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# **Maize markets in Eastern and Southern Africa (ESA) in the context of climate change**

Background paper for  
The State of Agricultural Commodity  
Markets (SOCO) 2018

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## Acronyms

COMESA	Common Market for Eastern and Southern Africa
ESA	Eastern and Southern Africa
FNS	Food and nutrition security
GHG	Greenhouse gas
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
IPCC	Intergovernmental Panel on Climate Change
SADC	Southern African Development Community
SSA	Sub-Saharan Africa

## Abstract

The background paper<sup>1</sup> provides a synthesis of the literature on the impact of climate change on maize production and markets in the Eastern and Southern African (ESA) region. The region relies heavily on rain fed agricultural systems and climate change is expected to have significant impacts on agricultural productivity and food availability. Given the importance of maize for human and animal consumption, the paper reviews the current and potential impacts of climate change on food and nutrition security (FNS) and discusses policy instruments currently in place to deal with FNS and climate change. Finally, the paper examines innovative climate smart approaches and suggests that governments should provide support to smallholder farmers, in particular, on the uptake of such approaches.

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<sup>1</sup> The 2018 edition of The State of Agricultural Commodity Markets (SOCO) deals with the potential of trade as an adaptation and mitigation tool. This paper represents one in a series of thematic papers that were commissioned to inform the writing of the publication. The author was asked to prepare a crop and regional specific background and case study paper, specifically considering the Federal Democratic Republic of Ethiopia, the Federal Republic of Somalia, the Republic of Kenya, the Republic of Uganda, the Republic of Burundi, the Republic of Rwanda, the United Republic of Tanzania, the Republic of Zambia, the Republic of Zimbabwe, and the Republic of Mozambique.

## Introduction

Maize is the third most important agricultural commodity worldwide after rice and wheat in terms of area planted and consumption. Different varieties are used for human consumption, animal feed, and as input for industrial processing and manufacturing. Originally planted in Middle America, due to its geographical adaptability and climatic resistance maize has successfully spread all around the globe with particular relevance in Latin America and sub-Saharan Africa (Abbassian, 2007). In 2017, global maize production added up to 1.04 billion tonnes, of which close to 15 percent were traded on international markets. Over the last few years the global stock-to-use ratio was around 25 percent which had a stabilizing effect on international maize prices (FAO-AMIS, 2017).

In 2016/2017, a total of 140 million tonnes (13 percent of total production) of maize were traded internationally, generating an estimated global trade volume of roughly USD 25 billion (USDA FAS, 2017). The United States of America, the Federative Republic of Brazil (hereafter “Brazil”), the Argentine Republic, and Ukraine are the largest exporters accounting for around 90 percent of total maize exports. This makes maize the second most traded agricultural commodity after wheat. Overall, maize represents one third of international cereal trade (FAO-AMIS, 2017). In absolute terms, the United States of America, the People’s Republic of China, European Union, Brazil, and the United Mexican States (hereafter “Mexico”) are the largest consumers of maize. However, relative to the population size, production and consumption is highest in Mexico, the Republic of Honduras, and selected countries in Eastern and Southern Africa.

In sub-Saharan Africa (SSA), depending on the region, the agricultural sector employs up to 70 percent of the labour force and contributes up to 65 percent of the national Gross Domestic Product (GDP). In the Eastern and Southern parts of Africa, where maize is the most important staple and the main source of calorie intake, agricultural households receive up to 20 percent of their income from maize production and spend more than 15 percent of their total household expenditure on maize alone (Chauvin *et al.*, 2017). Given its significance in production and traditional consumer preferences, total annual consumption ranges between 50kg-129kg per person.

The effects of climate change – including changing temperature and rainfall patterns, increasing greenhouse gas (GHG) concentration in the atmosphere, and a larger variability in weather patterns – negatively impact global food security. Although there is considerable uncertainty about the effect of climate change on the food system, climate change is expected to adversely affect agricultural yields and the conditions of natural resources, for instance by impelling soil retrogression and degradation. In addition, agricultural production and land use change are also major emitters of GHG emissions. Overall, agriculture and deforestation account for 25 percent of carbon dioxide, 50 percent of methane, and more than 75 percent of nitrogen (fertilizer application) emissions (Pinstrup-Anderson and Watson II, 2011).

Many studies identify Africa as a region highly vulnerable to climate change. The increase in temperature is expected to be between 3–4°C until the next century. Also rainfall patterns will change leading to a reduction in annual precipitation of 20 percent in selected areas (IPCC, 2016). Changing climate patterns, increasing weather variability and a higher frequency of extreme events already have direct impacts on agricultural production, productivity, and the stability of the food system. Climate change will reduce crop yields and in consequence will increase food prices forcing people to reduce their calorie intake or the nutritional quality of the diets. It is projected that agricultural yields in rain fed agricultural systems will be exposed to increasing water stress and could decrease by around 30 percent by 2050 in the worst-case scenario (Schlenker and Lobell, 2010). Overall, this could lead to a reduction in maize production between 20 percent and 40 percent in Eastern and Southern Africa. In temperate and tropical highland of the Republic of Burundi (hereafter “Burundi”), the Republic of Kenya (hereafter “Kenya”), the Republic of Rwanda (hereafter “Rwanda”), the Republic of Uganda (hereafter “Uganda”), and the United Republic of Tanzania a moderate increase in temperature and precipitation could significantly increase production by up to 50 percent while other regions experience losses around 5-10% (Thornton *et al.*, 2010). In southern Africa, the picture is generally worse with higher predicted losses. Therefore, to catch up with the increasing demand driven by a growing population sustainable intensification needs to be promoted (Pretty *et al.*, 2011).

The threat of climate change represents a serious challenge to the economic and socio-economic development of many developing and least developed countries. Many of these countries heavily rely on climate sensitive natural resources to foster economic growth and development, agricultural trade and to eventually advance food and nutrition security (FNS) for their population. The agricultural sector produces the food for the population and also provides an important source of economic livelihood for about one third of the global population (FAO, 2016). In this way, climate change is undermining the current efforts towards FNS and the reduction of malnutrition problems.

The Eastern and Southern African region, hereafter ESA, has a structural deficit in maize, although some countries, foremost Uganda, are regular exporters. Local markets in the region are found to be isolated from international price movements (Badequano and Liefert, 2014). However, regional market integration is well advanced in normal periods and surplus maize is shipped across borders to deficit regions in Kenya and the Republic of Zimbabwe (hereafter “Zimbabwe”) to stabilize local supply (Ihle *et al.*, 2011; Davids *et al.*, 2016). Although the Common Market for Eastern and Southern Africa (COMESA) countries are members of the community’s customs union, exports are often restricted when harvests are low which exacerbates the situation in food deficient countries in the region. Climate change and its impacts on food availability likely shift production to higher altitude areas, which affects trade patterns. Generally, national maize production of the countries in the region is sufficiently independent to utilize substantial benefits from regional trade liberalization integration. On the other hand, international trade

liberalization would reduce regional food trade in ESA, while demand will be met through international imports.

Due to the strategic importance of maize, markets are characterized by significant public intervention in the form of price stabilization programmes, domestic price policies, border measures, and input subsidy programmes. These policies are helpful to increase food availability and accessibility in the short-run, but encourage inefficient production in the long-run, which conflicts with the goal of sustainable intensification of agricultural production. In addition to that, adaptation and mitigation measures are promoted. Most promising are climate smart agricultural technologies, such as conservation agricultural and agroforestry, which increase productivity and respond to the challenges of climate change.

The aim of this background paper is to provide a synthesis of the literature on the impact of climate change on maize production and the performance of markets in the ESA area of SSA. Furthermore, it discusses current national policy options to respond to climate change in its two distinct forms by mitigating the emission of greenhouse gases in the atmosphere and by adapting to the conditions climate change induced. To set the stage, the subsequent section presents the current state of knowledge on the impacts of climate change on FNS in the ESA region. Section 3 includes a detailed discussion on policy instruments currently in place. A policy-by-policy discussion aims at providing an economic assessment of the extent to which these policy instruments are sufficient to address the challenges posed by climate change. Subsequently, innovative climate smart approaches are presented and their upscaling potential is assessed.

## **How climate change endangers food security**

### **How weather will change**

Since the first Intergovernmental Panel on Climate Change (IPCC) Assessment Report in 1990, several studies have been conducted correcting and updating the earlier projections on the effects of climate changes. The priority of these studies is to provide long-term predictions of precipitation and temperatures levels for all geographical regions, even on a disaggregated level. The latest Assessment Report from 2014 ascertains that the global surface temperature has increased by 0.85° Celsius since 1880 and that 1983–2013 was the hottest 30 year period since more than 1400 years. Depending on future CO<sub>2</sub> emissions and the related climate scenario, this trend will continue or even intensify. Specifically, the global average temperature is expected to increase between 0.3° and 4.8° Celsius by the year 2100, (IPCC, 2014). At the same time, the increase in temperature affects other weather phenomena through intensified evaporation. This can lead to an increase or decrease of precipitation levels as well as an accumulation of extreme weather events depending on the geographical location.

The effects of climate change are more notable in the southern hemisphere, which is already predominantly characterized by hotter and drier climate. The latest IPCC Report projects significant increases of temperature and reduction of rainfall for the Sahel zone

and southern Africa. Since there exists a high degree of uncertainty about future GHG emissions, several scenarios are considered, wherefore the effects are often reported in ranges.<sup>2</sup> For instance, the Commonwealth Scientific and Industrial Research Organization's (CSIRO) model is generally more pessimistic, while the medium resolution general circulation model (MIROC) model projects a moderate increase in global precipitation (Nelson *et al.*, 2010).

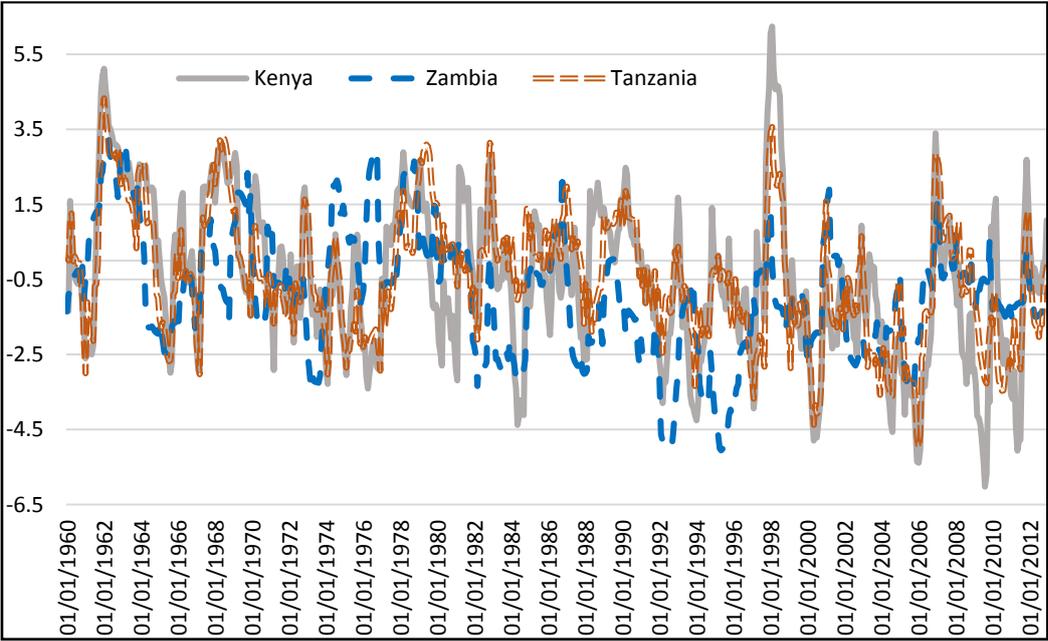
Global climate models expect the decrease in precipitation to be up to 20 percent, as compared to the levels of 2000, (IPCC, 2016). Moreover, the frequency and intensity of extreme weather events, such as tropical storms, floods, and severe droughts is likely to significantly increase. In general, it is difficult to make specific predictions for individual countries, instead climate change is likely to have distinct impacts on different regions within a country with high altitude areas of the Federal Democratic Republic of Ethiopia (hereafter "Ethiopia"), Kenya, and Uganda potentially benefiting from an increase in rainfall and warmer temperature. Specifically, areas in Ethiopia, Kenya, and Burundi are projected to experience more rainfall consistently across different biophysical climate models (Waithaka *et al.*, 2013). While, the projections for Rwanda, the United Republic of Tanzania, and Uganda vary from a significant reduction to a significant increase in precipitation (MIROC). Niang *et al.* (2014) also emphasize that future precipitation projections are subject to great uncertainty, but expect an overall increase in eastern Africa and an overall decrease in southern Africa. In all emission scenarios, and across different climate models, the future temperature will exceed current levels; in positive scenarios below 2°C in negative around 4°C. The Republic of Malawi (hereafter "Malawi"), the Republic of Zambia (hereafter "Zambia"), and Ethiopia expect the strongest increase, while Rwanda is likely to experience only moderate temperature changes.

