POLICY BRIEF

Climate Change and Agricultural Trade in sub-Saharan Africa

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Abstract

Climate change is a threat to the agricultural sector and food security of many countries in sub-Saharan Africa (SSA). However, changes in climate across the continent are not expected to be consistent as some countries will experience huge declines in rainfall and increases in temperature. This implies that changes in agricultural productivity due to climate change will not be uniform and this is likely to affect trade patterns on the continent. Using a combination of climate change scenarios from the Food and Agriculture Organization of the United Nations' Global Agro-Ecological Zones (FAO-GAEZ), cereals production data

from the Food and Agriculture Organization of the United Nation's FAOSTAT, and trade data from the United Nation's UN Comtrade database, this study explores the impact of climate change on agricultural trade, particularly trade in major cereals, within SSA. Results show that by the 2050s, climate change will lead to most countries experiencing an increase in their need to import cereals. However, some countries such as Burundi, Tanzania and Zambia could have the potential to increase their exports. This suggests that trade flows are likely to be important in strengthening the resilience of African food systems from shocks emanating from climate change. For example, countries in East Africa such as Tanzania could export maize to countries in Southern Africa that could experience maize deficits. Delivering food from surplus to deficit areas is likely to be important in the future, hence the need to improve the movement of food products across borders. Policies to be adopted may include improving trade facilitation, reducing intra-SSA tariffs, avoiding trade policy uncertainty, removing export bans, and encouraging the production of cereal crops where countries have gained a comparative advantage.

Introduction

The climate is changing, and it is a threat to the agricultural sector and food security of many countries in sub-Saharan Africa (SSA) (Lobell and Schlenker, 2010). By 2050, mean temperatures in SSA are expected to increase by 1.6 degrees Celsius and rainfall is expected to decrease by 10%, on average, especially in Southern Africa (IPCC, 2007). Increases in temperature and reduced rainfall levels are expected to lower agricultural productivity in many parts of the continent. This is likely to have detrimental effects on food security, poverty, nutrition outcomes, and the prevalence of infectious diseases (Serdeczny et al., 2015). However, the impacts of climate change will not be uniform, and the regions are expected to experience different patterns of climate change. For example, Southern Africa is likely to experience a decline in precipitation levels, whereas in Eastern Africa precipitation is expected to increase (Serdeczny et al., 2015). This, in turn, will have a differential impact on agricultural productivity across regions in SSA, where some regions will become more productive and others will be less productive in the future (Seo et al., 2009).

