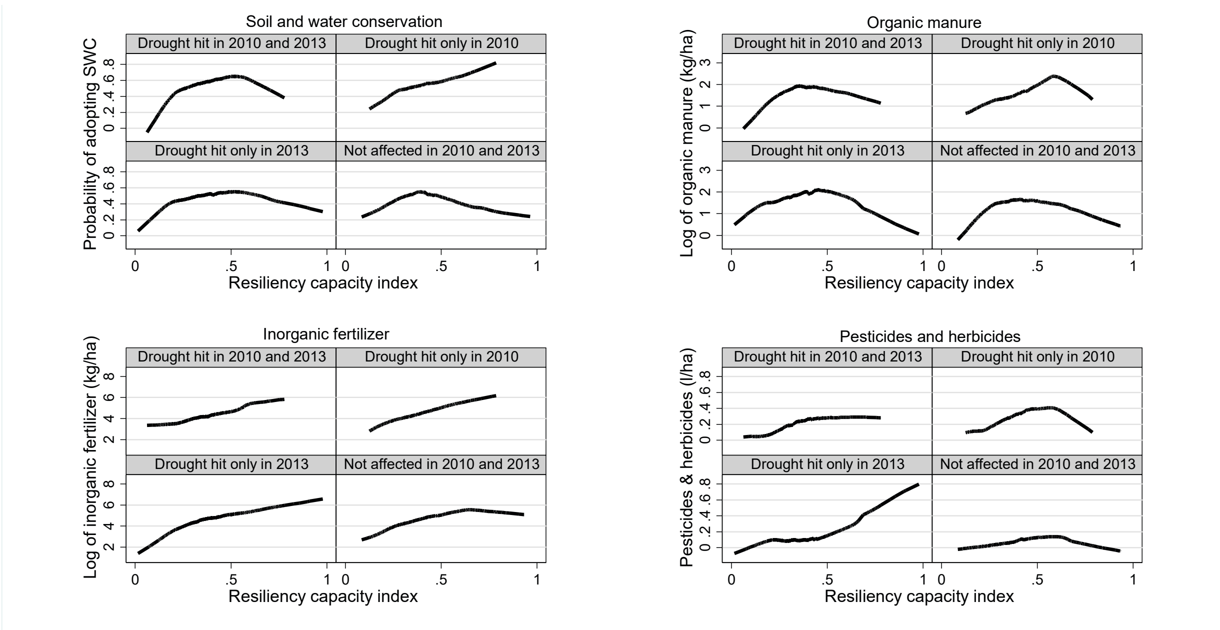


Figure 12. **Non-parametric regression of RCI on adoption of agricultural practices**

However, the relationships observed in Figures 11 and 12 may be biased due to omitted variable bias resulting from the nature of bivariate regression and the endogeneity problem arising from joint determination

[4] Current' period refers to 2013 when the data was collected.

of outcome variables and the household resilience capacity. To test the robustness of the relationships reported in Figures 11 and 12, we estimate parametric regressions in which we include other control variables and control for possible endogeneity of RCI. To save space, Figure 13 reports key results, with full results available upon request from the authors.

To control for the potential endogeneity bias in estimation outcome of interest (food security, crop productivity and adoption of agricultural practices) as associated with the inclusion of RCI as a regressor, we utilize the control function approach (Papke and Wooldridge, 2008). We use two exclusion restrictions for RCI at community level: the community's ability to prioritize its needs before taking action or mobilizing resources (dummy) and the share of households in a community with members having temporary work outside the community. These two restrictions are expected to have a direct effect on RCI but may not have direct effect outcome variables. Our control function estimation showed that, apart from crop productivity estimation, we reject the null hypothesis that RCI is endogenous in all estimations reported in Figure 13. The crop productivity model was estimated with residuals obtained from the estimation of RCI and included as an explanatory variable in the crop productivity estimation. To correct the standard errors for the first stage estimation, the productivity model was bootstrapped with 500 replications. The econometric estimates reported in Figure 13 confirm the existence of relationships observed in Figures 11 and 12 in our sample of smallholder farmers in Malawi. The following key findings are noteworthy.