The effects of climate change are already noticeable today. Figure 1 presents the Palmer Drought Severity Index (PDSI) for Kenya, the United Republic of Tanzania, and Zambia over the period between 1960 and 2012. A negative trend (towards drier climate) is clearly visible. Furthermore, the magnitude of extreme drought events has continuously increased. This was recently observed at the beginning of 2017, when reduced rainfall put several millions at risk in Kenya, the Federal Republic of Somalia (hereafter "Somalia"), and Ethiopia (FEWNET, 2017a). As a result, local prices of maize and other important staples reached near to or record levels in markets in Ethiopia, Kenya, Somalia, Uganda and the United Republic of Tanzania, as reported by FAO's Food Price Monitoring and Analysis Bulletin (FPMA).

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<sup>2</sup> See Nelson *et al.* (2010) for a detailed storyline of the scenarios. In short, the A1 scenario family describes a world with very rapid economic growth and global population peaking in mid-century and declining thereafter. In addition, the rapid introduction of more efficient technologies is assumed. Second, the A2 scenario family include very heterogeneous assumptions. The underlying theme is self-reliance and global population grows continuously with limits. Economic development is primarily regionally oriented and per capita economic growth. Last, technological change is slower than in the other scenarios. Third, the A3 scenarios assume a population development as in the A1 scenarios, but with rapid changes in the structures of the economic structures toward a service and information oriented economy including the introduction of clean and efficient technologies. The emphasis is on global sustainability solutions, but without additional climate initiatives. Last, the B2 scenario family describes a world with local solutions to economic, social, and environmental sustainability. Population growth is continuously increasing, but at lower rates than A2 and moderate levels of economic development. The technological change is also lower than in the B1 and A1 storylines. Each scenario family consists of six sub-scenarios: one group each in A2, B1, B2, and three groups in A1. The alternative sub-scenarios are characterized by alternative developments of energy technologies: A1FI (fossil fuel intensive), A1B (balanced), and A1T (predominantly non-fossil fuel).

**Figure 1: Palmer Drought Severity Index between 1960 and 2012 for selected countries<sup>3</sup>**



Source: Harvest Choice (2017).

**The impact of climate change on different dimensions of food security**

As widely acknowledged the concept of food security involves four dimensions: food availability, access to food, stability, and food utilization. Wheeler and von Braun (2013) criticize that most of the academic literature on climate change impacts limits food security issues on food availability. Therefore, here a broader view is taken by also looking at the effects on the other dimensions food accessibility, food stability, and food utilization.

Before turning to the specific impacts of climate change on food security, Table 1 gives a brief overview about food insecurity in the region. Child underweight and stunting are among the highest in the world contributing to child mortality rates from 5--8 percent and even 13.7 percent in Somalia. Although child obesity is also increasing within recent years, prevalence is still at much lower rates than stunting and underweight and the link to climate change is vague. The link between human health and ecosystem services, in the form of plant vegetation, biomass provision, and pasture conditions is well established. For instance, Brown *et al.* (2014) provide a review of empirical studies using satellite remote sensed Normalized Difference Vegetation Index (NDVI) to link weather events with child nutrition and health.

<sup>3</sup> The Palmer Drought Severity Index (PDSI), devised in 1965, is the first drought indicator to assess moisture status comprehensively. It uses temperature and precipitation data to calculate water supply and demand, incorporates soil moisture, and is considered most effective for unirrigated cropland. It primarily reflects long-term drought and has been used extensively to initiate drought relief.

**Table 1: Malnutrition rates across the study countries**

	Child underweight (Percent)	Child stunting (Percent)	Child mortality (Percent)	Child overweight (Percent)
Burundi	n.a.	56.6	8.2	1.4
Ethiopia	28.8	38.4	5.9	2.8
Kenya	19.1	26	4.9	4.1
Malawi	25.9	37.1	6.4	4.5
Mozambique	26.6	39.1	7.9	7.9
Rwanda	41.1	37.9	4.2	7.7
Somalia	n.a.	n.a.	13.7	n.a.
United Republic of Tanzania	32.3	34.4	4.9	3.6
Uganda	39	34.2	5.5	3.7
Zambia	45.9	40	6.4	6.2
Zimbabwe	44.7	27.6	7.1	5.6

Source: IFPRI *et al.* (2017) and UNICEF (2017).

### **Food availability**

The dimension of food availability predominantly deals with the issue of producing enough to feed the population. At the moment, in terms of average per capita food availability, the global production is sufficient to meet caloric requirements. However, as first pointed out by Malthus, the concern encompasses whether a rapidly growing population can be adequately fed in future. Overall food production can be increased by expanding the area under agricultural cultivation or by enhancing agricultural productivity (e.g. yields). After significant land expansion until the 1950s, the Green Revolution is now increasing agricultural yields in Africa, however, maize yields still massively lack behind other regions in the world. The potential promise for low productivity regions, like SSA, is to close the yield gap between achievable and actual yields using relatively easy to implement measures, which include adoption of modern technologies, irrigation, and input intensification (Burke and Lobell, 2017). However, in order to maintain current levels of self-sufficiency the acceleration of productivity growth towards achievable yields is inevitably (van Ittersum *et al.*, 2016).

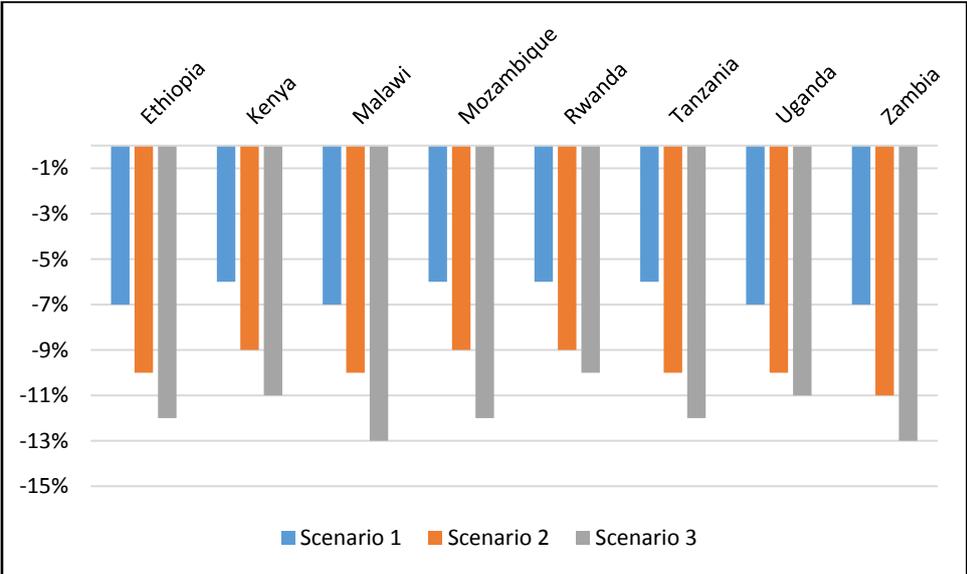
The projected changes in climatic conditions represent significant stress to the challenge to achieve agricultural productivity growth. Under various scenarios, global agricultural production will be adversely affected and the ability of many regions to achieve the zero hunger goal will be largely impeded (Lobell *et al.*, 2008). Two distinct approaches are used to estimate the effects of climate change on agricultural output. The first being the, so called, process based approach, an agronomic approach which makes use of experimental studies providing detailed information on the impact of soil quality, solar radiation, and projected daily rainfall and temperatures on plant growth and yields. This approach can be also used to simulate changes in management practices (e.g. adaptation) on production and yields. The second approach uses statistical regression to find a relationship between historically observed yield and historical weather patterns. Although some differences in model assumption and methodologies exist, the impact of global warming on maize productivity in Africa is robust (Knox *et al.*, 2012).

In an attempt to provide a first global assessment of the impact of climate change on agricultural production, Rosenzweig and Parry (1994) analyse the impact of a doubling of carbon dioxide concentration in the atmosphere on agricultural productivity using three site-specific agronomic crop models at 112 locations in 18 countries. While the enhanced concentrations of atmospheric CO<sub>2</sub> has the potential to support productivity growth, climatic changes are expected to lead to a small decrease in overall global food production. However, developing countries are likely to bear a large share of the burden, which cannot be compensated by adaptive measures of farmers.

The study of Rosenzweig and Parry (1994) revealed significant spatial variation in the impact on crop yields across the globe. Supported by other studies, there is evidence that yields in the northern hemisphere are expected to increase, while they are likely to decline in the southern hemisphere. Moreover, tropical areas seems to be negatively affected and higher altitudes become more productive through increasing temperature and rainfall. Adding up gains and losses, overall global productivity is likely to decline. It seems also apparent that areas with a decline in agricultural productivity coincide with the most food insecure regions in the world, where hunger and malnutrition are most prevalent (Wheeler and von Braun, 2013).

With respect to temperature, most models assume that maize yields increase up to 29 - 30°C and sharply decrease at higher temperature levels (Brown 2009). For instance, Lobell and Field (2007) reported a decrease of 8.3% in maize yield per 1°C rise above normal. Using the temperature-crop-yield relationships for maize in combination with spatial yield maps of Harvest Choice, Adhikari *et al.* (2015) analyse how yields of major crops in individual countries in the eastern African region will be affected by climate change. Given an increase in agricultural productivity and maize yields in the baseline scenario, Figure 2 provides the projected decline in maize yields under climate change for different emission scenarios (1: A2, 2: A1B, 3: B2) up to 2090.

**Figure 2: Estimated impact of climate change on maize yields**



Source: Adhikari *et al.* (2015)

More recently, models allow for an assessment of projected changes in the yield at a grid scale of 20 to 50 km. These predictions show that maize yields in some ESA areas increase, while coastal regions are prone to yield losses above 25 percent. Robertson (2015) provides crop model estimates on maize yields at grid cell level indicating yields losses between 5-25 percent in most areas of Eastern and Southern Africa until 2050, as compared to 2000. Instead, Thornton *et al.* (2010) predict yield gains in Burundi, Kenya, Rwanda, the United Republic of Tanzania and Uganda for high altitude areas. This holds for arid-semiarid and humid-sub-humid areas in Rwanda as well. On the other hand, production is likely to decrease between 1 percent to 5 percent by 2030 and 6 percent and 12 percent by 2050, respectively, in these agro-ecological areas of the United Republic of Tanzania and Uganda. This is in line with Easterling *et al.* (2007) who reports negative impacts on productivity in low-latitude regions.

Given the shortfall of national production as compared to an increasing demand through population growth and economic development, food imports need to be expanded. Using the impact model, Waithaka *et al.*, (2013) present country level projections for changes in yields, production, and net trade for Burundi, Ethiopia, Kenya, the United Republic of Tanzania, and Uganda. Accordingly, yield gains in Kenya and Uganda drive their national production to double and triple, respectively, until 2050, while production in Burundi, Ethiopia, and the United Republic of Tanzania hardly increases.

### **Food accessibility**

The access to food relates to the capability of the population to purchase enough food to satisfy energy and micronutrient requirements. This involves sufficient incomes to provide poor households with exchange entitlements to purchase food in the market and an adequate value of these exchange entitlements, which depends on the market prices of the respective food commodities.

There are two types of approaches to analyse the impact of climate change on food accessibility (Wheeler and von Braun, 2013). The first approach aims at assessing the impact on communities and households from a micro perspective. The Ricardian approach, pioneered by Mendelsohn, allows one to estimate the effects of climate change on farm income using econometric analysis of cross-sectional farm data. Jain (2007) finds that an increase of temperature and a reduction of rainfall, decrease net farm revenue for maize farmers in Zambia. The same holds for Zimbabwe where rain fed agriculture is significantly constrained by climatic factors, while irrigated farms are more resistant (Mano and Nhemachena, 2007). Empirical studies from Kenya and the United Republic of Tanzania suggest that agricultural incomes erode as result productivity losses (Kabubo-Mariara and Karanja, 2007; Sanga *et al.*, 2013). Among others, Di Falco *et al.*, (2011) emphasizes the need of adaptation to climate change and provide empirical evidence that households who adapt, earn higher agricultural incomes and are more food secure.

Overall, exposure to climate shocks destabilizes agricultural incomes and forces farmers to adapt by selling productive assets, job switching, and migration. In absence of formal insurance markets, risk sharing is a typical coping strategy of rural households. However, in the instance of weather shocks, which are spatially auto-correlated and affect

communities simultaneously, risk sharing networks collapse. On the other hand, these micro studies can also be used to assess the effects of climate change adaptation.

Macro models, that estimate the effect of yield changes on food availability, trade volumes, agricultural incomes, and prices, represent the second approach to assess the accessibility to food. The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) of the International Food Policy Research Institute (IFPRI) connects different climate change scenarios with economic consequences, including effects on food supply, market prices, energy and nutrient availability, and nutritional indicators like underweight and stunting (Nelson *et al.*, 2010). As opposed to micro models, the weakness of macro models is their limited capacity to account for adaptation measures. As a notable exemption, de Pinto *et al.* (2017) link inputs and outputs of three different models to use climate scenarios and the IMPACT model to estimate climate change effects on market prices and food security outcomes, with and without climate change adaptation. Under business as usual, international maize prices are expected to increase from 50 –100 percent with severe consequences on undernourishment of children. Estimating the impact on local prices is subject to great uncertainty regarding future consumer preferences and effects of regional and international trade. However, given the expected imbalances between supply and demand in the region, the country level studies in Waithaka *et al.* (2013) project maize prices to at least double until 2050 in all study countries.