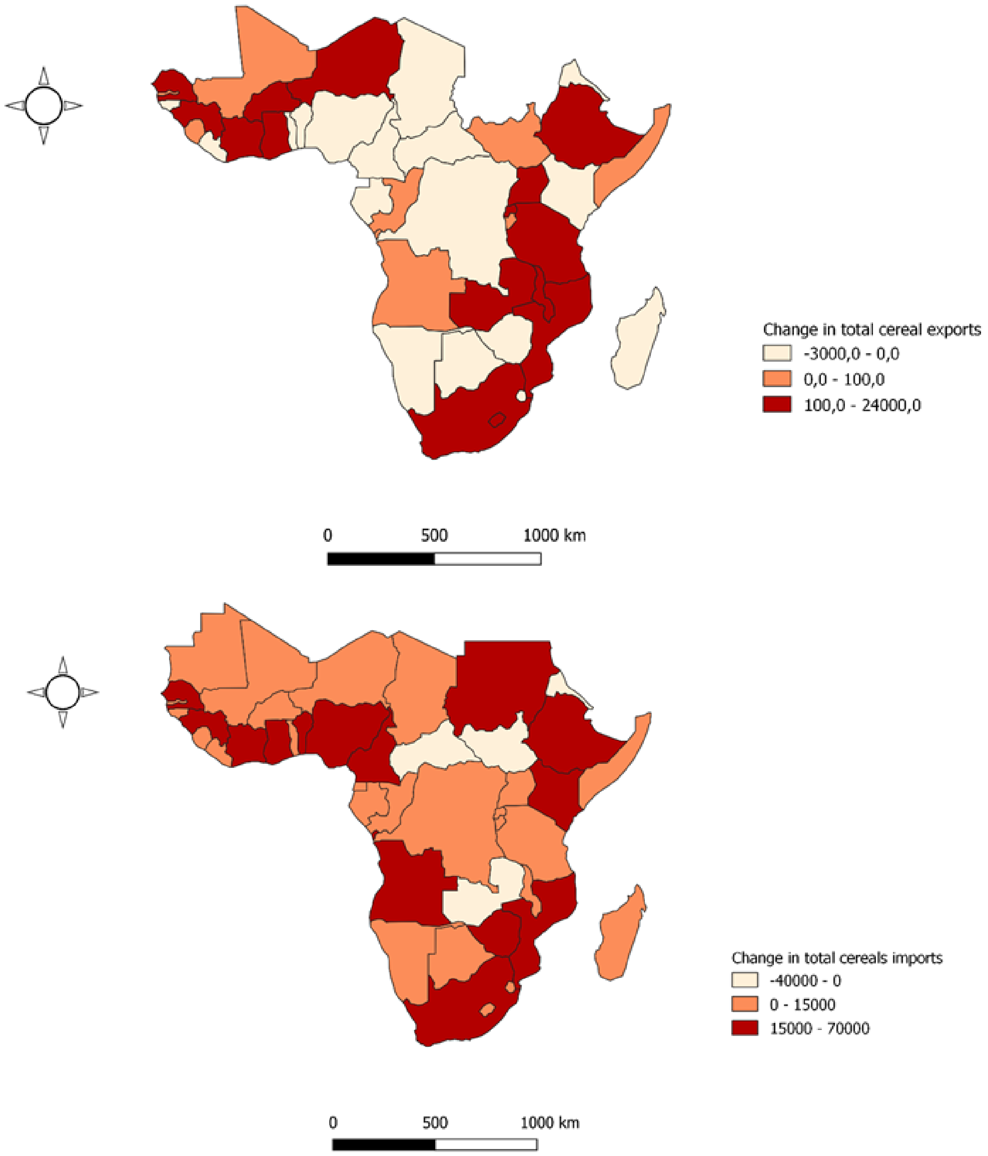
These changes in productivity levels will affect agricultural trade flows in SSA through changes in comparative advantage, where changes in temperature and rainfall levels affect agricultural comparative advantage (Nelson et al, 2009; Costinot et al., 2016). The assumption is that climate change may affect comparative advantage in the agricultural sector and, therefore, result in changes in the composition of trade flows as producers respond to new conditions. Trade in five major cereals in SSA is likely to be affected by climate change as production patterns change. The production of maize, rice, millet, wheat, and sorghum has declined since 1980 because of global warning and it is expected that it could decline by as much as 20% by the middle of this century (Lobell & Schlenker, 2010; Lobell et al., 2011). Understanding the impacts of climate change on cereals trade flows is important for several reasons. First, cereals trade is of critical importance for many countries in SSA. For most of the population in the region, cereal production and trade is an important part of the food system, as cereals are a major staple food. Therefore, access to regional and international cereal markets is an important pathway out of grinding poverty and food insecurity.

Second, the ability of the agricultural sector and food security systems to respond to climatic shocks also depends on trade in cereal products. Empirical evidence has shown that the negative impacts of climate change are dampened when trade patterns adjust (Costinot et al., 2016). Intra-African and international cereals trade is important because trade has the potential to help reduce the effect of climate change by delivering food from surplus areas to countries experiencing food productivity declines (Govereh, 2007; Duchin and Juliá, 2007). To achieve this, there is a need to promote and facilitate freer movement of cereals. Free trade allows nations to fully exploit their comparative advantage and the existence of barriers to trade exacerbate climate change effects by reducing the responsiveness of consumers and producers to incentives. This points to the importance of trade policies in SSA if they are to respond effectively to changes in climate, among other adaptation strategies that include irrigation and the adoption of improved varieties. Recent empirical evidence has shown that trade costs are high in SSA and have a negative effect on food prices, agricultural income, and welfare (Porteous, 2016).

Although recently there has been some considerable interest in studying the linkages between climate change and international trade, little is known in SSA about the impact of future climate change on intra-SSA cereals trade. This paper addresses the issue by simulating the impacts of climate change on bilateral exports and imports in SSA by combining estimates from a historical relationship between production and cereals trade, and post-climate change cereals productivity estimates for each country and crop in the region. To restrict the number of agricultural products in the analysis, the study focusses on cereals trade as it forms the major share of food consumption goods and is the focus of climate change estimates. Documenting the impacts of climate change on cereals trade flows and the potential role of trade as an adaptation strategy is critical for improving food security policy design. The output from this research will be of great use to national governments, and international and regional development organizations that are seeking ways to reduce food insecurity and undernutrition through facilitating the access of farmers to markets in the face of adverse shocks.