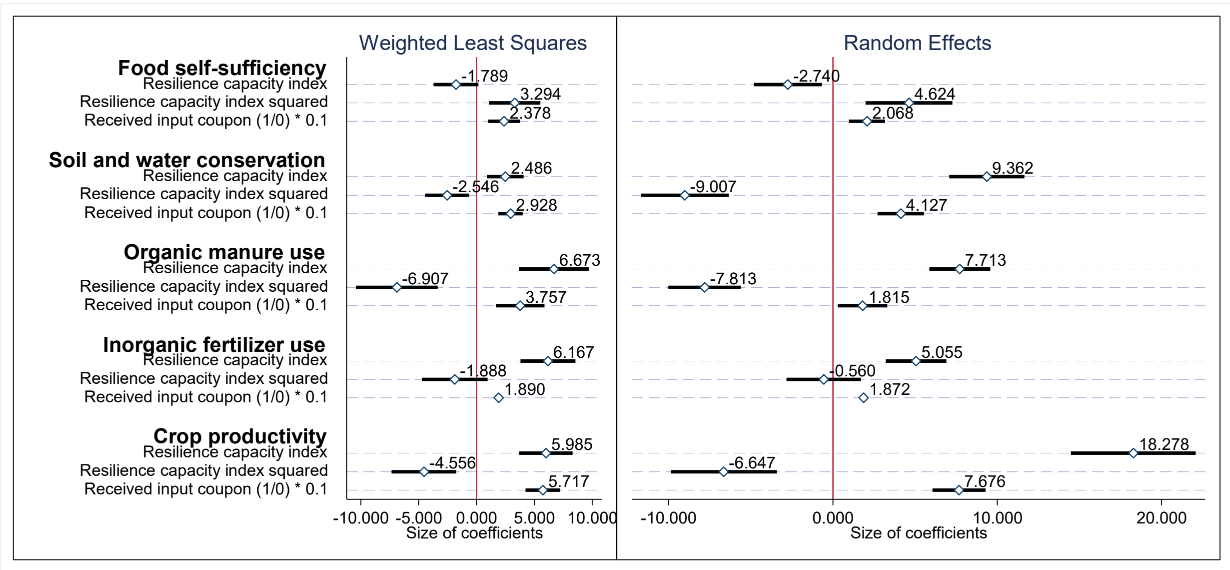


Figure 13: **Regression of RCI on food security, crop productivity and adoption of agricultural practices.**

Other explanatory variables included in the regressions not reported included: Frequency of drought occurrence 5 years before 2010 and since 2010; Frequency of flood occurrence 5 years before 2010 and since 2010; Frequency of crop disease/pest occurrence 5 years before 2010 and since 2010; Frequency of livestock diseases occurrence 5 years before 2010 and since 2010; Frequency of sharp low price change occurrence 5 years before 2010 and since 2010; Frequency of sharp high price change occurrence 5 years before 2010 and since 2010; Frequency of development project introduction 5 years before 2010 and since 2010; Frequency of new roads or improved transportation 5 years before 2010 and since 2010; Presence of irrigation scheme in the community (dummy); Number of fertilizer sellers in the community; Number of hybrid maize seed sellers in the community; distance to agricultural extension office (km); and household obtained input coupons during the 2009/2010 during 2012/2013 cropping seasons.

In general, there is evidence to show the existence of a relationship tending toward a J-shaped curve between food self-sufficiency and household resilience capacity (Figure 11, left panel). That is, as the household starts to build and strengthen its resilience capacity, food self-sufficiency levels are initially declining-possibly in the short-run - toward a certain threshold beyond which additional effort to strengthen the resilience capacity increases food self-sufficiency in a gradual and sustained pattern - possibly in the long-run. Figure 11 shows that food self-sufficiency declines with resilience capacity up to about 30% of full anticipated resilience capacity, beyond which it begins to improve. Three explanations for this finding are possible.