### **Food utilization**

The impact of climate change on food utilization is least obvious, but its consequences must not be neglected. The concept of food utilization includes the nutritional aspect of food security as well as the biological capacity of the individual to make productive use of the food. Thus, it expands the traditional view by considering the impact of climate change on dietary quality of the food consumed and health aspects (Aberman and Tirado, 2014).

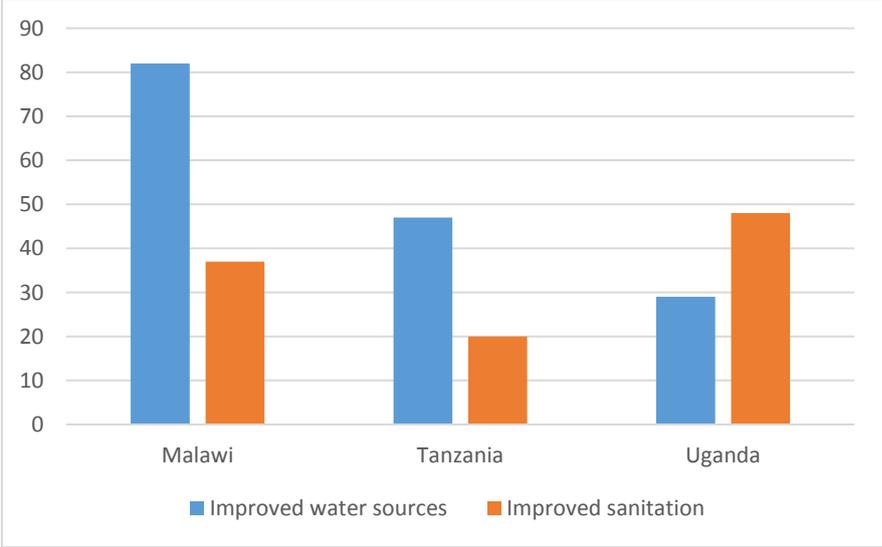
The increase in carbon dioxide in the atmosphere seems to have a direct link to the nutritional quality of crops. Studying data from 143 comparisons of crops cultivated in different experimental locations in Japan, Australia, and the United States, Myers *et al.* (2014) report a statistically significant decrease in the concentration of zinc and iron in rice, wheat, maize, soybeans, field peas, and sorghum. Given that anaemia due to a shortage of iron and zinc deficiency, in particular among young children, is widespread in the ESA region, a further decrease in the availability of these micronutrients has severe negative implications.

Moreover, climate change impinges on diet quality by attracting focus away to the production of staple food crops such as maize. However, next to inadequate energy consumption, micronutrient deficiency is a major cause for childhood growth disorders and increased vulnerability to illness for both children and adults. Most common are deficiencies in iron and vitamin A, which currently concern about 40 percent and 20 percent, respectively, of all children in the region (UNICEF, 2017). It is a well observed pattern that nutritional quality improves as income increases. When prices of staple foods increase, the purchasing power of households goes down. As a result of substitution and the negative income effect for vegetable and protein-rich products, higher prices for

staple are often associated with lower dietary diversity (d’Souza and Joliffe, 2014). For rural Tanzanian households, Abdulai and Aubert (2004) showed how an increase in maize prices reduced the demand for other nutrients, which directly translates into iron and vitamin A deficiency. In Ethiopia, food price increases between March 2012 and February 2013 forced households to reduce the number of meals per day and to switch to less preferred meals (Matz *et al.*, 2015).

The increase in temperature has additional effects, which influence food utilization and the health of the population. A generally hotter and more humid climate alters the conditions for food safety and provides a conducive environment for vector, water, and food-borne diseases (e.g. salmonellosis and listeriosis). The effects are alarming and a whole chapter of the fourth International Plant Protection Convention (IPPC) assessment report is designated to the topic. According to that report, hygienic conditions become very important, which is of concern as the prevalence of improved water and sanitation facilities is pretty low in ESA (Figure 2).

**Figure 2: Percentage of household with improved water sources and sanitation facilities**



Source: DHS (2016)

**Food stability**

The main determinant of the stability dimension of food security relates to the time dimension of the other food security dimensions. Climate change puts the stability of the food system at risk. Von Braun and Tadesse (2012) argue that, if the world food equation is in imbalance as it was during the global food crisis between 2007 and 2011, small shocks on the supply and demand side may have large impacts on price fluctuation. Stability in FNS is strongly affected by food price stability, as price fluctuations hit a household’s purchasing power when they spend a significant share of their income on food.

More frequent extreme weather events make the system prone to imbalances between supply and demand. Production instability indicates the stability of the system as it indicates the likelihood of such extreme events. Since demand and supply must match, there is a strong link between variability of supply (X) and consumption (C). Inter year carryover stocks (S) balance the variation in supply between agricultural seasons and entire crop cycles.<sup>4</sup> From the equality condition, Kornher and Kalkuhl (2016) derive the coefficient of variation of consumption as a function of the coefficient of variation of supply and the propensity to store ( $\gamma$ ) which is the constant average share of total available supply that is stored from one period to the other:

$$CV(C) = \sqrt{\frac{1-\gamma}{1+\gamma}} CV(X) \quad (1)$$

To account for population growth and the increasing trend in maize consumption, we compute the coefficient of variation from the per capita maize supply to measure the relative instability of the system. The production variability by country is shown in Table 3. The figures indicate large fluctuations in year-to-year maize production; above 20 percent for all countries except Burundi, the Republic of Mozambique (hereafter “Mozambique”)and Kenya. In addition, the figures reveal that stability has improved only in Burundi, Malawi, Somalia, Tanzania, Zambia, and Zimbabwe since 1960, while not improved in the other countries.

**Table 3: Per capita maize production variability in selected countries**

	1960-1979 (percent)	1980-1999 (percent)	2000-2014 (percent)
Burundi	7.5	14.2	17.1
Ethiopia	n.a.	27.1	21.6
Kenya	12.5	18.8	10.3
Malawi	10.1	18.9	22.5
Mozambique	16.8	26.5	19.4
Rwanda	31.0	36.1	77.1
Somalia	20.0	42.9	36.4
Tanzania	28.2	17.4	22.9
Uganda	28.1	22.5	24.9
Zambia	24.9	32.1	35.7
Zimbabwe	33.5	48.1	25.3

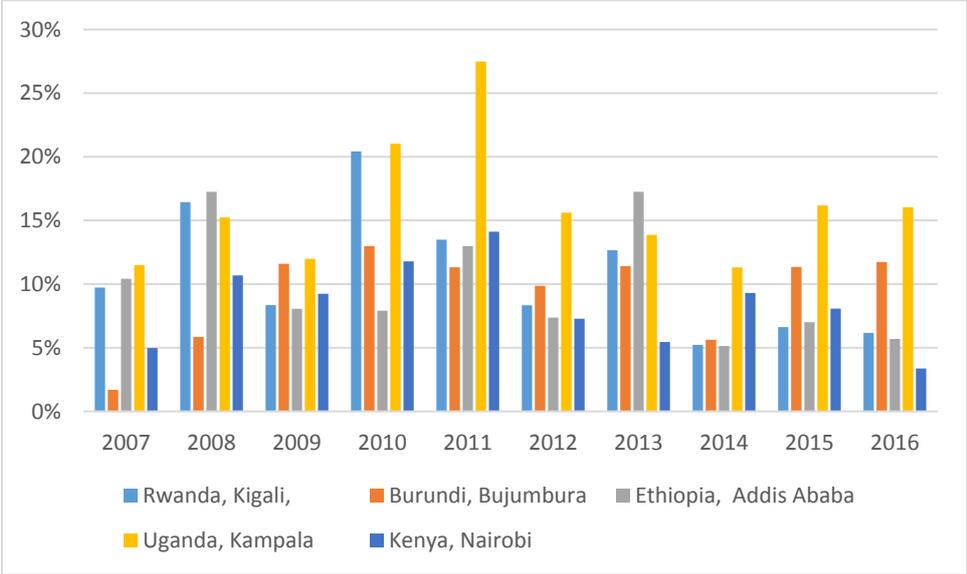
Source: Author’s calculation based on FAOSTAT (2017).

While the inter-year variability in production serves as an indicator for long-term instability of the food system, intra-year price fluctuations are more suitable to represent the short-term stability of the component of food security. Intra-annual price instability for each country in the ESA region is presented in Figure 3 and 4. Maize price volatility is computed from the standard deviation of price returns in markets of the capital of the respective country; thus they represent a de-trended coefficient of variation. While the outliers in maize price volatility in Zimbabwe in 2007 and 2008 are caused by general

<sup>4</sup> The market equality condition is given by:  $C_t = X_t - \Delta S_t$ .

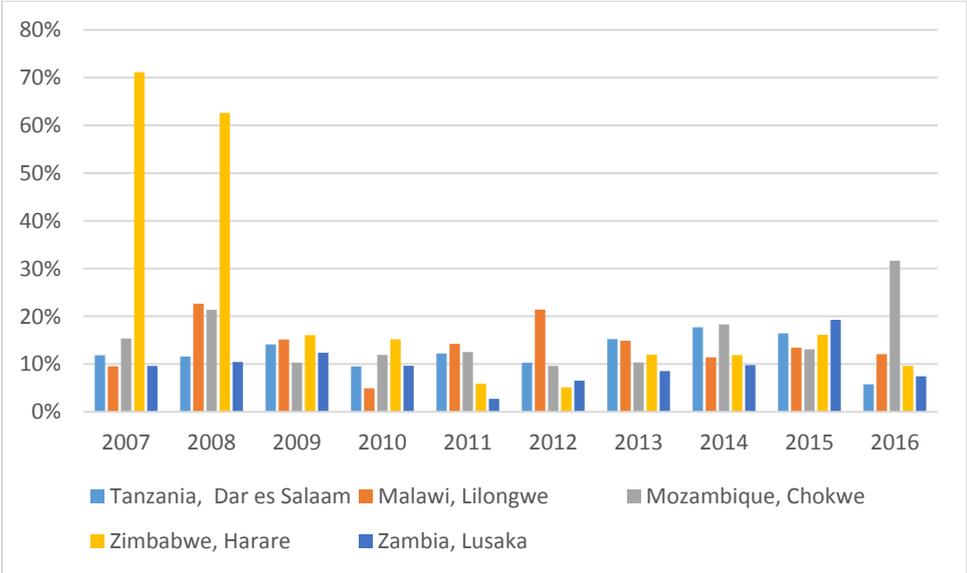
macroeconomic instability, volatility in all ESA countries is substantial, in many cases larger than 15 percent.

**Figure 3: Maize price volatility in Eastern African markets**



Source: Author’s calculation based on FAO GIEWS (2017).

**Figure 4: Maize price volatility in Southern African markets**



Source: Author’s calculation based on FAO GIEWS (2017), FEWSNET (2017c), and WFP VAM (2017).

## The maize market in Eastern and Southern Africa

Maize is by far the most important food crop in the ESA region accounting for a large share of energy requirements of the population (Table 5). Apart from human consumption, maize is also used as important feed for livestock. The utilization as input for biofuel production is however negligible in the region. Human consumption is highest in Malawi, Tanzania, Kenya, Zambia, and Zimbabwe, while the crop has lower importance in the remaining countries.<sup>5</sup> Consumers prefer white maize and use yellow maize primarily for feed manufacturing. Maize is predominantly consumed mixed with water as maize meal. Milling often takes place directly at the household or community level. However, in Kenya and Zambia, industrial processing of flour and subsequent retailing to consumers is more common (Chauvin *et al.*, 2017).

The importance of maize for smallholder farmers becomes apparent when looking at the share of maize in household income and expenditures as shown in Table 4. On average, from 6-21 percent of total household expenditures is spent on maize alone, while maize sales are responsible for 5.5-21 percent of total household income. The crop is concurrently indispensable as source for economic livelihood and energy supplier. No other crop is close to being as important in the region.

**Table 4: Importance of maize in the region**

	Budget share (percent)	Income share (percent)
United Republic of Tanzania	15.7	18.2
Malawi	20.9	21.3
Zambia	15.8	12.0
Uganda	6.0	5.5
Ethiopia	11.8	8.5

Source: Chauvin *et al.* (2017) based on LSMS data

Ethiopia and the United Republic of Tanzania are the largest producers in terms of total quantity, but, relative to the population size, maize production is highest in Malawi and Zambia, where per capita consumption is also highest. The ESA region, as a whole, is a net importer of maize and relies on exports from South Africa and sometimes from the United States and Latin America. Nevertheless, currently, intra-regional trade has an important role in buffering domestic production shocks (Davids *et al.*, 2016). Kenya, Mozambique, Rwanda, and Zimbabwe have a structural maize deficit, which needs to be compensated by food imports. For instance, exports from Uganda and the United Republic of Tanzania often supply deficit regions in Kenya (FEWSNET, 2017c).

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<sup>5</sup> Ethiopia, Burundi, Mozambique, Rwanda, Somalia, and Uganda.