Figure 1 shows the distribution of the average 2000–2016 change in cereals trade across SSA countries. The first map shows that the change in cereals exports varies across countries, with countries such as South Africa, Zambia and Niger experiencing a large increase in exports. Most countries experienced a small change in cereal exports, while others experienced a decline. The second map in Figure 1 also shows that there is a wide variation in change in cereal imports, with the countries observed to be experiencing increased exports also importing more cereal products. The study relies on this historical variation across time and countries to estimate a relationship between production and trade for each country and major cereal crop.

Figure 1: Distribution of average 2000–2016 change in cereals trade (US$'000) in sub-Saharan African countries



Source: Author using data from FAOSTAT and Geographic Information Systems (GIS) shapefiles.

To further highlight the relative importance of cereals trade in SSA, Table 1 shows the shares of major cereals trade in total trade for SSA countries. The analysis in this paper draws on five major cereal crops whose aggregate share in total trade is presented in Table 1. Between 2000 and 2016, the share of cereals exports in total trade was low for most countries in SSA. In West Africa, countries such as Benin, Burkina Faso and Senegal had the highest share of cereal exports. The share of cereal exports had been increasing in Benin and Senegal. In Benin, the share of cereal exports increased to 42% in 2010 and then declined to 0.01% in 2016, whereas in Senegal the share increased from 0.01% in 2000 to 6% in 2005 and dropped to 4% in 2016. In other West African countries such as Cameroon, Côte d'Ivoire, Nigeria, Niger, Togo, and Ghana the share of cereal exports in total trade was very low over the 2000–2016 period. Uganda, Tanzania, and Ethiopia had the highest shares of cereal exports in the East African region, while countries such as Rwanda, Kenya, Burundi, and Eritrea had low shares of cereal exports. The share of cereal exports was above 5% for Uganda in 2001, 2005, 2006, 2012, 2015 and 2016. In Tanzania, the share of cereal exports reached 21% in 2002 and declined to 1.4% in 2016. Ethiopia had the highest share of cereal exports at 13% in 2012 and had the lowest share in 2009. Southern Africa is one of the major producers of cereals in SSA as is reflected in their relative importance in cereals trade. Malawi has the largest share of cereal exports in the region. In 2007, the share of cereal exports in Malawi was about 32%, which was lowest in 2006. In Zambia, the share of cereal exports had been increasing over the 2000–2016 period, increasing to 14% in 2012. Other countries in the region recorded low shares of cereal exports over the period. These statistics that show the variation in the changes in the share of cereal exports in total trade across countries and time reveal that there are differences in the relative importance of cereals trade across countries in SSA. The relative importance may be altered as result of climate change as production specializations change.