First, the results observed in Figure 13 and the right panel of Figure 11 give an evidence-based explanation. The latter shows a relationship between crop productivity and household resilience tending toward an inverted-J curve (right panel, lower curves) and linear curves (right panel, upper curves), while the former generally shows a reserved but inverted-J relationship between probability to adopt soil and water conservation practices, the use of organic manure and household resilience capacity. These relationships suggest that improving crop productivity initially requires investments in soil fertility enhancing practices and inputs. This in turn constrains household consumption capacity as some households may dispose of their crop produce in exchange for fertility inputs or investments in soil and water conservation structures, hence declining food self-sufficiency. Then beyond a certain tipping point, further investments in soil fertility improvements result in declining crop productivity while food self-sufficiency is increasing sustainably. This is because as more cash returns are gained from increasing crop productivity, households tend to engage in off-farm income generating activities, invest in less labor intensive on-farm practices such as soil and water conservation structures and the use of organic manure, and instead increase investments in purchased and less labor intensive inputs like inorganic fertilizers, pesticides and herbicides (Diiro, 2009). Ultimately, crop productivity declines as the efficiency of inputs like inorganic fertilizers depends on complementary adoption of agronomic and soil and water conservation practices (Diir0, 2009). Despite the declining crop productivity, however, the returns gained from improved crop productivity will have enabled some households to build strong resilience through increased off-farm activities and hence are able to sustain high and increasing food self-sufficiency. There is evidence to show that households with multiple income sources have a strong resilience capacity. Figure 14 shows that household resilience capacity increases substantially with an increasing number of income sources.

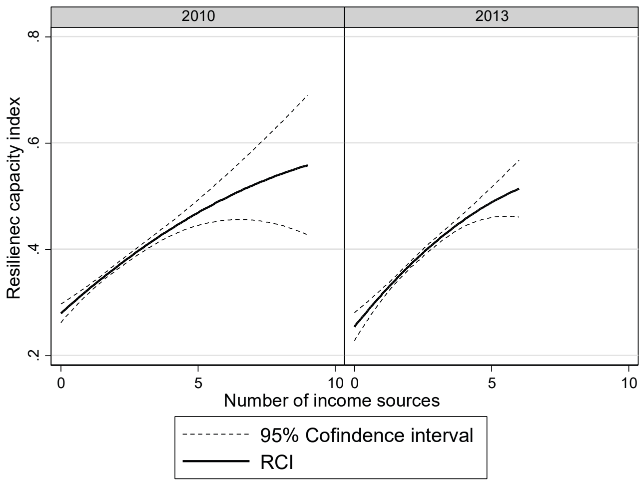


Figure 14. **The effect of income sources on RCI.**

The preceding discussion points to short- and long-run implications. In the short-run, as smallholder farmers prepare to build resilience against adverse shocks, they initially invest in low- cost, easy to access but labor-intensive agricultural productivity improving practices such as organic manure, soil and water conservation practices. This also implies that, in the short-run, the labor-land ratio is high and there are incentives for the farmer to keep the soil nutrient high by adopting soil conservation technologies. In the long-run, however, after attaining necessary returns gained from improved agricultural productivity, smallholder farmers move on to diversify their income alternatives. Consequently, labor-land ratio declines due to labor migration into off-farm income generating activities, and the incentive to use soil conservation technologies declines as the use of purchased inputs like inorganic fertilizers and pesticides increases. Much as this turn of events from short- to long-run yields a strong resilience capacity with secure food self-sufficiency, it may not deliver the desired agricultural transformation and the sustainability of this capacity and food security remains an area for further investigation. Agricultural transformation may not be achieved if resilient farm households focus on increasing the application of purchased-productivity enhancing inputs while dis-adopting soil and water conservation practices. This puts a question to the subsidy programs that have largely supported deployment of fertilizer and seed inputs with less focus on the adoption of complementary agronomic and conservation practices. In the wake of non-climatic shocks such as macro-economic shocks, what happens to a household if resilience capacity is largely dependent on off-farm income source diversification? Overall, even if having subsidy coupons improves food self-sufficiency and crop productivity, and enhances the adoption of soil and water conservation practices, application of organic and inorganic fertilizer (Figure 13), policy efforts to incentivize smallholder farmers to sustain adoption of soil and water conservation technologies are essential for successful subsidy programs and a means to agricultural transformation.

7 Conclusions and policy implications

The recent El Niño-induced drought in Southern Africa caused crop failure resulting in worrying food shortages in Angola, Namibia, Botswana, Zimbabwe, Lesotho, Malawi, Swaziland, Zambia, Madagascar and South Africa. A large share of the population in these countries, especially smallholder farmers, experienced food deficits as food imports rose to astronomical levels and strained the not-so-strong national foreign exchange reserves. Using open access online data and publications largely from UN agencies and the World Bank, the paper assessed current and historical impacts of drought in Southern Africa.