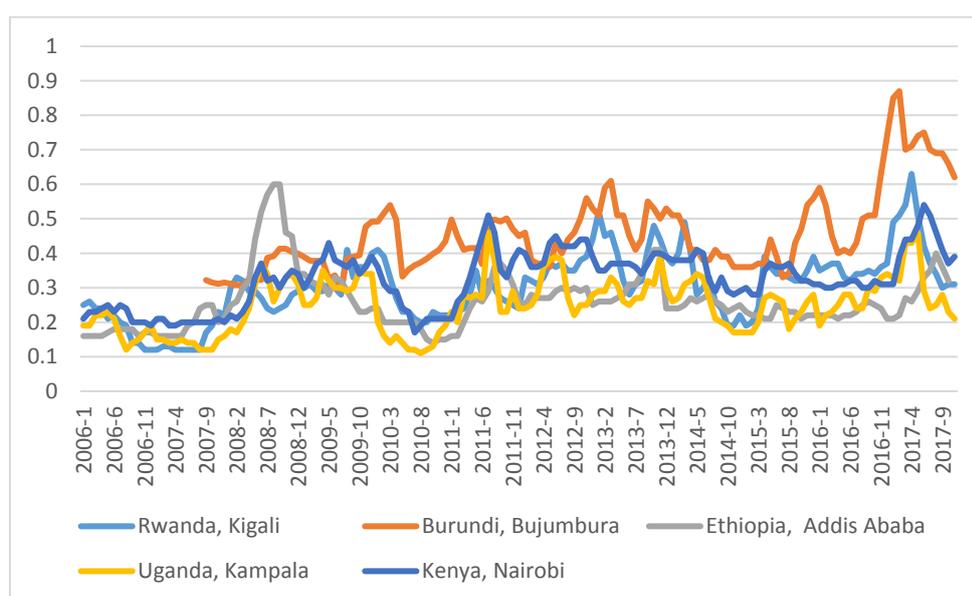
**Table 5: Supply and demand of maize in selected countries**

	Population (2013)	Production (2013)	Per capita consumption (2013)	Average trade balance (2010-2013)	Carryover stocks (2013)
	million	tonnes	Kg/cap/year	tonnes	tonnes
Burundi	9.6	162 000	n.a.	-23 797	5,000
Ethiopia	94.6	6 500 000	42.08	2 747	700 000
Kenya	44.8	3 600 000	76.20	-197 360	280 000
Malawi	16.5	3 600 000	129.24	75 094	800 000
Mozambique	26.4	1 200 000	54.56	-96 157	650 000
Rwanda	11.1	670 000	14.34	-82 665	135 000
Somalia	13.1	150 000	n.a.	69 353	0
United Republic of Tanzania	50.6	5 400 000	58.47	11 636	550 000
Uganda	37.5	2 700 000	48.95	106 090	305 300
Zambia	15.2	2 500 000	118.68	359 841	1 950 000
Zimbabwe	15.1	860 000	93.68	-342 076	200 000
<b>Total Region</b>	<b>335</b>	<b>27 342 000</b>		<b>-117 294</b>	<b>5 575 300</b>

Source: FAO GIEWS (2014) and FAOSTAT (2017)

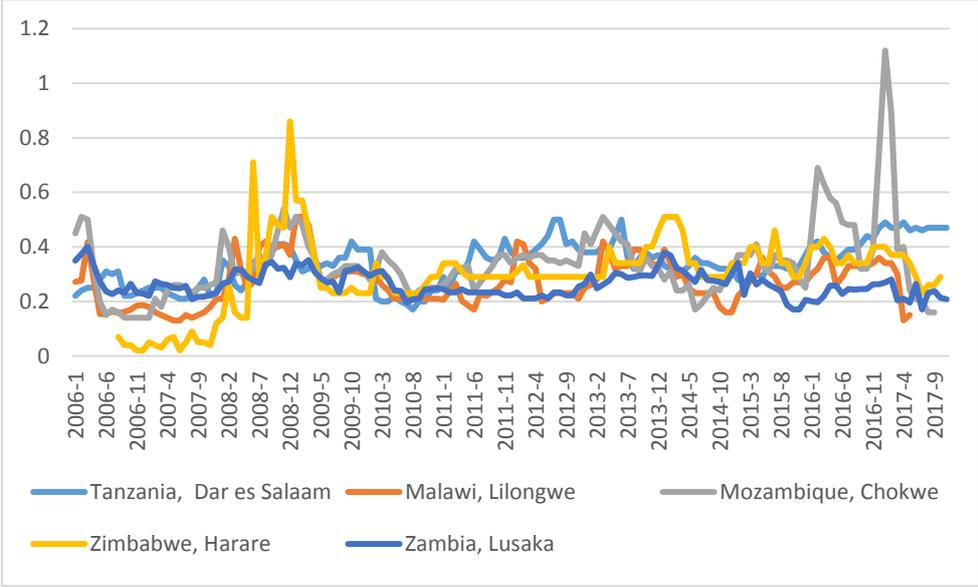
Co-movement of country specific maize price trends, as illustrated in Figure 5 and Figure 6, suggest that markets in the region are relatively well integrated. Although Southern African Development Community (SADC), and COMESA are officially free trade zones, in practice, trade flows are often restricted driven by national interests to stabilize domestic food supply (Porteous, 2017). However, Burke and Myers (2014) and Davids *et al.*, (2017) also show empirical evidence, that national markets are connected with markets in neighbouring through formal and informal trade. Several studies (e.g. Gross *et al.*, 2015) identify Kenyan markets (in particular Nairobi and Mombassa) as the lead markets in the region.

**Figure 5: Maize price (USD/kg) in Eastern African markets**



Source: FAO GIEWS (2017)

**Figure 6: Maize price (USD/kg) in Southern African markets**

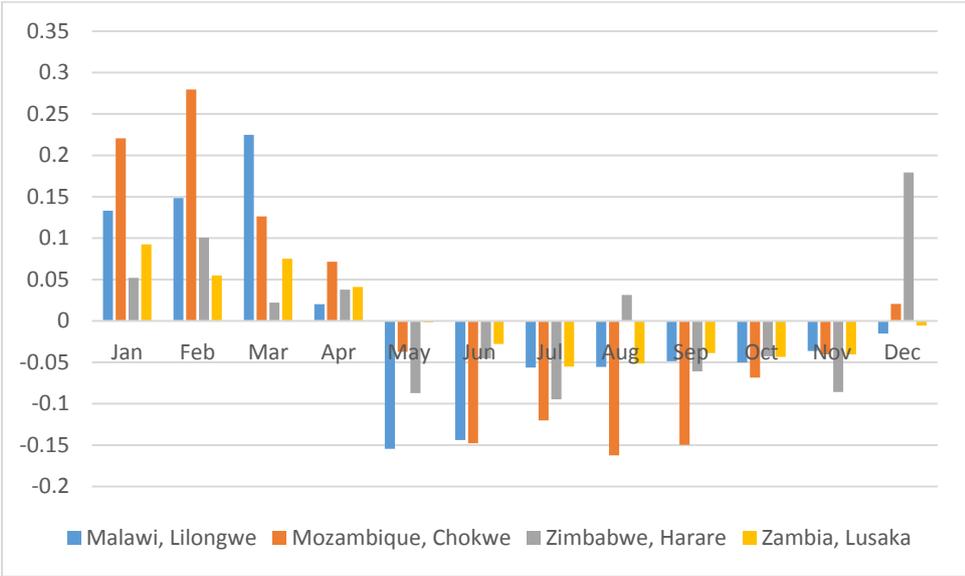


Source: FAO GIEWS (2017), FEWSNET (2017c), and WFP VAM (2017)

Agricultural markets in the region are exposed to strong seasonal price fluctuations with seasonal gaps of more than 50 percent (Gilbert *et al.*, 2017). Maize markets in the region are among the most volatile markets worldwide (Kornher, 2014). The seasonality of a price series can be computed by comparing the price in a given month to the prices within the whole year. The seasonal gap is then the differences between the maximum and minimum price within one calendar year. Applying the procedure to the price series from above, shows that seasonal gaps range between 38 percent and 44 percent in Malawi and Mozambique and 11 percent in the United Republic of Tanzania (Figure 7). The main reason for the seasonality lies in the seasonal nature of agriculture production. Moreover, the demand for staple food is price-inelastic and consumers are willing to pay higher prices, which offers arbitrage opportunities for traders. However, food storage across different periods enables all year supply. Limited storage capacity and high costs of inter-temporal arbitrage, as well as the non-existence of functional forward contracting (e.g. through commodity exchanges) are the major causes of the seasonal price variability.

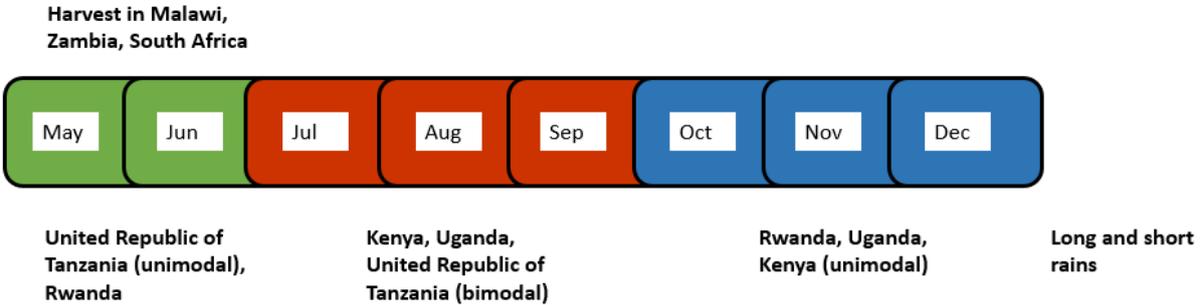
Intra-regional trade has limited capacity to reduce price seasonality as production cycles of maize are largely aligned within the region as shown by Figure. The possibility to plant and harvest twice a year is the main advantage for farmers in the United Republic of Tanzania, Rwanda, Uganda, Kenya, and Burundi. This is also a likely reason for lower seasonal variation in these countries. Intra-regional maize trade between Kenya and Uganda, which is the main trade route in eastern Africa, follows seasonal patterns peaking shortly after the respective harvests in February and September (FEWSNET, 2017c).

**Figure 7: Price seasonality in southern African markets**



Source: Author’s calculation based on FEWSNET, 2017c

**Figure 8: Production cycle for maize**



Source: Adapted from FEWSNET, 2017c

Price seasonality has a direct consequence on rural households, who often sell at low prices and (re)buy at a later time during the marketing season at higher prices (Burke *et al.*, 2017). It is often argued that this is driven by liquidity constraints in connection with unpostponable purchases (Stephens and Barrett, 2012). Further, high storage costs in rural areas may make traders to transport food to urban areas to store and to re-ship it to the rural areas in the lean season (Benirschka and Binkley, 1995). Climate change and its impact on the timing of annual rains is likely to affect price seasonality by shifting the seasonality. In addition, a reduction in the number of rainy days could reinforce existing seasonal variation with larger seasonal gaps (Pohl *et al.*, 2017).

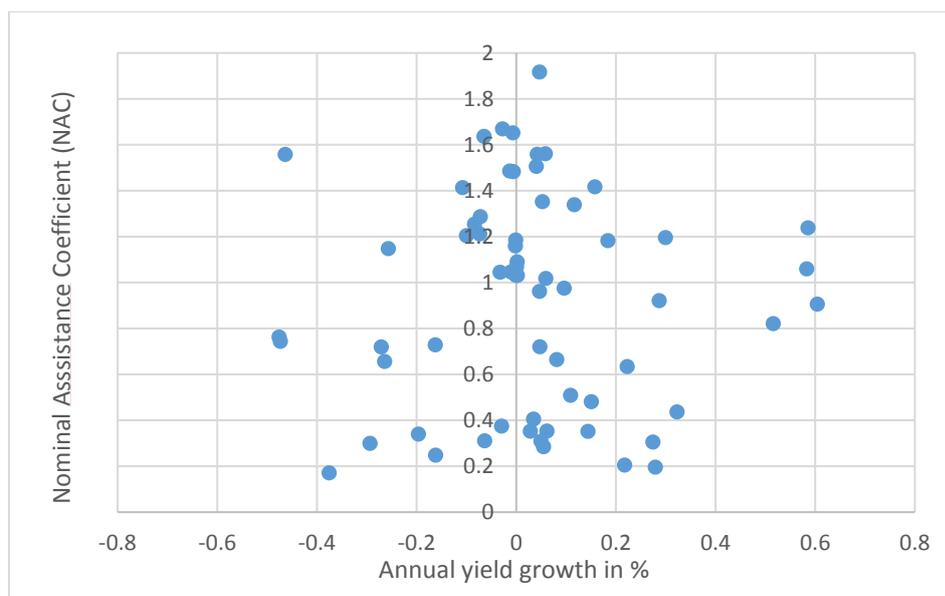
## The current policy environment

Current national agricultural policies in the ESA region, are not designed with the goal to directly address the challenges of climate change, but certain policies can indirectly address the effects of climate change. . For instance, input subsidies enable productivity gains and can offset declining productivity in consequence of drier and hotter climate. Therefore, there are clear linkages between climate change, agricultural production, trade activities, and government interventions. A list of the most common agricultural policies and the associated textbook economics of food policy analysis are shown in the technical appendix.

The level of distortions is usually measured by the nominal rate of assistance (NRA). The NRA represents the percentage differences between the potentially distorted producer price and the undistorted free market price at the border (either import or export parity). A positive NRA implies that governments raise producer prices to support the domestic producers. As opposed to this, a negative NRA is associated to a discrimination of domestic producers in favour of international imports and consumers. Thus, a negative NRA aids consumers. In the past, agricultural price policies in African countries often created a bias towards urban consumers (Anderson and Masters, 2008). Magrini *et al.*, (2017) analyse the effect of the Nominal Assistance Coefficient (NAC), a variant of the NRA, on all dimensions of food security. Their empirical findings suggest that a NAC around 1.2, which implies moderate support to agricultural producers, is most favourable to enhance food security.