Table 1: Share of value of cereals exports in total trade 2000–2016 (trade values in US$'000)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Benin	0.01	0.03		0.00	0.01		0.02	3.68	7.11	15.68	41.98	13.20	15.68	13.22	5.13	0.11	0.01
Botswana	0.39	0.60	0.69	0.51	0.87	0.64	0.75	0.08	0.10	0.36	0.12	0.13	0.12	1.45	0.04	0.03	0.06
Burkina Faso	5.42	7.53	2.42	0.13	1.73	0.82		4.32	2.35	4.29	3.38	1.59	0.98	2.16	2.40	3.55	1.50
Burundi			1.79		0.51		0.12	0.92	1.12	0.44	0.95	0.68		0.00	0.35	0.03	0.00
Cameroon	0.00	0.00	0.00	0.13	0.01	0.00	0.00			0.00	0.20	0.18	0.06	0.17	0.65	1.44	1.95
Cape Verde						5.02						0.00	8.24	0.00			
Congo. Rep.										0.01	0.01				0.00		
Côte d'Ivoire	0.01	0.13	0.09	0.05	0.23	0.15	0.06	0.02	0.34	0.47	0.16	0.37	0.43	0.33	0.48	0.42	0.42
Djibouti										0.95							
Eritrea	0.17	0.00	0.00	0.65													
Ethiopia*	0.97	2.52	4.18	0.83	4.45	4.44	0.39	0.14	0.04	0.00	2.88	0.89	12.66	0.23	0.85	0.16	
Former Sudan									0.00	0.00		0.93					
Gabon	0.06	0.15	0.09	0.00	0.07	0.01	0.00	0.00	0.00								
The Gambia										0.19	0.00	0.00	0.00	1.61	15.54	0.15	0.45
Ghana	0.06	0.24		0.17	0.01	0.00	0.00	0.09	0.00	0.00	0.36	0.00	0.00	0.01			0.01
Guinea	0.41		3.40		0.00	0.01	0.08		15.76					0.00	0.01	0.04	
Guinea-Bissau					18.84												
Kenya	0.18	0.12	0.98	0.26	0.35	0.25	0.28	0.26	0.32	0.37	0.52			0.41			
Lesotho	0.98	2.94	1.43	2.83	1.18				2.31	0.34	0.23	0.10	0.06	0.03	0.06	0.04	
Madagascar	0.33	1.37	1.77	0.14	0.34	0.01	0.32	0.44	0.01	0.02	0.00	0.00	0.08	0.03	0.00	0.05	0.01
Malawi	8.40	1.43	1.51	13.30	1.16	0.30	2.68	31.79	7.17	4.87	2.02	17.38	0.94	1.30	0.90	0.63	1.23
Mali	0.72	1.06	0.49	0.11	0.63	0.36	0.75	0.04	0.13		0.17	0.30	0.04				0.00
Mauritius	0.02	0.01	0.04	0.04	0.06	0.00	0.08	0.10	0.14	0.28	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Mozambique		1.06	3.37	0.82	1.25	0.88	1.06	0.64	1.05	1.29	0.73	0.84	0.21	0.05	1.15		0.10
Namibia	0.14	0.06	0.13	0.19	0.06	0.06	0.02	0.03	0.05	0.04	0.02	0.04	0.01	0.01	0.01	0.01	0.00

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Table 1 Continued

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Niger	0.05	0.02	0.03	0.08	0.00	0.14	0.57	0.05	0.01	0.00	0.01	0.36	0.00	0.00	0.03	0.00	0.06
Nigeria	0.01	0.00		0.02								0.00		0.21			
Rwanda		0.00		0.00		0.00	0.64	1.93	0.07	0.01	0.42	0.24	0.59	0.61	0.09	0.43	2.12
Senegal	0.01	0.00	0.25	1.91	4.29	5.87	0.36	3.38	1.24	5.20	1.95	3.57	3.31	3.17	3.12	3.15	3.81
Seychelles	0.00	0.00		0.00	0.00			0.00									0.04
South Africa	1.26	1.20	3.65	2.97	2.19	3.41	1.86	0.37	4.88	4.64	1.76	1.45	1.48	1.79	1.84	1.61	2.11
Sudan													42.82			0.27	
Swaziland	0.07	0.04	0.06	0.13	0.09	0.13	0.09	0.13						0.05	0.04	0.01	0.02
Tanzania	2.04	5.64	20.63	10.34	3.31	2.85	1.59	1.74	1.86	0.54	1.23	1.30	3.24	1.97	6.22	1.07	1.39
Togo	0.67	0.56	0.58	0.11	0.11	0.02		0.40	0.01	0.00	1.42	0.09	2.78	0.00	0.31	0.08	0.01
Uganda	0.73	8.72	2.50	2.93	3.81	5.67	6.99	2.95	1.81	2.13	4.47	3.63	9.16	3.10	2.87	6.59	6.12
Zambia	1.52	0.59	0.65	1.51	5.60	2.23	1.81	5.82	4.90	2.49	2.64	8.62	14.02	4.82	3.20	12.02	
Zimbabwe	2.28	0.07	0.42		0.01	0.03	0.00	0.01	0.00	0.03	0.03	0.05	0.07	0.07	0.04	0.08	0.08

Notes: *Ethiopia excludes Eritrea
Source: UN COMTRADE through WITS (2018)

Agricultural trade and food security in sub-Saharan Africa

Agricultural trade is of critical importance for many SSA countries. Improvements in agricultural trade in the region is likely to be associated with economic growth and poverty reduction, as most poor people in the region are dependent on agricultural production for income generation and food security. SSA countries are known for being chronically food insecure and highly dependent on food aid, however, less is known about SSA's highly productive and food surplus regions (Govereh, 2007). Agricultural trade is important for linking food surplus zones with food deficit regions, thereby increasing food security in deficit regions through food availability and accessibility. This will be particularly important in the face of extreme events such as frequent occurrences of droughts and flooding because of climate change. In addition to increasing the resilience of food security systems to cater for changes in climate through delivering food to deficit regions, agricultural trade will also reduce price volatility, improve producer incentives, and increase agricultural growth (Govereh, 2007). Other studies have noted that improvements in world trade is an important adjustment mechanism for negative shocks arising from climate change (Duchin and Juliá, 2007; Baldos and Hertel, 2015).

