Climate Change, Agricultural Production and Trade in Africa

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Abstract

According to IPCC (Intergovernmental Panel on Climate Change) (2013) predictions climate change is forecast to hit Africa heavily, with temperatures rising on the continent more than the global median, extreme weather events becoming more prevalent, and drier areas becoming even drier. Additionally Africa's economy is highly dependent on agriculture most vulnerable sector to the impacts of climate change and supports nearly 90 percent of its population. A critical challenge facing the continent is how to feed an expected population of around 2.4 billion by 2050 which will be double the current population size while simultaneously reducing and responding to climate change. Unless action is taken now to make agriculture more sustainable, productive and resilient, climate change impacts will seriously compromise food production in countries and regions that are already highly food-insecure. Embedded in these, climate change possess substantial challenges in agricultural production, but also creates opportunities for trade. Trade is often built into the economic model which assess climate change and agriculture, but are rarely the focus of such analysis. Despite the considerable opportunities trade creates in moving goods from surplus to deficit area, only a limited number of studies have explicitly investigated the interaction between trade, climate change and agriculture in Africa. Although there is a growing number of studies analyzing how agricultural productions and commodity markets need to be adjusted for promoting interregional balance in agricultural production and food security in response to climate change, few of them have had interests for potential adjustments in intra Africa agricultural trade in changing climate. By reviewing different literatures, this paper provides an overview of the climate change, agriculture and trade nexus in Africa and highlights how the trade aspect of the nexus is missing in present literature reviews. It also identifies and puts forth entry points for regional nexus dialogue.

Keywords: Climate change, trade, food security, agricultural production and Africa

1. Introduction

1.1. Background

Africa is most vulnerable to the impacts of climate change, especially in agriculture, a key sector of its economy that supports nearly 90 percent of its population. There is wide consensus that climate change, through increased extremes, will worsen food security in Africa. The continent already experiences a major deficit in food production in many areas, and potential declines in soil moisture will be an added burden. Food-importing countries are at greater risk of adverse climate change, and impacts could have as much to do with changes in world markets as with changes in local and regional resources and national agricultural economy. A critical challenge facing the continent is how to feed an expected population of around 2.4 billion by 2050 which will be double the current population size (UN, 2015) while simultaneously reducing and responding to climate change. Unless action is taken now to make agriculture more sustainable, productive and resilient, climate change impacts will seriously compromise food production in countries and regions that are already highly food-insecure.

Most studies and models on impacts of climate change on agricultural production in Africa indicate that there will be negative effects on crop yields and livestock management over next century (Ahmed et al., 2012; Muller and Robertson, 2014; Nakaegawa et al., 2012; Roudier et al., 2011). These impacts of climate change will reduce food availability that underpins food security in Africa. The continent can expect to have between 55 and 65 million extra people at risk of hunger by 2080s if temperature increases by 2.5^{0}C (Parry et al., 1999 as cited by Niang et al., 2014). On the other hand, most global studies predict that cereal production will increase over the next century, even under climate change, and will be sufficient to feed the world's growing population (Fischer et al., 2005; OECD/FAO, 2016; Niang et al., 2014; Parry et al., 2004; Sultan, 2013). However, these studies also highlight that global cereal production will be highly uneven between regions, with increased yield at high and mid-latitudes, and decreased yield at lower latitudes. This pattern is expected to be more pronounced as time progresses.

As Africa has more areas with lower latitudes, fewer people in different regions of the continent will be able to feed themselves, and hence there will be more and more reliance on markets and trade to meet food security under changing climate. Although there is a growing number of studies analyzing how agricultural productions and commodity markets need to be adjusted for promoting interregional balance in agricultural production and food security in response to climate change (Ahmed et al., 2012; Asafu-Adjaye, 2014; Berg et al., 2013: Brenton et al., 2014; Nalson et al., 2009; Nalson et al., 2014; Muller. and Robertson, 2014), few of them have had interests for potential adjustments in intra Africa agricultural trade in changing climate. The potential implications for trade in climate change and agricultural production in Africa are substantial, yet with some exceptions the body of literature touching upon this topic is limited. Trade is often built into the economic model which assess climate change and agriculture, but are rarely the focus of such analysis. Trade is usually assumed to provide a mitigating force against the impact of climate change, smoothing volatility and decadal developments in agricultural production. It is usually considered an autonomous adaptation but can in fact be reinforced by policy measures to represent more of a planned adaptation. Conversely, the current policy constraints to trade in agriculture could adversely affect the assumption that trade will assist in mitigating climate-induced agricultural impacts.