In the ESA region, NAC levels for maize vary substantially across countries. In the United Republic of Tanzania and Ethiopia agricultural price policies tend to favour consumers, while policies in Burundi and Uganda aim at supporting producers. For Kenya, Malawi, and Mozambique NAC levels centre around 1 (MAFAP, 2017). Figure 9 shows no clear pattern regarding the association between domestic agricultural support and growth of annual yields suggesting no effects on agricultural productivity. Similarly, Chapote and Jayne (2009) argue that maize production has increased most significantly in countries with liberalized markets like Uganda and Mozambique. In light of climate change, when efficient resource usage becomes more important, efficiency losses in production can have negative long-run consequences on food availability. Moreover, inefficient production increases market prices and hampers accessibility to food. In the following, the individual support measures, employed by the countries in the ESA region, are screened and it will be investigated how they may contribute to food security in view of climatic changes.

**Figure 9: Correlation between NAC and yield growth**



Source: FAOSTAT (2017) and MAFAP (2017)

### **Counter-cyclical trade policies**

While trade policies are often used as an instrument to determine the domestic price level, to redistribute income, and to generate revenue, they can also be applied in a counter-cyclical manner to insulate the domestic market from international price fluctuations (Martin and Anderson, 2012). In doing so, export restrictions can reduce price instability in exporting countries, whereas import facilitation, through subsidizing imports, reduces volatility in importing countries (Kornher *et al.*, 2017). For instance, large rice exporting countries, such as the Republic of India and the Socialist Republic of Viet Nam banned exports to control domestic supply during the world food crisis in 2007/2008. Kornher *et al.*, (2017), in support of the arguments by Martin and Anderson (2012), provide empirical evidence that, on average, counter cyclical policy changes did reduce intra-annual volatility for countries involved in food trade in the period between 2000 and 2011. However, this practice generates negative externalities to food importing countries by reducing available supply at international markets.

Governments in the ESA region regularly limit export quantities by imposing bans and quotas. For instance, Zambia introduced short term export bans for maize in 2002, 2005, 2008, 2013, and 2016; the United Republic of Tanzania banned exports in 2008, 2010, and 2011; Malawi in 2005, 2008, 2011, and 2017; Kenya in 2008 and 2017; Ethiopia in 2006, 2008, 2010, and 2011 (FAPDA, 2017; Porteous, 2017). On the other hand, a reduction of import tariffs was used by Burundi in 2008 and 2017; Rwanda in 2010; Kenya on several occasions between 2008 and 2010; the United Republic of Tanzania in 2007 and 2008; Zimbabwe in 2010 and 2011 (FAPDA, 2017). Most of the export restrictions were related to local supply shortages, while the reduction of import tariffs was used to reduce the consumer price for imported maize.

According to Sitko *et al.* (2014), these trade regulations had insignificant to negative consequence on domestic price stability in ESA countries. Similarly, Porteous (2017) shows that short-term export bans were not successful in lowering prices in the

implementing country, but may have exacerbated the situation in food deficit areas. This surprising result could be explained by the collective action problem described by Martin and Anderson (2012), which arises when importing countries reduce import tariffs in response to export restriction of exporting countries. Hence, the price differential remains the same, but the terms of trade improve towards exporting countries.

The possible short-run benefits of temporary export restrictions for consumers need to be weighed against the distortions of intervening in food markets and the long-rung unpredictability caused by ad hoc trade policy changes (Pieters and Swinnen, 2016). For instance, maize export bans lowered producer prices and wages, which led to increased rural poverty in the United Republic of Tanzania (Diao and Kennedy, 2016). Spatial and temporal variation in prices represent the basis for profitable business activities in storage and trade. Inconsistent policy-making creates an unstable operating environment for traders and investors and, through the retirement of businesses, can cause additional market volatility, as seen in Kenyan maize markets (Maitre d'Hotel *et al.*, 2015).

### ***Public food reserve and price stabilization***

Usually, the market mechanism efficiently stabilizes commodity prices across space and time, however, not everywhere. In developing countries, where high costs of capital, for transactions, and the maintenance of warehouse (including drying) prevail, commodity storage is expensive. Consequently, the free market stock level often falls short of the government's target stock level associated with the desired level of price stability. In this case, it may be rational to engage in public stockholding.

Historically, food price stabilization has been of great relevance in ESA countries for many years, which is largely related to the strategic importance of maize as a commodity. Nowadays, in spite of the liberalization of agricultural markets, public price stabilization programmes still dominate the policy environment in these countries. Public grain storage has been used for two purposes. First, to stabilize prices through buffer stocks and second, to facilitate emergency food distribution through strategic reserves (World Bank, 2012). Table 6 presents a list of national price stabilization programmes and provides information on current stock levels/ targets of the national reserve from reliable sources. The significance of the reserve can be evaluated by comparing its target level to national production and consumption levels in Table 5.

In contrast to strategic reserves, buffer stock schemes do not have target stock levels and their degree of intervention can be rated by the difference between free market and intervention prices. Buffer stock programmes, like the Food Reserve Agency (FRA) in Zambia and the Agricultural Development and Marketing Corporation (ADMARC) in Malawi act as a normal market player buying and selling the food commodity at all times. By announcing pre-harvest floor prices, at which the government institutions buys in any case, it takes the excess supply off the market. At the end of the agricultural season, when prices usually increase, stocks are re-allocated to the market at a maximum price (ceiling).

**Table 6: Overview about public price stabilization programmes and strategic reserves**

	Strategic reserve (Target level)	Buffer stock scheme	Source:
Burundi	o	o	
Ethiopia	Only teff and wheat	o	
Kenya	Strategic Grain Reserve 4 mil. bags (actually 1.5 mil.) equivalent to 360,000	National Cereals and Produce Board	USDA FAS (2017)
Malawi	Strategic Grain Reserve (250,000 mt)	Agricultural Development and Marketing Corporation	WFP (2016)
Mozambique	o	o	
Rwanda	National Strategic Reserve (187,000 mt)	o	USAID (2013)
Somalia	o	o	
United Republic of Tanzania	National Food Reserve Agency (150,000 mt)	o	ICTSD (2016)
Uganda	o	o	
Zambia	Food Reserve Agency (500,000 mt)	Food Reserve Agency	FEWSNET (2017b)
Zimbabwe	Strategic Grain Reserve (500,000 mt)	Grain Marketing Board	FEWSNET (2016)

Note: o indicates no reserve or buffer stock scheme in place.

In theory, the public institution substitutes for missing or limited private storage and stabilizes the price across the agricultural season and, if needed, between different marketing years. Empirical evidence from Kenya and Zambia shows that maize prices were less variable than they would have been without state intervention since the 1990s. In Kenya, maize marketing policy implemented by the National Cereals and Produce Board (NCPB) reduced the coefficient of variation of wholesale prices from 33 – 45 percent (Jayne *et al.*, 2008). For Zambia, a simulation by Mason and Myers (2013) yielded a reduction of maize price variability by 14 – 36 percent through the operation of the Food Reserve Agency (FRA). The evidence is not limited to the region and maize (e.g. Martinez *et al.*, 1998). Thus, buffer stocks can partially absorb the instability caused by climate change and contribute to the stability of the food system in the short-run. By stabilizing consumer prices during crises, stocks also ease market access at affordable prices, although intervening through buffer stocks is associated with a general increase in prices that benefits wealthier producers (Jayne *et al.*, 2008; Mason and Myers, 2013).

In spite of large price stabilization programmes, price variability in Malawi, Zambia, and Zimbabwe is higher than in many neighbouring countries, who rely on trade (mainly regional) to stabilize markets (Minot, 2014). This may well be a *hen-and-egg problem* but could be also driven by improper management of the stabilization reserve. Fixing the producer floor prices sends signals to producers and makes public procurement a direct competitor to local traders. In 2008 in Kenya, the NCPB set procurement prices too low and farmers refused to sell in anticipation of price increases. After increasing the procurement price, subsidized maize distribution was undermined by fraud and flawed management decisions (Nzuma *et al.*, 2013). ADMARC in Malawi is reported to often

purchase from traders instead of farmers. When maize prices rose rapidly in 2008, due to inadequate financial endowment, ADMARC was not able to buy as much as they had intended to at the announced procurement price (Jayne *et al.*, 2010). Moreover, uncertainty about how ADMARC will react to different market situations (e.g. by subsidized food distribution) hampers private sector imports in times of supply shortages (WFP, 2016).

In any case, buffer stock schemes tie substantial financial resources. It is estimated that spending on the public stock programme in Zambia was equivalent to about 1.9 percent of the Zambian GDP in 2011. Less than half of the total costs were spent on subsidized food distribution (42.5 percent), while storing the inventory and transport accounted for 18 percent and 16 percent, respectively, of the bill (World Bank, 2012). Keeping larger reserves to achieve higher price stability targets is associated with exponentially increasing fiscal costs (Larson *et al.*, 2012; Kornher and Kalkuhl, 2016). Finally, food reserves need to be rotated at a regular base to prevent losses due to deterioration; if not done additional costs will arise. This happened for instance in Kenya, where NCPB struggled to sell off more than three million bags of six-year old maize stocks in 2015.<sup>6</sup>

At first sight, the benefits of public price stabilization programmes are not limited to the dimensions stability and accessibility, but also increase the availability of food commodities in the system by making production more profitable. This, however, might be a fallacy. Although producer prices increase (and so do agricultural returns), maize production in countries pursuing food price stabilization policies, with the exception of Malawi, has not grown at rates to match production growth in other countries in Sub-Saharan Africa. By artificially boosting agricultural returns through subsidized market purchases, inefficient producers remain in the market and necessary investments to increase agricultural total factor productivity are not undertaken, which generates losses to the whole system. Moreover, keeping price instability at a minimum makes storage activities unprofitable and pushes private traders and investors out of the market. In Zambia, private trading activities have essentially stopped, while increasing necessary stock rotation by ADMARC in Malawi endanger private trading business (World Bank, 2012). In the described manner, public price stabilization programmes harm the food system by reducing long-term food availability and stability.

Different to buffer stock, strategic reserves hold food stocks to act in an emergency situation only. In the instance of a drought or a price hike, the governments distribute subsidized (or entirely free) food to the most vulnerable population to bridge the time until food imports arrive or to bypass weak infrastructure. In doing so, reserves are very efficient to overcome temporary supply shortages. Strategic reserves do not affect the market during regular times, but only intervene in markets during severe food crises and if the private sector fails to provide sufficient supply. Consequently, both market distortions and the financial contribution are lower, as compared to price stabilization programmes, depending on how large the reserves are (Maunder 2013).

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<sup>6</sup> [https://www.the-star.co.ke/news/2015/12/29/ncpb-maize-stocks-rise-as-flour-prices-remain-high\\_c1266395](https://www.the-star.co.ke/news/2015/12/29/ncpb-maize-stocks-rise-as-flour-prices-remain-high_c1266395).

However, the stocks of strategic reserves also need to be renewed regularly, wherefore engagement in market purchases and sales becomes necessary. If these purchases and sales are associated to public price announcements, strategic reserves and buffer stocks often become undistinguishable. However, if properly managed, reserves can be an important piece of the puzzle to achieve food security in all dimensions in a world exposed to changing climate. A key to the effective use of emergency food stocks is the successful integration into a comprehensive social safety net system, which allows targeted food distribution (Rashid and Lemma, 2011).

Strategic reserves represent an efficient instrument to mitigate severe food crises, such as the drought in Southern Africa in 2016, when multiple countries are affected and cross border trade is unlikely to happen (WFP, 2016). Moreover, they come at moderate fiscal costs, as compared to stabilization reserves, and without significant impact on private business activities. In response to the international food crises in the last decade, international and regional food reserves have been in the public debate. Since they make use of risk pooling to reduce required target stock levels, substantial financial resources are saved whenever production shocks are not perfectly correlated among member countries (Koester 1986). However, its implementation may not be trivial. The selection of warehouse facilitates needs to minimize transportation costs and needs to take into account the capacity of the regional road network. In addition to that, governance issues need to be determined defining clear rules of financial contributions and stock releases. Ideally, this task could be taken over by an international organization, such as the World Food Program (Briones 2011; Kornher and Kalkuhl 2016).

### *Input subsidies*

With about a total of USD 1 billion, which amount to almost a third of total public expenditures on agriculture, input subsidy programmes are one of Africa's most important agricultural policies. The aim of such programmes is to push agricultural productivity by reducing the costs of input factors, such as fertilizer and seeds. However, input subsidy programmes are often untargeted and do not necessarily benefit deprived smallholders. In addition, Jayne and Rashid (2013) argue that politicians often misuse these programmes to prove their commitment to their constituencies.

Given that fertilizer use in Africa is still very low, there may be a great potential for improving agricultural productivity. Much of the productivity gains of the Green Revolution have been achieved by increasing use of chemical and organic fertilizers, wherefore irrigation and mechanization technologies received less attention by policy makers (Sheahan and Barrett, 2017). However, in their review, Jayne and Rashid (2013) do report only marginal profitability, if not unprofitability, of fertilizer use, which they attribute to high fertilizer prices and a low proportion of crop area under irrigation. Crop responses also depend on geographical remoteness, irrigation practices, and soil quality.