The findings indicate that in both current and past drought episodes, the impact of drought on livelihood strategies is heterogeneous across countries. Similarly, their capacities to overcome drought impacts vary greatly. This is evidenced in the variation of crop yields and food security indicators over time following drought occurrences across countries. Countries that have put in place long term mechanisms to reduce vulnerability to climate change related shocks were least affected. For example, compared to other Southern African countries, South Africa has well- established social security and protection schemes and a good enabling environment for doing business that attracts private sector in mitigating shocks by providing easy access to services and goods to absorb shocks. While the study was able to find information on long-term mechanisms for resilience to climatic shocks in South Africa, there is the possibility that the majority of countries in Southern Africa deploy reactive and short-term to medium term adaptive solutions to climatic shocks. These include declaring states of emergency and provision of food assistance that may include food-for-work assistance. Key questions that remain unanswered are: Are there long-term policies in place for resilience building and for which countries? If these policies exist, to what extent do they accommodate private sector investment? To what extent are they implemented? The answers to these questions have policy implications for support institutions to put to scale proven interventions to influence the right policies that promote private sector investments and induce high adoption rates of climate change adaptation and resilience building technologies.

The paper further finds supporting evidence that farmers tend to intensify or expand the production of drought tolerant crops like roots and tubers or early maturing crops like vegetables as a coping mechanism to drought shocks. Interestingly, there are significant correlations between changes in the yields of these crops and food security indicators: high yields are positively correlated with less prevalence of undernourishment and food inadequacy. Roots and tubers and vegetables may not be as highly prioritized as maize is in a number of Southern African countries, but these crops exhibit promising adaptation mechanisms.

References:

Acock, A. C. 2013. Discovering structural equation modeling using Stata. Revised Edition, College Station, TX, Stata Press.

AGRA (Alliance for a Green Revolution in Africa). 2016. Strategies and Policies to Support Household Resilience to Drought. AGRA Policy Brief No 3, AGRA, University of Georgia and USDA

Alem, Y. and Broussard, N.H. 2016. The Impact of Safety Nets on Technology Adoption: A Difference-in-Differences Analysis. Environment for Development, Discussion Paper Series, EfD DP 16-13

Adimassu, Z. and Kessler, A. 2015. Impact of the productive safety net program on farmers' investments in sustainable land management in the Central Rift Valley of Ethiopia. Environmental Development, 16: 54–62.

Armbruster, W.J., 2008. Challenges and Issues in the Next Decade: A Proactive Role for Agricultural and Resource Economists. Agricultural and Resource Economics Review 38 (1): 1-7.

Beck, N. and Katz, J. N, 1995. What to do (and not to do) with time-series cross-section data. The American Political Journal Review 89(3): 634-647.

Center for Research on Epidemiology of Disasters (CRED). 2016. The Emergency Events Database (EM-DAT). The International Disaster Database. http://www.emdat.be/. Accessed October, 2016.

Constas, M., Frankenberger, T. and Hoddinott, J. 2014. Resilience Measurement Principles. Food Security Information Network Technical Series 1. Rome: Food and Agriculture Organization and World Food Programme.

Conway, D., Archer van Garderen, E., Deryng, D., Dorling, S., Krueger, T., Landman, W., Lankford, B., Lebek. K., Osborn, T., Ringler, C., Thurlow, J., Zhu, T., Dalin, C. 2015. Climate and southern Africa's water–energy–food nexus. Nature Climate Change, 5: 837–846, doi:10.1038/nclimate2735

Corsino, R. 2016. Southern Africa El Niño Preparedness: Regional Supply Chain Assessment. Issues Paper, World Food Program, Johannesburg, South Africa.

d'Errico, M. and Di Giuseppe, S. 2018. Resilience mobility in Uganda: A dynamic analysis. World Development 104: 78–96

d'Errico, M. and Pietrelli, R. 2017. Resilience and child malnutrition in Mali. Food Security, 9(2), 355–370

Diiro, G., 2009. Impact of Off-farm Income on Agricultural Technology Adoption Intensity and Productivity. IFPRI Report. IFPRI, Washington D.C

Dufour, C., Kauffmann, D. and Marsland, N. 2014. Enhancing the links between resilience and nutrition. In S. Fan, R. Pandya-Lorch, and S. Yosef (Eds.), Resilience for Food and Nutrition Security (pp. 107–117).