It is evident that agricultural production and commodity markets need to be adjusted to promote inter-regional balance in agricultural production and food security in response to climate change. As such, an improved understanding of how decadal climate change will impact agricultural trade for Africa's food security would be of particular value. In addition to achieving food security through agricultural trade, identifying a country's comparative advantage in order to export crops that benefited from climate change would help policymakers and the private sector in forward planning and adapting to changes. However very few studies so far have critically examined the role continental and inter regional agricultural trade would play as a response to the undeniable climate change and for African countries to use trade as a tool for economic transformation and poverty eradication. Given the urgency and importance of this topic, this paper addresses the gap in current literature. Thus, it focuses on identifying opportunities for African agriculture in meeting the challenges posed by climate change with the right policy framework. The aim of the discussion is to help in mitigating food security challenges in Africa taking trade as a pull factor.

1.2. Defining the nexus

In this paper "The Nexus" is defined as the place where climate change, agricultural production and trade intersect. At its heart is a robust understanding of the interdependencies between these three systems to achieve food security in Africa. As a concept, The Nexus is being promoted as a process by which trade plays as a pull factor in a way that ensures food security for an ever-growing population at a time of climate change. Agriculture is the most sensitive sector for climate change however it is also evident that our planet already produces enough food for everyone, but it is not getting everywhere as needed due to perverse subsidies and other trade barriers. This study therefore focuses on the need for tradeoffs, compromise and synergies between climate change, agricultural production and trade. Nexus thinking will be a prerequisite for success. Not just as an emergency response to solve crises when they occur, but as an established approach to address challenges and opportunities in a hyper-connected landscape. The Nexus thinking is beneficial to identify and resolve trade-offs, foster synergies, and optimize outcomes across different actors and sectors.

1.3. Methodology

There is plenty of work on food security and climate change in Africa, but a comprehensive literature review on trade, food security and climate change in Africa seems to be missing. This paper provides a review of the different methodologies currently employed by the body of literature assessing trade in climate change and agricultural production in Africa. Although its main purpose is identifying literature gaps and targeting areas in which further research would be especially valuable, it also draws upon the key outcomes from this literature to present a summary of findings useful for stimulating policy thinking and responses. The literature review applied a wide range of sources which included learned papers; project reports; professional journals; institutional records, web sites and etc. where the main focus lies on three different methodological approaches to assessing trade in climate change and agricultural production in Africa: Computable General Equilibrium Modelling, Qualitative Analysis, and Empirical Modelling. This is followed by key findings and summary from a nexus project conducted for two years on the same title from ECOWAS region. It is included to get a clear glimpse on the methodological gap for the nexus work and identify entry points for a regional nexus dialogue.

2. Climate change in Africa

Adapting to and mitigating climate change will be a defining challenge over the next few decades for Africa. Increasing temperatures, changing rainfall patterns, and more frequent and intense extreme weather events, including droughts and floods, are projected across the region (Muller et al., 2014). The recent extreme droughts in the region offer some insight into the likely challenges ahead (OECD/FAO, 2016; WFP, 2016).