A recent study by Sheahan and Barrett (2017) questions the myths about low fertilizer use in Africa using micro level data. They find that inorganic fertilizer use in Ethiopia and Malawi is well above widely presumed levels. Lower fertilizer prices in these countries

could be an explanation. In Malawi, for instance, the Input Subsidy Programme started in 2005 boosting yield growth in the first years of implementation. Chibwana *et al.* (2010) ascertain positive yield gains for households who received the input vouchers, which increase in combination with improved seeds. Apart from the direct returns to productivity and production, increasing land productivity allows planting of high value crops and let farm employment and agricultural wages rise (Arndt *et al.*, 2016). Similarly, Zambia's Farmer Input Support Programme is found to increase maize yields and total maize output, however, without the indirect gains found for Malawi. In addition to that, the programme is expected to crowd out commercial agro-input dealers (Mason *et al.*, 2013). In Kenya and the United Republic of Tanzania input subsidies and fertilizer distribution programmes stimulated adoption and increased yield, but productivity growth slowed down with a reduction of public spending on these programmes (Aylward *et al.*, 2015). However, both input subsidy programmes in Malawi and Zambia had only little effect on market retail prices of maize. Thus, benefits are limited to the farmers who receive the subsidy and effects on food accessibility are low (Ricker-Gilbert *et al.*, 2013).

Importantly, increased chemical fertilizer usage must not be understood as a substitute for employing soil organic matter. Marenya and Barrett (2009) criticize that many available studies on crop responses of fertilizer use neglect the linkage with soil organic matter. In degraded soils fertilizer use is often unprofitable. Multi-crop systems involving legumes are important to restoring soil organic carbon and make fertilizer applications yield enhancing. Jayne and Rashid (2013) conclude that input subsidy programmes increase agricultural production in the short run, especially if input use is limited. However, they argue comparing costs and benefits of other agricultural policies may have a better cost benefit ratio. In particular, these programmes tie public financial resources and in this way negatively affect food accessibility in the long-run. Mason *et al.* (2017) also emphasize that differences in design and implementation, in particular proper targeting, explain why some programmes are more effective than others.

### **Safety net policies**

Economically, the most efficient policy involves direct monetary transfers to the poor, which entitle them to additional consumption. By transferring money unconditionally, the allocative decision remains with the beneficiaries without causing distortions. However, such income transfers are the exception in developing countries. Instead, societies often provide direct subsidies for key products to alleviate extreme poverty. Food is often considered to be a merit good justifying the special treatment. The programmes can target special groups of beneficiaries or provide general subsidies on food (Garcia and Moore, 2012). Most common targeted food subsidy programmes include dual prices systems, in which eligible households pay a lower market price in special shops, food stamps, and in-kind transfer programmes like food for work and school feeding programmes.

In consequence of the transfer or the subsidy the demand curve shifts to the right increasing the equilibrium price. The higher food price can create a stimulus to producers causing more intensive input use. Rising output and agricultural incomes in subsequent production cycles in turn increase demand and benefit household in the whole economy. Additional household income can also trigger additional spending. Thus, safety net

programmes can be a case for multiplier effects (Hanson, 2010) increasing food availability and accessibility in short and long term.

In Africa, safety net programmes are typically small and fragmented and implemented for a short time related to an emergency situation. These programmes are often financed and implemented by donor organizations without sufficient targeting of the vulnerable population. As a result, although large amounts of money are spent, many safety net programmes are ineffective (el Ninno and Mills, 2015). Monchuk (2013) provides a detailed review about the different safety net programmes implemented in sub-Saharan Africa. Accordingly, food for work and school feeding programmes are most common. Targeted cash transfers to the poor in Malawi and the United Republic of Tanzania are often limited to a special group and do not serve a larger population. However, the Cash Transfer for Orphans and Vulnerable Children and the Hunger Safety Net Programme in Kenya and the Vision 2020 Umurenge Program in Rwanda are poverty-targeted programmes in the process of being up-scaled nationwide. Beneficiaries of the Hunger Safety Net Programme are less food insecure, eating more meals, having higher consumption expenditures, and are 10 percent less likely to fall below the national poverty line (Merttens *et al.*, 2013).

Moreover, Ethiopia's Productive Safety Net Programme and the Food Subsidy Programme in Mozambique provide benefits to more than 100,000 beneficiaries, however, at a relative small scale (Garcia and Moore, 2012). The Productive Safety Net Programme targets household that are both food insecure and asset poor and consists of two tiers; first, a public sector employment programme, and second, direct payments to severely vulnerable beneficiaries. A recent evaluation yielded positive a positive impact of the transfer component of the programme on school attendance, but the public employment programme increased child labour (Berhane *et al.*, 2017). This illustrates the need for proper programme implementation and evaluation to avoid unintended outcomes of the safety net programme.

**Table 7: Evaluation of agricultural policies on food security in the short and long term**

	Food security dimension					
	Availability		Access		Stability	
	Short-run	Long-run	Short-run	Long-run	Short-run	Long-run
Price stabilization programme	+	-	+	?	+	?
Emergency food reserve	+	0	+	+	+	+
Domestic support	+	-	+	-	0	0
Input subsidies	+	?	+	?	0	0
Safety net policies	+	+	+	+	0	0
Counter-cyclical Trade policy	+	-	+	-	+	-

Note: 0 indicates no effect on respective dimension.

Source: Author's illustration.

## Mitigation and adaption policies

Mitigation and adaptation policies both address climate change. Adaptation is the response to climate change to deal with the consequences, while mitigation instruments have the objective to slow down or stop climate change. Ideally, adaptation and mitigation policies should complement one another, however, there may be obvious conflicts between the two. Adaptation to climate change may even result in additional greenhouse gas emissions. For instance, adapting to production risks by diversifying income through livestock farming increases emissions. Moreover, deforestation and the sale of timber generate income foreign exchange earnings, but releases sequestered carbon to the atmosphere (IPCC, 2014).

In order to ensure global warming remains well below 2°C above pre-industrial levels requires halving of carbon dioxide and GHG emissions by 2050 (IPCC, 2016). Africa's share in global GHG emissions is only about 4 percent, while the largest part comes from deforestation and agricultural production. Due to its relatively low contribution to global emissions, climate change mitigation in agriculture has a low potential for a significant control of global warming (Collier, 2008). Therefore, national policies often focus on adaptation to climate change.

According to the classification by Smit and Skinner (2002), adaptation to climate change can be classified into four categories according to the involvement of different agents (producers, industries, governments), or in other words, the level at which the adaptation measures needs to be implemented. First, the provision of technological developments, which may be employed by farmers affected by climate change. This involves crop development, weather and climate information systems, and resource management innovations. The provision of new improved crop varieties allows increasing agricultural productivity under water and heat stress. Detailed weather information allows better decision making about planting and harvesting. For instance, progress have been made to provide farmers with daily weather updates through customized services.<sup>7</sup> Last, resource management strategies aim at water and nutrient conservation in the soil. The provision of technological advances requires research and development activities in the respective industry. In addition, government policies need to create a fertile environment for research activities and need to provide a legal framework allowing improved technologies in the market. Liberalizing the national seed sector is an important condition for a greater availability improved crop varieties and hybrids.

The development of drought tolerant maize varieties has been put at the top of the agenda of biotechnological companies and research centres in the region for a long time. The Drought Tolerant Maize for Africa (DTMA) project was launched in 2006. Since then, the initiative made 60 hybrids and 57 open pollinated varieties available to smallholder farmers. Seed multiplication of these varieties is particularly successful in Malawi, Kenya,

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<sup>7</sup> <https://www.standardmedia.co.ke/business/article/2001258917/why-accurate-weather-forecasts-are-essential-for-businesses>.

Zambia, and Zimbabwe (CIMMYT, 2017). Nevertheless, seed certification is often delayed and regional seed markets lack harmonization of regional laws and regulations, which makes market entry less attractive for private breeders. As a response, the DTMA Seed Scaling (DTMASS) project was established as a follow-up project to increase demand and availability of seeds. Langyintuo *et al.* (2010) identifies credit constraints of seed entrepreneurs and limited exchange between the private and public sector as additional bottlenecks in the maize seed value chain.

The second category of adaptation strategies describes institutional responses to climate change, which should support risk management strategies. Among these strategies are agricultural subsidy and support programmes, crop insurance, and resource management programmes, such as land and water use practices. Support programmes should provide compensation for disaster related income losses of farmers. These programmes require sufficient public financial resources, which are not always available in developing countries. The adoption of sustainable resource management practices also lacks financial incentives offered to farmers. However, the promotion of adoption of these technologies is part of the national climate change adaptation and mitigation strategies and local agricultural extension officers can initiate adaptation by spreading knowledge and supporting the implementation (di Falco *et al.*, 2011).

The last two categories of adaptation options are implemented at the farm level. On the one hand, farm production practices, such as changing to other crops or varieties, shifting planting dates, diversifying agricultural incomes, fallow and minimum tillage practices, irrigation, as well as soil and water conservation. On the other hand, farmers can adapt to climate change by using financial instruments. These instruments include crop insurance, contract farming, inventory credit, informal risk sharing, and income diversification outside the agricultural sector.

Crop choice and shifting planting dates are adaptation measures easy to implement, but without great potential to improve agricultural productivity and to increase incomes in ESA countries (Waha *et al.*, 2013). The adoption of other farm level practices often requires financial investments, public infrastructure, and the know how to employ the new agricultural practice. In the subsequent section, selected production practices are discussed in more detail including the barriers to their wider adoption.

Besides changing agricultural practices, it appears important to develop financial adaptation measures at the same time. These measures should be able to offset income losses as result of unfortunate weather events and provide financial resources for investment in adaptation instruments. Currently, the provision of financial services, such as credit and insurance is also limited in the region due to high transaction costs and asymmetric information between smallholder farmers and insurance companies. Micro insurance programmes, such as weather index insurance, have the potential for great diffusion as they reduce operational costs and are affordable for a large number of

farmers. However, the uptake of weather index insurance remains low, partly explained by the fact that actual losses are imperfectly correlated with indemnity payments (Binswanger-Mkhize, 2012). On the other hand, it is necessary to make sure that such programmes do not impede structural adjustment of the agricultural sector, such as adoption of new and suitable technologies, migration, income diversification, as well as other adaptation strategies.

As one example for weather index insurance, the Syngenta Foundation launched a pilot project in 2009. By 2012, the programme had insured about 65,000 farmers in Kenya and Rwanda and was transferred into a for-profit enterprise (Agriculture and Climate Risk Enterprise Ltd. (ACRE)) in 2014. Currently, more than 1 million farmers in Kenya, Rwanda, and the United Republic of Tanzania are insured against losses of more than 56 million USD. ACRE is an intermediary institutions that links different actors in the value chain, in particular farmers, local insurers, re-insurers, as well as financial institutions (Ceballos *et al.*, 2017).

To enhance adaptation and mitigation it is necessary to provide a supportive policy environment that guides stakeholders in planning and implementing adaptation interventions. To advance this progress in the ESA region, the three regional communities namely Common Market for Eastern and Southern Africa (COMESA), Southern African Development Community (SADC) and the East African Community (EAC) developed a common Programme on Climate Change Adaptation and Mitigation. The programme includes the implementation of national and regional laws, regulations, and strategies, as well as the commitment by all countries to participate in the Tripartite Free Trade Area (TFTA) (Viljoen, 2013). The programme constitutes of several initiatives addressing the various challenges of climate change and show the commitment of national governments to take actions at national and regional level. However, it needs to be seen whether its plans are able to improve the adaptive capacity of the population in ESA countries. In particular, the technical and financial capacity to support adaptation at farmer level needs to be enhanced.

### **The gains of trade liberalization**

At the heart of the Smithsonian theory, specialization and the division of labour in combination with the exchange of goods and services offers great potential to generate additional wealth. According to the neoclassical trade theory, comparative advantages in the production of agricultural commodities source the welfare gains of international trade. There are both static and dynamic gains of international trade. Static gains emerge as direct welfare gains from the introduction of foreign trade to a closed economy in a specific economic sector. The cheaper production in exchange for another good – produced at lower (relative) costs in the exporting country – carries the jump to a higher indifference curve, as compared to the no trade situation. The welfare gains for both trade partners are brought about by reallocation of resources and the associated increase in overall efficiency.

Trade liberalization also represents an adaptation strategy, as it addresses the uncertainty in food supply induced by climate change. This is of particular importance as

the spatial patterns of climate change impacts remain unclear (Stevanović *et al.*, 2016). Integrated markets are able to respond quickly to spatial variability in agricultural production by reallocating available food between different countries. Since global maize production is relatively stable, as compared to national production, trade liberalization could increase maize supply substantially in case of extreme weather events and subsequent production failures.

Besides the immediate effect on food availability, trade liberalization involves dynamic changes which include long-term adjustments in the structure of the economy of a country. This involves shifts of production inputs and land use from one crop to another, which has implications for the structure of the whole economy, and is accompanied by redistribution of economic welfare between producers and consumers. In addition, uncompetitive agricultural producers will be squeezed out of the market. There are winners and losers as the result of structural adjustments in the agricultural sector.