Agricultural trade has been an engine for economic growth and structural transformation in developed regions (Porteous, 2016). In Organisation for Economic Coordination and Development (OECD) countries, agricultural trade has expanded rapidly and has been a vehicle for raising the standard of living (Aksoy, 2005; Aksoy and Ng, 2010). Aksoy (2005) reports that during the period 1980/1981 to 2000/2001 intra-European Union (EU) agricultural imports increased from 51% of total agricultural imports to 66%, and intra-NAFTA imports rose from 29% to 44% during the same period. The growth in intra-regional trade in OECD countries has been attributed to successful trade policy reforms. The value of world agricultural trade increased between 2000 and 2016, exhibiting an average annual growth rate of 6%, and emerging economies have been increasing in importance in world agricultural markets (FAO, 2018). South Africa was the only country from SSA in the top 20 agricultural exporters between 2000 and 2016. An important feature of the increased participation of emerging economies in world agricultural trade has been the rapid growth of South-South trade, that is, agricultural trade within middle and low-income countries (FAO, 2018).

However, in SSA the situation has been different. Agricultural trade within SSA countries, and between SSA countries and the rest of the world has been low (Rakotoarisoa et al., 2012). Patterns of agricultural trade documented in the literature show that the share of food and agricultural exports is declining in SSA, contributing 33% to total merchandise exports in 1990, from a level as high as 56% in 1980, while there are increasing levels of agricultural imports (Andriamananjara and Benavides, 2006). As a share of world agricultural trade, African trade was less than 5% between 2005 and 2007 (Rakotoarisoa et al., 2012). SSA has increasingly become a net importer of food and agricultural products in the last two decades, with agricultural imports growing at an annual average rate of about 13% (Rakotoarisoa et al., 2012; USDA-FAS, 2015). These constituted mainly imports of cereals and livestock products, which are important for improving food security and the nutritional status of individuals. Climate shocks may affect the importation of these products, as climate shocks are likely to be associated with the potential of countries to increase their import of food through changes in comparative advantage and income.

About 30% of agricultural imports into SSA come from other developing regions such as Asia, with Thailand, Malaysia, India, and Indonesia being the top countries (USDA-FAS, 2015). European Union countries contributed about 25% of the imports. Intra-regional trade in food and agriculture products has been relatively low, accounting for about 17% of total merchandise exports, however, intra-regional trade has been growing over the years but at a slower rate compared to international trade (USDA-FAS, 2015). Cereals trade account for only about 5% of total trade.[1] In SSA, regional production patterns determine trade flows within the continent. SSA has traditional areas of food surplus and food deficit, for example, the Horn of Africa and the Sahel are drought-prone areas and usually suffer from food shortages, while the food surplus areas constitute those areas that are highly productive with favourable and reliable rainfall (World Bank, 2012). As a result, Southern Mali exports surplus sorghum to Niger and coastal West Africa, and other “staple-food-basket zones” with climates that support the production of different cereals such as Northern Zambia, Eastern Uganda, Northern Mozambique, most of Tanzania and South Africa export various food products to Democratic Republic of the Congo, Malawi, Kenya, Zimbabwe, and other parts of Mozambique. In West Africa, Nigeria is a major producer of food crops such as rice and exports millet, sorghum, and yam to neighbouring countries. Most of the rice imported by West African nations such as Senegal and Côte d’Ivoire are sourced from Thailand.

The poor performance of intra-regional trade can be attributed to several factors, most importantly trade policies, complex transit procedures, poor institutional environments, and high transport costs. Josling (2008) and Porteous (2016) note that SSA countries face much higher trade-related costs than other countries in getting their products to international markets. This is likely to exacerbate the impact of climate shocks. For example, high trade costs have been shown to reduce the adoption of agricultural technologies that may be important for adapting to climate change shocks (Porteous, 2016).

1 It should be noted that a significant portion of cereals trade in SSA is informal.

To shed light on the role of climate change on agricultural trade patterns and the potential role of trade as a mechanism to reduce the impact of climate shocks, this study adds to the literature by simulating the impacts of climate change on bilateral trade in cereals.