Fan, S., Pandya-Lorch, R. and Yosef, S (Eds). 2014. Resilience for Food and Nutrition Security. First edition. International Food Policy Research Institute, Washington DC.

FAO. 2014. Strengthening the links between resilience and nutrition in food and agriculture. Discussion paper, Food and Agriculture Organization of the United Nations. URL: http://www.fao.org/2/i3777e Accessed 25 January 2018.

FAO (Food and Agriculture Organization of the United Nations) 2016a. Southern Africa El Niño Response Plan (2016/17). http://www.fao.org/3/a-i5981e.pdf. Accessed October, 2016.

FAO. 2016b. UN seeks to boost response to El Niño's dire impact in Africa and Asia/Pacific, urges La Niña preparedness. http://www.fao.org/news/story/en/item/423058/icode/. Accessed October, 2016.

FAO. 2016c. GIEWS Country Briefs. http://www.fao.org/giews/countrybrief/index.jsp. Accessed October, 2016.

Food and Agriculture Organization of the United Nations (2016d). Analysing Resilience for better targeting and action: Resilience Index Measurement and Analysis – II (RIMA-II). Available at: http://www.fao.org/3/a-i5665e.pdf

FAOSTAT, 2016. Food and Agriculture Organization of the United Nations statistics division. http://faostat3.fao.org/home/E. Accessed October, 2016.

Hoddinott, J. 2014. Looking at development through a resilience lens. In: Shenggen F., Pandya-Lorch, R. and Yosef, S. (Eds). Resilience for Food and Nutrition Security. pp. 19 – 26.

IMF (International Monetary Fund). 2007. World Economic Outlook: Globalization and Inequality. International Monetary Fund, Washington, D.C., USA.

IPPC (Intergovernmental Panel on Climate Change). 2013. Fifth Assessment Report (AR5): Climate Change 2013: The Physical Science Basis. Geneva. http://dspace.africaportal.org/jspui/bitstream/123456789/34958/1/AGF-Implications-Africa-CDKN-Special-Briefing-small1.pdf?1

Njuki, J., Poole, J., Johnson, N., Baltenweck, I., Pali, P., & Mburu, S. (2011). Gender, livestock, and livelihoods indicators. International Livestock Research Institute, Nairobi, Kenya.

OCHA (United Nations Office for Coordination of Humanitarian Affairs). 2016. http://www.unocha.org/el-nino-southern-africa

Pace, M.L., Batt, R.D., Buelo, C.D., Carpenter, S.R., Cole, J.J., Kurtzweil, J.T., Wilkinson, G.M. 2017. Reversal of a cyanobacterial bloom in response to early warnings. PNAS 114(2):352–357, DOI 10.1073/pnas.1612424114

Papke, Leslie E., and Jeffrey M. Wooldridge. 2008. “Panel data methods for fractional response variables with an application to test pass rates.” Journal of Econometrics 145: 121–33.

Pizer, S. D. 2016. Falsification Testing of Instrumental Variables Methods for Comparative Effectiveness Research. Health Services Research, 51(2): 790-811.

Rufino, M.C., Thornton, P.K., Ng’ang’a, S.K., Mutie, I., Jones, P.G., van Wijk, M.T. and Herrero, M. 2013. Transitions in agro-pastoralist systems of East Africa: Impacts on food security and poverty. Agriculture, Ecosystems and Environment Vol. 179: 215–230

SADC (Southern African Development Community). 2016. Regional early warning bulletin for the 2016/17 rainy season. SADC CSC, Gaborone, Botswana

USAID, 2016. Southern Africa - drought fact sheet #5. https://www.usaid.gov/sites/default/files/documents/1866/southern_africa_fs05_08-23-2016.pdf

World Bank, 2016. World Bank open data. http://data.worldbank.org/. Accessed October, 2016.

Zivot, E. and Wang, J. 2006. Modelling Financial Time Series with S-PLUS, chapter 9, pages 313–360. Springer, doi: 10.1007/978-0-387-32348-0.