To model these changes, general and partial equilibrium models, such as the IMPACT model and the Modular Applied GeNERal Equilibrium Tool (MAGNET) of the Wageningen Economic Research team at Wageningen University, are employed. MAGNET is a general equilibrium model which describes the determination of commodity prices, production, and trade between countries. It can be used to assess the economic consequences of changes to the world economy, such as changes in trade policies. The model differentiates between several regions in the world, amongst Eastern Africa and the Rest of Southern Africa (Southern Africa without South Africa), and several commodities. For the Eastern African region, the commodity group *other grains* consists mainly of maize.

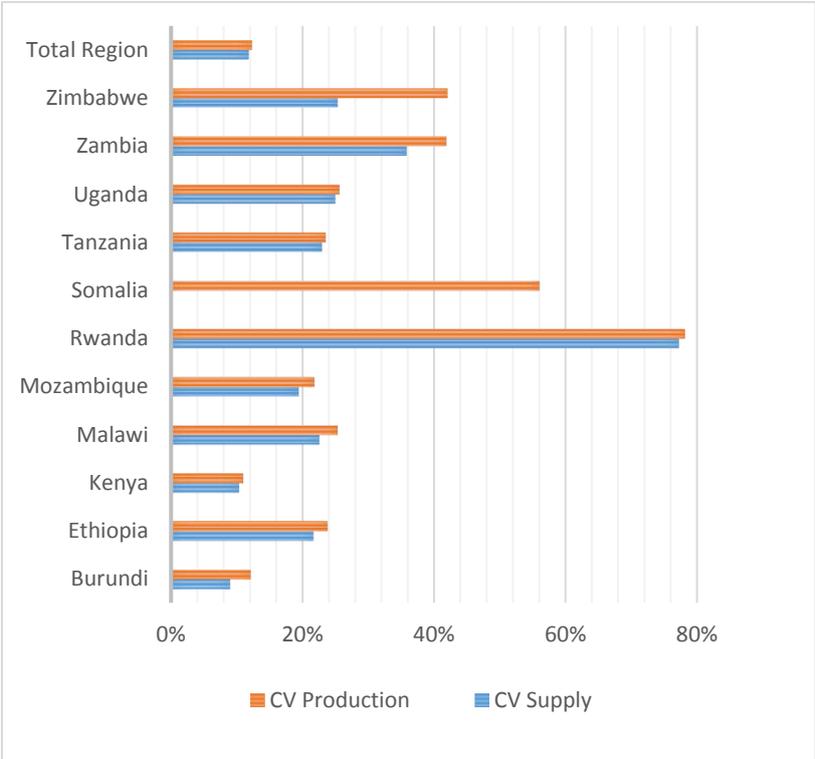
In a current attempt, as part of the 2018 edition of SOCO, the potential of trade liberalization as an adaptation tool to climate change is evaluated. This was done by comparing the impacts of climate change in a baseline scenario as compared the impacts of climate change with complete trade liberalization. The differential between the two scenarios illustrates how trade liberalization mitigates part of the climate change impacts. In both regions, the model predicts slight reduction in maize production and consumption under climate change. However, the production shortfall can be offset by trade integration.

More interestingly, as a result of changes in the comparative advantage in agricultural production, the MAGNET model simulates changes in trade values for several commodities. The simulation results reveal an increase in maize exports of USD 6.5 million (2011 prices) by countries in Eastern Africa until 2050. This increase is partly driven by additional intra-regional trade and mostly caused by additional exports to Southern Africa (3.69 million USD). At the same time, imports would increase by USD 6 million, which would change the net trade position of the region towards net exporter. In the free trade scenario (with climate change), the increase in food exports reduces to USD 4.6 million caused by a decline in intra-regional trade. Instead, the region is projected to raise imports (+USD 25 million), mainly from Russia (+USD 53 million), to satisfy food demand, while reducing imports from Southern America (-29 mil. USD). Thus, trade liberalization is likely to offset production shortfalls, but increases import dependency and boosts global trade for Eastern African countries.

For Southern Africa (excluding South Africa), the results of the MAGNET simulations are somewhat distinct. Climate change and status quo trade policies are projected to decrease maize imports by USD 49 million by 2050, while exports are kept constant. This is driven by a sharp decline of imports from South Africa (- USD 117 million), although imports from Brazil and Southern America are projected to increase. Under the free trade scenario, intra-regional trade is projected to accelerate, while the decline in imports from South Africa would be even more pronounced than in the climate change scenario (without free trade).

Overall, the impacts of climate change on agri-food production are associated to a GDP loss of 0.07 percent for East Africa and 0.24 percent for Southern Africa. By contrast, trade liberalization for agri-food products (without climate change impacts) would increase the regional GDP by around 0.3 percent in both regions. The positive impact of trade liberalization also remain if climate change impacts are considered. However, the positive impacts are not equally distributed. Producers benefit from higher food prices in consequence of climate change. By contrast, consumers lose in the climate change scenario, but benefit from lower prices with trade liberalization. The exact re-distributional effects depend on the elasticities of supply and demand (Stevanović *et al.*, 2016).

**Figure 10: Variability of year-to-year maize production and supply, 2000 - 2015**



Source: Author’s computation based on FAOSTAT (2017).

While full trade liberalization at the global scale may not be realistic, regional trade liberalization is *de jure* in place in the SADC and COMESA region. However, currently it is *de facto* not implemented. If we assume international maize imports are too expensive, due to high transaction costs, regional trade liberalization could have similar effects. The region specific food security gains from trade liberalization depend on the correlation of agricultural production shocks across the countries in the region. Following Koester (1986), regional trade integration, in absence of trade restrictions, can act like an insurance scheme pooling production risk of policyholders.

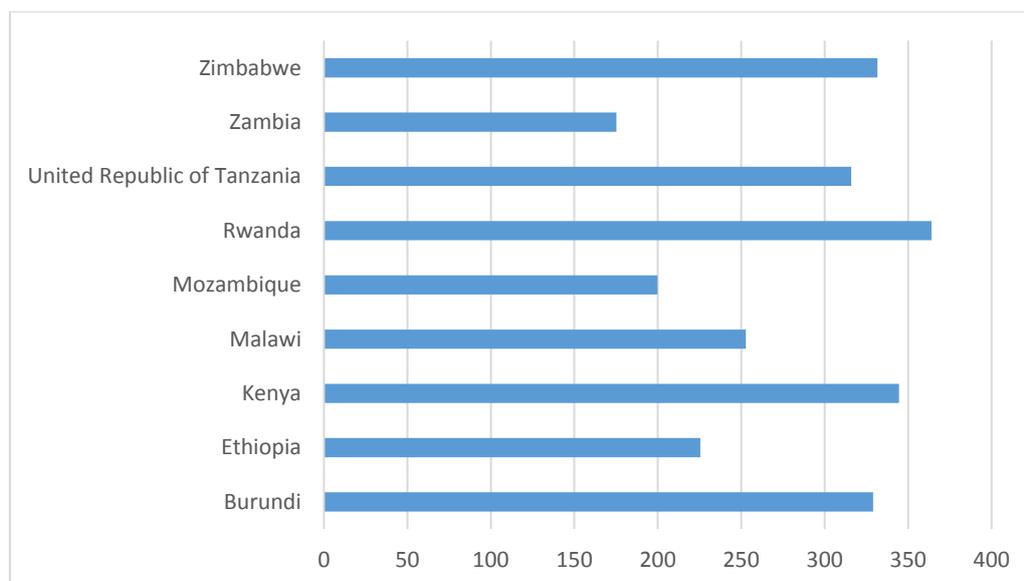
Figure 10 presents the coefficient of variation in per capita maize production and per capita supply for all individual countries and the region as a whole since 2000.<sup>8</sup> During this period, production was most stable in Kenya and Burundi with 12 percent variability in year-to-year fluctuations. Production variability was highest in Somalia and Rwanda with 58 percent and 78 percent, respectively. By contrast, total production variability of all countries together was only about 12.3 percent. This means that full regional trade liberalization could reduce regional consumption variability in the region. All countries already make successful use of international trade to reduce variability in total domestic supply, which can be seen as the coefficient of variation of for supply is smaller than the coefficient of variation of production (Figure 10). The benefits of trade integration would be particularly strong for food Zimbabwe, Rwanda, Somalia, and the United Republic of Tanzania. This observation is consistent with findings for other regions in Africa (Kornher and Kalkuhl, 2016).

To analyse shifts in maize production between countries in the region, as a consequence of increasing market integration, it is necessary to assess the comparative advantage in maize production across countries. The relative comparative advantage (RCA) for maize can be measured as the importance of maize in a country's total exports. In detail, the portion of maize exports in total exports is divided by the portion of global maize trade in total global trade (Sukati, 2016). Sukati (2016) computes the RCA for agricultural products and countries in the COMESA region. The results indicate a structural advantage for maize production in Malawi, Zambia, Uganda, and to some extent Burundi. High agricultural productivity and cost efficient production are possible drivers of the RCA. However, in presence of large distortions to agricultural trade, the export activity alone may not tell the complete story. Figure 11 illustrates producer prices for maize in selected countries. Assuming comparable transaction costs across the region, producer prices also reflect the comparative advantage in maize production. The figures confirm a comparative advantage for Zambia and Malawi, but also for Mozambique and Ethiopia. These results indicate that maize production would shift to these countries with trade liberalization.

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<sup>8</sup> To account for population growth and the increasing trend in maize consumption, we compute the coefficient of variation from the per capita maize supply to measure the relative instability of the system.

**Figure 11: Average producer prices (USD per ton) in selected countries**



Source: FAOSTAT (2017).

### **Innovative approaches to improve food security**

This section reviews innovative responses to climate change at the farm level with upscaling potential. These include climate smart agricultural (CSA) innovations and possible market development strategies, both aiming at improving FNS at the household level.

#### ***Climate smart agriculture***

According to the definition by Lipper *et al.*, (2014), CSA is characterized by delivering on three components. First, CSA approaches increase agricultural productivity. Second, they represent an adaptation to the effects of climate change, for instance by building resilience. Last, CSA approaches also contribute to climate change mitigation by reducing GHG emissions or increasing carbon sequestering. Thus, CSA can be considered as a holistic approach to the food system including agronomic, environmental, and economic aspects. In their modified version of the IMPACT model, de Pinto *et al.*, (2017) model the impact of climate change considering the adoption of CSA techniques. They show that maize production could be increased by more than 50 percent accompanied by a substantial reduction in GHG emissions.

#### **Conservation agriculture**

Land degradation through repeated ploughing of agricultural lands resulting in soil compaction and loss of topsoil (organic material and fine particles) coupled with climate change implications are gradually becoming matters of concern for agricultural productivity (Rockström *et al.*, 2009; Kirui and Mirzabaev, 2014). These concerns call for enhanced sustainable agricultural technologies, like Conservation Agriculture (CA), that are capable of supporting production and maintaining the ecosystem to serve the interest of the present as well as future generations. CA enhances natural biological processes

above and below the ground, and it is based on three main principles: minimum soil disturbance (minimum or no soil tillage), permanent organic soil cover, and diversified crop rotation. Many acclaim CA as a yield enhancing and a water productivity improving crop production technology, without high upfront investment (Rockström *et al.*, 2009).

Different forms of CA are practiced on over 117 million hectares of land around the world (Kassam, *et al.*, 2010), with the greatest proportion in South and North America (about 80 percent), while less than a percent of arable land is cultivated in that manner in Africa (Derpsch and Friedrich, 2009). According to Kassam (2015) about 330 000 ha of the agricultural area in Zimbabwe are under CA, while Zambia and Mozambique use about 200 000 ha and 150 000 ha, respectively. In the other countries (the United Republic of Tanzania 25 000 ha, Kenya 33 000 ha, Malawi 65 000 ha) of the region, CA is only at the beginning.

The lack of uptake of CA in many countries is surprising as a number of studies find strong positive effects of CA technologies on agricultural productivity (Corbeels *et al.*, 2014 for an extensive review). Rockström *et al.* (2009) reports yield improvements in the range of 20–120 percent in smallholder rain fed CA trials in Ethiopia, Kenya, the United Republic of Tanzania and Zimbabwe. Gowing and Palmer (2008) also note that CA will deliver the productivity gains that are required to achieve food and nutrition security and poverty targets, if farmers have access to fertilizers and herbicides. Besides productivity gains, CA can also produce higher net returns relative to conventional farming (Knowler and Bradshaw, 2007; Stevenson *et al.*, 2014). Abdulai (2016) finds that higher agricultural returns also translate into higher overall household well-being in his study from Zambia. Thierfelder *et al.* (2017) consolidate the literature on potential benefits of CA in Southern Africa. They find strong empirical evidence with respect to the adaptation component and significant productivity benefits, which can be utilized after 2-5 cropping seasons. However, they question the mitigation potential. Yet, it is worth noting that CA impacts are often side-specific and they increase with the duration of the observation period (Zheng *et al.*, 2014).