Data source

We use annual data from 2000 to 2015 on exports, imports, and value of agricultural production for about 42 sub-Saharan African countries.[2] Data on exports and imports were obtained from UN Comtrade (UN Comtrade, 2018). Export and import prices were estimated by dividing the export or import value by export or import quantity, respectively. The study considers trade in five major cereal crops (maize, millet, rice, sorghum, and wheat). The value of agricultural production for each country and crop was obtained from FAOSTAT (FAOSTAT, 2018). A dataset of exports, imports and production was created, consisting of data for 42 SSA countries from 2000 to 2015.

Post-climate-change estimates of productivity changes were obtained from the GAEZ project implemented by the FAO (FAO-GAEZ, 2019). The estimates from the GAEZ project are based on agronomic models predicting how each crop will perform in growing conditions available at a particular location. The agronomic models are based on three inputs that include growing characteristics of a particular location (soil type and conditions, elevation, average land gradient) and climate variables such as rainfall, temperature, wind speed and sun exposure. The other input is crop-specific parameters that govern the relationship between a set of growing characteristics and yield of that specific crop. An aggregation of such parameters found in the agronomic literature is used. The last input into the model is assumptions about the use of complementary inputs such as irrigation, fertilizers, machinery, and labour to the growing of a crop at each location. Different sets of productivity predictions are estimated for different scenarios of the application of complementary inputs. The analysis in this study is based on a 'high-inputs' scenario, where production is based on high yielding varieties and fully mechanized with low labour intensity and rain-fed water supply.

Future estimates are available for the 2020s, 2050s and 2080s. This paper uses scenarios for the 2050s as this period is examined in several studies (Ahmed et al., 2010; Arndt, Farmer et al., 2012; Arndt, Chinowsky et al., 2012; Costinot et al., 2016). This will allow us to compare results from this study with similar studies. Also, the effect of climate change is expected to be severe by mid-century. The productivity estimates are calculated at a grid cell and at country level thus allowing heterogeneity within countries. For some data not at the country level, spatial resolution allows

2 Only countries that have data for all variables are considered.

the calculation of data at the country level by aggregating the cell estimates using geographic information system (GIS) software. The GAEZ estimates are based on an average of 30-year periods and uses the predicted future daily weather. The estimates of predicted future daily weather are obtained from average runs of general circulation models (GCM) under different emission scenarios as outlined in the "Special report on emission scenarios" (SRES) from the Intergovernmental Panel on Climate Change (IPCC, 2000). There are various scenarios corresponding to different assumptions about the economy and population growth, and the GAEZ estimates are based on around 11 GCM-SRES pairs. This study follows Costinot, Donaldson and Smith (2016) who base projections on a Hadley CM3 A1FI model. However, sensitivity tests are carried out for the remaining 10 scenarios. Pre-climate-change estimates of productivity for each country and crop are also obtained from the GAEZ database and are based on average crop yields for the period 1961–1990.

Conclusions and policy recommendations

The climate is changing and its impact on agricultural production in SSA countries is likely to be negative, which may have implications for food security and poverty for most of the population in the region. However, although there are challenges associated with a changing climate, there are also opportunities as countries can take advantage of changing comparative advantages to explore new trade potentials within the region. As climate is an important input in agricultural production, differential changes in rainfall and temperature across countries is likely to affect productivity. Some countries are expected to experience an increase in rainfall, which may result in increased productivity for those countries. Consequently, climate change is expected to affect patterns of production differently across countries in SSA and may have implications for patterns of trade.

Using a combination of climate change scenarios data from FAO-GAEZ, production data from FAOSTAT and trade data from UN COMTRADE, this study explored the impact of climate change on agricultural trade, particularly trade in major cereals, within sub-Saharan Africa. The empirical results show that by the 2050s, climate change may lead to the region increasing its need to import maize and wheat, and increasing its potential to export millet, sorghum, and rice. Few countries in the region will have the potential to increase their exports to fellow SSA countries. For example, maize exports are likely to decline for the majority of SSA countries, but countries such as Burundi, Cameroon, Côte d'Ivoire, Ghana, Guinea, Madagascar, Malawi, Rwanda, Tanzania, Togo, Uganda, and Zambia are likely to have the potential to increase maize exports. The results suggest different countries gaining comparative advantages in different cereal crops, pointing to the importance of trade as a country can export a crop where they have gained a comparative advantage and import a crop where they have experienced a decline in comparative advantage.