Appendix A

Table 1. Determinants of household resilience capacity (RCI)

Variables	Estimates
Household level characteristics	
Household received extension service on new seed varieties (0/1)	0.018** (0.006)
Household received extension service on pest control (0/1)	0.015** (0.007)
Household received extension service on fertilizer use (0/1)	0.009 (0.006)
Household received extension service on irrigation (0/1)	0.013** (0.006)
Household obtained input coupons during the 2009/2010 and 2012/2013 (0/1)	-0.186*** (0.039)
Shocks experienced at community level	
Frequency of drought occurrence 5 years before 2010 and since 2010	-0.017*** (0.004)
Frequency of flood occurrence 5 years before 2010 and since 2010	0.003 (0.005)
Frequency of crop disease/pest occurrence 5 years before 2010 and since 2010	-0.004 (0.007)
Frequency of livestock diseases occurrence 5 years before 2010 and since 2010	0.002 (0.005)
Frequency of sharp low price change occurrence 5 years before 2010 and since 2010	0.024*** (0.004)
Frequency of sharp high price change occurrence 5 years before 2010 and since 2010	-0.011 (0.009)
Other community level characteristics	
Community's ability to prioritize its needs before taking action or mobilize resource (0/1)	-0.023*** (0.006)
No households in community with members having work elsewhere (0/1)[d]	0.010** (0.005)
Very few households in community with members having work elsewhere (0/1)[d]	0.009 (0.006)
At least half of households in community with members having work elsewhere (0/1)[d]	-0.003 (0.012)
Frequency of development project introduction 5 years before 2010 and since 2010	-0.008** (0.003)
Frequency of new roads or improved transportation 5 years before 2010 and since 2010	0.007 (0.005)
Presence of irrigation scheme in the community (0/1)	0.018*** (0.005)
Number of fertilizer sellers in the community	-0.007* (0.004)
Number of hybrid maize seed sellers in the community	0.015*** (0.004)
Constant	**0.367*** (0.007)**
F-Value	**16.707*** **
Number of observations	**4838**

Note: Robust standard errors are in parentheses.

[d]To avoid dummy variable trap, a dummy with denoting a quarter of households in community with members having work elsewhere was dropped.

***, **, * Significant at the 1%, 5%, and 10% levels, respectively.

Table A2. Descriptive statistics of Key household and community level characteristics

	2010 survey		2013 survey	
Key household level characteristics				
Food self-sufficiency ratio	1.33	(2.13)	1.29	(1.77)
Proportion of households using SWC	0.471	(0.499)	0.511	(0.5)
Amount of organic manure used (kg/ha)	472	(559)	422	(507)
Amount of inorganic fertilizer used (kg/ha)	191	(151)	196	(163)
Resilience capacity index	0.363	(0.137)	0.376	(0.14)
Annual value of crop productivity (US $/ha)	886	(1776)	1316	(2092)
Household obtained input coupons (1/0)	0.548	(0.498)	0.462	(0.499)
Distance to agricultural extension office (km)	0.436	(1.31)	0.403	(1.17)
Proportion of households having experienced shocks				
Drought or irregular rains (1/0)	0.439	(0.496)	0.609	(0.488)
Floods and landslides (1/0)	0.048	(0.214)	0.142	(0.349)
Earthquake (1/0)	0.078	(0.268)	0.031	(0.172)
Crop diseases and pests (1/0)	0.067	(0.251)	0.176	(0.381)
Livestock diseases and pests (1/0)	0.075	(0.263)	0.207	(0.405)
End of regular assistance or remittances or aid (1/0)	0.016	(0.124)	0.109	(0.312)
Income reduction (1/0)	0.235	(0.424)	0.342	(0.475)
Community level characteristics				
Frequency of development project introduction 5 years before 2010 and since 2010	0.354	(0.63)	0.382	(0.645)
Frequency of new roads or improved transportation 5 years before 2010 and since 2010	0.178	(0.42)	0.208	(0.421)
Presence of irrigation scheme in the community (0/1)	0.172	(0.377)	0.158	(0.364)
Number of fertilizer sellers in the community	0.614	(1.47)	0.767	(2.27)
Number of hybrid maize seed sellers in the community	0.712	(1.5)	0.847	(2.28)
Number of observations	2419		2419	

Figures in parentheses are standard deviations

[1] Government of Ghana (2010) Medium Term Agriculture Sector Investment Plan (METASIP) 2011 – 2015, Ministry of Food and Agriculture, Republic of Ghana

AGRA
Growing Africa's Agriculture

Contact Details:

West End Towers, 4th Floor | Kanjata Road | P.O. Box 66773-00800, Nairobi, Kenya

Tel: +254 703 033000 | Fax: +254 20 3675 401