Despite the benefits of these strategies, adoption rates remain low. This could have many different causes including foremost prohibitively high investment costs and lack of knowledge about the technology. Moreover, limited access to inputs as well as high costs of inputs, decoupled output markets, and limited tenure security are also named in the literature as reasons for low adoption rates (Thierfelder *et al.*, 2015). Vanlauwe *et al.* (2014) argue that the exploitation of the full potential of CA to increase productivity requires a sufficiently high level of fertilizer application. Thus, poor adoption of fertilizer in Africa may impede the profitability of CA for many farmers. Results from a meta-analysis by Corbeels *et al.* (2014) suggest that no-tillage alone may not bring significant productivity gains without applying mulching and crop rotation. Derpsch and Friedrich (2009) consider lack of knowledge as an important constraint to adoption. CA is a significant change to the agricultural production system and it seems difficult to transmit the knowledge through scientific research without on-ground support by public and

private actors (Kassam *et al.*, 2010). Understanding the obstacles to adoption is crucial to enhance the diffusion of beneficial agricultural innovations.

### **Agroforestry systems**

Agroforestry refers to land use systems combining perennial trees, shrubs, or palms as well as agricultural crops or animals on the same land management unit. The main advantage is that agroforestry systems make use of both ecological/ agronomic and economic interaction between the different components. At the ecological side, the system acknowledges dynamic agronomic processes and its impact on soil fertility, erosion, and moisture content. Besides, there is also an economic component, since agroforestry systems improve the resilience of farm households by providing additional products that can be used for sale and home consumption. These products include fruits, medicine, fodder, fibre and fuel.

Agroforestry can appear in a number of different forms, for instance i) permanent tree intercropping, ii) sequential tree fallow, iii) annual relay intercropping and iv) biomass transfer. In permanent tree intercropping, nutrient-fixing trees are scattered across the field or planted in rows, while the annual crops are planted in between the trees. In this case, trees need to be cut back (coppiced) to make light penetration possible. Alternatively, tree planting is used to improve fallow on uncultivated fields. This requires fast growing leguminous trees or shrub species. After the fallow period trees can be mulched or burned with the aim to return nutrients and carbon to the soil. Annual relay intercropping also involves the planting of fast growing species, which are planted shortly after the crop itself and ploughed into the soil before the sowing of the next season's crop. This allows sparing fallow periods with limited nutrient loss in the soil. Last, and similar to annual relay intercropping, biomass transfer shifts leaf and twig matter used as mulch to the field where the crop is planted (Kascan *et al.*, 2013).

Planting trees and shrubs is a cost effective substitute for the use of inorganic fertilizers, wherefore agroforestry is often referred to as 'fertilizer tree systems' in the region. It helps to maintain soil cover, improves nutrient levels and conservation, increases soil organic matter, and enhances water conservation (Garrity, *et al.*, 2010). Leguminous agroforestry species can be used for their ability to sequestering atmospheric nitrogen in the soil making it available to other plants.

According to Dixon (1995) a total of 585 to 1 215 million ha of arable land worldwide is suitable for agroforestry. Ramachandran Nair *et al.* (2009) vaguely estimated that the total area under agroforestry globally would be around 1 billion ha, while a precise figure is difficult since some countries report the area as forests and others as arable land. Zomer *et al.* (2014) make an assessment based on geospatial remote sensing and find that about 120 million ha of agricultural land in Africa exhibit at least 10 percent tree cover. Latest statistics indicate a continuous trend in deforestation, but to some extent agroforestry counters the development and slows down deforestation rates (FAO, 2015).

A meta-analysis by Akinnifesi *et al.* (2010) looks at several studies from SSA and the impact of agroforestry on yields and soil quality for on-farm trials in Malawi, the United

Republic of Tanzania, Zambia and Mozambique. They find that ‘fertilizer trees systems’ add more than 60 kg nitrogen per ha per year. Moreover, tree planting reduces the requirement for nitrogen fertilizer by 75 percent and improves agricultural crop yields. Maize yields can be doubled if agroforestry systems are under good management without external fertilization. This translates into higher net returns, and thus into improved household welfare. Sileshi *et al.* (2008) examine maize response to agroforestry system with legumes across SSA. Accordingly, maize yields in these systems increase between 1.3-1.6 tonnes per ha over unfertilized and mono-cropped maize. Coulibaliy *et al.* (2017) analyse the impact of the adoption of fertilizer trees on household food security in Malawi and find that the value of the food crops significantly increased, especially on small farms. Besides positive effects on agricultural productivity and food security, Ajayi *et al.* (2011) also find positive effects on environmental indicators. The improvement of physical soil quality reduces water run-off and soil erosion.

The clear benefits of agroforestry with regards to saving mineral fertilizers, eco-system maintenance, and the positive effects on agricultural productivity and welfare call for widespread adoption and scaling up of fertilizer trees systems. Reliable data on the adoption of agroforestry systems is very limited. As an exemption, micro data from the LSM surveys suggest that about one third of farmers in the study countries have trees on their farm land (38 percent Ethiopia, 22 percent Malawi, 55 percent the United Republic of Tanzania, 30 percent Uganda). The low adoption rates are partially explained by the usual reasons, such as investment costs. However, Mercer (2004) argues that limited knowledge about the complex management requirements and tedious testing over a long time period are the most relevant obstacles to wider adoption. Intercropping seems relatively common in the United Republic of Tanzania and Uganda, where tree cash crops dominate, but not widespread in Ethiopia and Malawi (Miller *et al.*, 2017). Furthermore, Miller *et al.* (2017) find that proximity to forest areas and higher annual mean temperature are positively related to the adoption of agro-forestry systems.

### ***Market access and development***

The development of agricultural markets and the provision of financial services are essential to increasing agricultural productivity and rural welfare. Improving the efficiency of agricultural value chains creates a virtuous circle by improving access to input markets, boosting productivity, increasing incomes, and eventually enhancing food security. Certainty in economic planning and better access for smallholder farmers to domestic and international markets guarantee efficient resource allocation and higher output prices, which encourages investment in agricultural technologies. Next to provision of hard (reliable road network) and soft (legal framework) infrastructure, the promotion of smallholder commercialization and the enhancement of smallholder farmers’ liquidity should be important objectives.

### ***Smallholder commercialization***

Commercialization of agricultural systems means to shift production practices from current self-consumption-orientation towards market-orientation. Currently, transaction costs of market participation are often prohibitively high and keep farmers away from

output markets. However, market participation exposes smallholder farmers to increasing competition, which leads to higher allocative efficiency. Commercial farmers are able to exploit their comparative advantage and through trade contribute to economic growth and increased welfare (Barrett, 2008).

In a cross-country study, Mather *et al.* (2013) examine the determinants of commercialization of smallholder maize farmers in Mozambique, Zambia, and Kenya. Their findings suggest that, due to advances in modern communication technologies, market distance does not explain maize sales. Instead, access to price information and improved technologies, such as hybrid seeds and chemical fertilizer increase the probability of maize sales. Households in the northern and eastern zones of the United Republic of Tanzania, that participate in commercial maize marketing, have consumption expenditures 25 percent higher than subsistence farmers (Mmbando *et al.*, 2015).

Montalbano *et al.* (2017) find that value chain participation is positively associated to the application of improved seeds and the usage of hired labour as well as higher output prices for Ugandan maize farmers. Kamara (2004) also identifies increased input use as the main channel through which market participation improves agricultural productivity. Improving the productivity of smallholder farmers by better access to improved technologies enhances technical and environmental efficiency. Given the challenges of climate change including resource scarcity, improving technical efficiency is vital for sustainable agricultural systems. Therefore, there is a need for promoting smallholder market participation to enforce agricultural transformation in developing countries (von Braun and Kennedy, 1994).

### **Warehouse receipt system**

Smallholder farmers in developing countries often face liquidity constraints forcing them to sell productive assets. In addition, farmers also need to sell their crop right after harvest without exploiting the sharp seasonal price gap, which is usual for markets of staple grains in developing countries. Access to other financial resources, such as credit, has a positive impact on sales behaviour and can improve household welfare (Stephens and Barrett, 2011).

A possible solution, in absence of functioning rural financial markets, is the provision of warehouse receipt systems (WRS). WRS involves a storage facility offering smallholder farmers to store their farm produce from the harvest to the lean season. To overcome liquidity constraints farmers can acquire a warehouse receipt, which the holder can use as collateral for a credit at a local financial institution (in the region often called SACCO) or to sell it for cash to a buyer. The operator of the warehouse, who is in the possession of the stocks, guarantees the delivery of the stored commodity against the receipt. This includes possible theft, deterioration, and damage in consequence of fire and other catastrophes (Coulter and Onumah, 2002). The price risk remains with the holder the receipt (e.g. the producer), but solves the issue of liquidity constraints after harvest.

In Uganda, private sector WRS initiatives are in place since 2004. Initially piloted for coffee and cotton, warehouse providers also accept cereals and pulses. A study by Katunze *et al.* (2017) finds that uptake for maize is very low, as farmers prefer to sell at the farm

gate instead of paying for the storage and handling services. In the United Republic of Tanzania, WRS was introduced in 2007 and it is currently operational in 14 regions supported by three financial institutions. Currently there are very few studies available that analyse the determinants of adoption. The results of William and Kaserwa (2015) suggest that lack of access to credit and malfunctioning output markets are the main drivers of WRS adoption. In Malawi WRS is relatively new and an institutional framework is still missing. Nevertheless, two providers operate 19 certified warehouses in larger settlements. Edelman *et al.* (2015) find that wider adoption of WRS services is limited due to high minimum deposit requirements, expensive transport to the WRS facility, and a lack of trust in the operation. As WRS services are relatively new, there is a need to provide evidence based research on the welfare implications of WRS adoption.

Besides offering benefits to smallholder farmers, WRS can overcome another problem of agricultural markets, namely the large seasonal price fluctuations as result of limited intra-annual storage (Edelman *et al.*, 2015). Currently, high storage costs and limited availability of storage facilities in rural areas cause price spikes towards the end of the agricultural cycle.

## Summary and conclusion

This paper discusses the impact of climate change on the maize market in Eastern and Southern Africa. Given the heavy reliance of rain fed agricultural systems, which are predominant in SSA, climate change is expected to have significant impacts on agricultural productivity and food availability. The imbalance between supply and demand will increase market prices and negatively affects the access to food and food utilization for large parts of the population. A higher frequency of extreme weather events will generally make the food system unstable.

The Eastern and Southern African region has a structural deficit in maize and depends on imports from South Africa. Intra-regional trade can offset inter-annual fluctuations, but currently national governments restrict maize exports when harvests fall short. This causes uncertainty in the market and creates disincentives for spatial arbitrageurs to invest.

Traditionally, maize markets in the region are characterized by a high level of intervention. In Malawi, Zambia, and Kenya public price stabilization programmes control the market and prices. Excessive minimum prices paid to farmers can increase food production in the short-term, but allows inefficient farmers to stay in the market. Overall, there is no evidence for a causal effect between domestic producer support and agricultural productivity increases. However, there seems to be a positive correlation between adaptation strategies of farmers and agricultural productivity.

Following standard economic theory, among the price policies, the best option for governments is to provide financial support to consumers through social safety net programmes, which lifts the demand curve and can create a multiplier effect leading to increased production, higher agricultural incomes, and food security. Emergency stocks

should be built up to provide additional supply in case of harvest failures and natural catastrophes.

Instead of using agricultural price policies, governments should enhance adaptation and mitigation of smallholder farmers by encouraging and supporting scientific research and providing an institutional environment that eases the certification of improved seed varieties and stimulates the diffusion of adaptation measures through agricultural extension services. Two viable options, referred to as climate smart agriculture – conservation agriculture and agroforestry – have great potential to increase agricultural productivity and agricultural incomes, while mitigating climate change.

In addition, policies need to increase commercialization of smallholder farmers, which are found to improve agricultural productivity through higher input use and improved technical efficiency. Liquidity constraints of farmers can be overcome by providing micro credit solution in rural markets, such as WRS. It becomes apparent that no one policy will be able to address the varied aspects of climate change and the impacts on food security, calling for a set of complementary policies.

## Technical appendix

### Theory of domestic support measures

National governments intervene in agricultural markets in many different ways. Governments can influence prices by using subsidies or imposing taxes. In case of subsidizing food imports for consumers, the domestic price for both consumers and producers falls below international prices. This increases imports and consumption, but disincentivizes domestic production. Subsidizing food exports by supporting farmers has the opposite effect and leads to increased production and exports, but at the expense of reduced domestic consumption. It is also possible to subsidize consumers or producers without hurting the other. For instance, subsidizing domestic consumption of export goods does not affect producer prices and supporting producers of import goods does not alter consumer prices. Taxes on imports or exports work in a similar way. Import restrictions increase domestic production and lower consumption. As opposed to this, export restrictions enhance consumption but create disincentives for production. All interventions cause distortions to the agricultural sector resulting in deadweight losses to society. Table A1 gives an overview of the effects of different policy measures and presents their impact on the efficiency of production. Many policies have the tendency to reduce overall trade. As trade improves the allocative efficiency of productive resources, trade reducing policies are likely to incur additional efficiency losses (Timmer *et al.*, 1983).

**Table A1: Effects of domestic price policies**

Type of policy	Production	Consumption	Trade volume
Producer subsidies on importable commodities	+	0	-
Producer subsidies on exportable commodities	+	-	+
Consumer subsidies on importable commodities	-	+	+
Consumer subsidies on exportable commodities	0	+	-
Restrictions on imports	+	-	-
Restrictions on exports	-	+	-

Source: Adapted from Timmer *et al.* (1983).

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