The empirical results showing the effect on bilateral trade, that is, if the partner country can meet the demand for exports or if their demand for imports can be satisfied, suggest that there may not be export capacity to meet the demand for cereal imports from within the continent, and in other instances, export supply of cereal crops in some countries in the region may not be demanded by countries in the region as the change in import demand is low compared to the change in exports. This mismatch suggests that there is a need to diversify sources of imports and destination of exports to create a balance, which may be achieved by deeply integrating regional and international cereal markets.

To mitigate the adverse effects of climate change on food security, the result from this study suggests that trade flows are likely to be important in strengthening the resilience of African food systems in the face of shocks emanating from climate change. Delivering food from surplus areas to deficit areas is likely to be important for improving availability and reducing food price volatility from climate shocks, hence the need to improve the movement of food products across borders. Policies to be adopted may include improving trade facilitation by removing complex regulatory environments and improving transportation infrastructure, reducing intra-SSA tariffs, avoiding trade policy uncertainty and removing export and import bans. The results of the study have implications for improving food security in the face of climate shocks, as the physical availability of food through trade is also an important component of food security. In addition, as climate change will alter specialization patterns, countries are encouraged to concentrate on producing those cereal crops where they have gained comparative advantage because of climate change instead of traditional crops they have been used to growing.

This study did not tease out the general equilibrium effects of climate change; it is expected that changes in climate is likely to influence the whole economy through linkages between the agricultural sector and other sectors of the economy. This is likely to underestimate or overestimate the effects of climate change reported in this study. Future studies should consider incorporating these general equilibrium effects in examining whether climate change will affect trade patterns. Another important concern is that the study did not address discrepancies in bilateral data, especially as informal trade in grains is common. Future studies could consider using a linear programming approach to allocating the increases in export potential across the countries with increasing import needs.

References

Ahmed, A.S., N.S. Diffenbaugh, W.T. Hertel, D.B. Lobell, N. Ramankutty, A.R. Rios, and P. Rowhani. 2010. "Climate volatility and poverty vulnerability in Tanzania". *Global Environment Change, 21:* 46–55.

Ahmed, S.A., N.S. Diffenbaugh, T.W. Hertel and W. Martin. 2012. "Agriculture and trade opportunities for Tanzania: Past volatility and future climate change". *Review of Development Economics:* 429–47.

Aksoy, M.A. and F. Ng. 2010. *The Evolution of Agricultural Trade Flows.* Washington, D.C.: World Bank.

Arndt, C., P. Chinowsky, K. Strzepek and J. Thurlow. 2012. "Climate change, growth and infrastructure investment: The case of Mozambique". *Review of Development Economics:* 463–75.

Arndt, C., W. Farmer, K. Strzepek and J. Thurlow. 2012. "Climate change, agriculture and food security in Tanzania". *Review of Development Economics:* 378–93.

Asafu-Adjaye, J. 2014. "The economic impacts of climate change on agriculture in Africa". *Journal of African Economies:* ii17–ii49.

Baldos, U.L. and T.W. Hertel. 2015. "The role of international trade in managing food security risks from climate change". *Food Security*, 7: 275–90.

Burke, M., J. Dykema, D. Lobell, E. Miguel and S. Satyanath. 2011. *Incorporating Climate Uncertainty into Estimates of Climate Change Impacts, with Applications to US and African Agriculture.* Cambridge, Massachusetts: NBER.

Calzadilla, A., T. Zhu, K. Rehdanz, R.S. Tol and C. Ringler. 2013. "Economywide impacts of climate change on agriculture in Sub-Saharan Africa". *Ecological Economics,* 93: 150–65.

Calzadilla, A., T. Zhu, K. Rehdanz, R.S. Tol and C. Ringler. 2014. "Climate change and agriculture: Impacts and adaptation options in South Africa". *Water Resources and Economics*, 5: 24–48.

Costinot, A., D. Donaldson and C. Smith. 2016. "Evolving comparative advantage and the impact of climate change in agricultural markets: Evidence from 1.7 million fields around the world". *Journal of Political Economy,* 124(1): 205–47.

Duchin, F. and R. Juliá. 2007. "World trade as the adjustment mechanism of agriculture to climate change". *Climate Change:* 393–409.

FAO. 2018. *The State of Agricultural Commodity Markets 2018. Agricultural trade, climate change and food security.* Rome: Food and Agricultural Organization of the United Nations.

FAO-GAEZ. 2019. *Global Agro-Ecological Zones.* Retrieved January 2019, at: http://gaez.fao.org/Main.html#

FAOSTAT. 2018. *Value of Agricultural Production.* Retrieved December 2018, at: http://www.fao.org/faostat/en/#data/QV

Govereh, J. 2007. "Regional trade in food staples: Using trade policy to improve farmer incentives and food security". Paper presented at the Conference on Strengthening and Widening Markets and Overcoming Supply Side Constraints for African Agriculture, 3–5 June.

Hertel, T. 2018. *Climate Change, Agricultural Trade and Global Food Security.* Rome: Food and Agricultural Organization of the United Nations.

Intergovernmental Panel on Climate Change (IPCC). 2000. "Special report on emissions scenarios". Cambridge, UK: Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). 2007. "Climate change 2007: Synthesis report". Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change, Geneva.

Josling, T. 2008. "World bank work program on regional integration and agricultural trade policy framework document". The World Bank, Washington, D.C.

Kurukulasuriya, P. and R. Mendelsohn. 2008. "Ricardian analysis of the impact of climate change on African cropland". *African Journal of Agricultural and Resource Economics,* 2(1).

Lee, H.-L. 2009. "The impact of climate change on global food supply and demand, food prices, and land use". *Paddy and Water Environment, 7,* 321–31.

Lobell, D.B. and W. Schlenker. 2010. "Robust negative impacts of climate change on African agriculture". *Environment Research Letters.*

Lobell, D., M. Bänziger, C. Magorokosho and B. Vivek. 2011. "Nonlinear heat effects on African maize as evidenced by historical yield trials". *Nature Climate Change:* 42–5.

Molua, E.L. 2008. "Turning up the heat on African agriculture: The impact of climate change on Cameroon's agriculture". *African Journal of Agricultural and Resource Economics,* 2(1).

Msowoya, K., K. Madani, R. Davtalab, A. Mirchi and J.R. Lund. 2016. "Climate change impacts on maize production in the warm heart of Africa". *Water Resources Management*, 30: 5299–312.

Nelson, G., A. Palazzo, A.C. Ringer, T. Sulser and M. Batka. 2009. "The role of international trade in climate change adaptation". International Centre for Trade and Sustainable Development (ITCTSD) and International Food & Agricultural Trade Policy Council.

Porteous, O.C. 2016. "Essays on agricultural trade in sub-Saharan Africa". Unpublished PhD thesis, University of Berkeley, Department of Agricultural and Resource Economics.

Rakotoarisoa, M., M. Iafrate and M. Paschali. 2012. "Why has Africa become a net food importer? Explaining Africa agricultural and food trade deficits". Trade and Markets Division, Food and Agricultural Organisation of the United Nations, Rome.

Seo, N.S., R. Mendelson, A. Dinar, R. Hassan and P. Kurukulasuyira. 2009. "Ricardian analysis of distribution of climate change impacts across agro-ecological zones in Africa". *Environment and Resource Economics*, 43: 313–32.

Serdeczny, O., S. Adams, F. Baarsch, D. Coumou, A. Robinson et al. 2015. "Climate change impacts in sub-Saharan Africa: From physical changes to their social repercussions". *Regional Environmental Change.*

Simbanegavi, W. and C. Arndt. 2014. "Climate change and economic development in Africa: An overview". *Journal of African Economies*, 23 (AERC Supplement 2): ii4–ii16.

United States Department of Agriculture, Foreign Agricultural Service (USDA-FAS). 2015. "A turning point for agricultural exports to sub-Saharan Africa". United States Department of Agriculture.

Ward, P.S., R.J. Florax and A. Flores-Lagunes. 2014. "Climate change and agricultural productivity in sub-Saharan Africa: A spatial sample selection model". *European Review of Agricultural Economics,* 41(2) 199–226.

World Bank. 2012. "Africa can help feed Africa: Removing barriers to regional trade in food staples". The World Bank, Washington, D.C.

Mission

To strengthen local capacity for conducting independent, rigorous inquiry into the problems facing the management of economies in sub-Saharan Africa.

The mission rests on two basic premises: that development is more likely to occur where there is sustained sound management of the economy, and that such management is more likely to happen where there is an active, well-informed group of locally based professional economists to conduct policy-relevant research.

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