2.1. Observed trends

Near surface temperatures have increased by 0.5°C or more during the last 50 to 100 years over most parts of Africa, with minimum temperatures warming more rapidly than maximum temperatures (Collins 2011; Grab and Craparo, 2011; Hoffman et al., 2011; Mohamed, 2011; Stern et al., 2011; Funk et al., 2012; Nicholson et al., 2013). In recent decades, North African annual and seasonal observed trends in mean near surface temperature indicate an overall warming that is significantly beyond the range of changes due to natural (internal) variability (Barkhordarian et al., 2012a). During the warm seasons (March- April-May, June-July-August) an increase in near surface temperature is shown over northern Algeria and Morocco that is very unlikely due to natural variability or natural forcing alone (Barkhordarian et al., 2012b). The region has also experienced positive trends in annual minimum and maximum temperature (Vizy and Cook, 2012).

Over West Africa and the Sahel, near surface temperatures have increased over the last 50 years. Collins (2011) shows statistically significant warming of between 0.5°C and 0.8°C between 1970 and 2010 over the region using remotely sensed data with a greater magnitude of change in the latter 20 years of the period compared to the former.

The equatorial and southern parts of eastern Africa have experienced a significant increase in temperature since the beginning of the early 1980s (Anyah and Qiu, 2012). Similarly, recent papers from the Famine Early Warning Systems Network (FEWS NET) indicate that there has been an increase in seasonal mean temperature in many areas of Ethiopia, Kenya, South Sudan, and Uganda over the last 50 years (Funk et al., 2011, 2012). In addition, warming of the near surface temperature and an increase in the frequency of extreme warm events has been observed for countries bordering the western Indian Ocean between 1961 and 2008 (Vincent et al., 2011). A continued warming in the Indian- Pacific warm pool has been shown to contribute to more frequent East African droughts over the past 30 years during the spring and summer seasons (Shongwe et al., 2011; Williams and Funk, 2011). It is unclear whether these changes are due to anthropogenic influences or multi-decadal natural variability (Lyon and DeWitt, 2012; Lyon et al., 2013).

In recent decades, most of southern Africa has also experienced upward trends in annual mean, maximum, and minimum temperature over large extents of the sub-region during the last half of the 20th century, with the most significant warming occurring during the last 2 decades (Zhou et al., 2010; Collins, 2011; Kruger and Sekele, 2012). The impact of drought has been felt acutely this season over southern Africa, as

El Nino hit hard. El Niño conditions have caused the lowest recorded rainfall between October 2015 and January 2016 across many regions of Southern Africa in at least 35-years. The period also recorded the hottest temperatures in the past 10 years. Short-term forecasts, based on more recent data, (February to May) indicate the high probability of continuing below-normal rainfall across the region, signaling this may become one of the worst droughts in recent history (WFP, 2016).

2.2. Projected trends

Temperatures in Africa are projected to rise faster than the global average increase during the 21st century (Joshi et al., 2011; Sanderson et al., 2011; James and Washington, 2013). Global average near surface air temperature is projected to move beyond 20th century simulated variability by 2069 (+/-} 18 years) under Representative Concentration Pathway 4.5 (RCP4.5) and by 2047 (+/-} 14 years) under RCP8.5 (Mora et al., 2013). However, in the tropics, especially tropical West Africa, these unprecedented climates are projected to occur 1 to 2 decades earlier than the global average because the relatively small natural climate variability in this region generates narrow climate bounds that can be easily surpassed by relatively small climate changes.

Precipitation projections are more uncertain than temperature projections and exhibit higher spatial and seasonal dependence than temperature projections (Rowell, 2012; Orlowsky and Seneviratne, 2012). Based on the Coupled Model Intercomparison Project Phase 5 (CMIP5), most areas of the African continent do not exhibit changes in mean annual precipitation that exceed the baseline variability in more than 66% of the models in either the mid- or late 21st-century periods for RCP2.6 (Niang et al., 2014). The CMIP5 ensemble projects very likely decreases in mean annual precipitation over the Mediterranean region of northern Africa and southern Africa in the mid- and late 21st century periods for RCP8.5 (Niang et al., 2014).

Many CMIP5 models for Central, Eastern and Western Africa precipitation projections indicate a wetter core rainfall season with a small delay to rainy season by the end of the 21st century (Biasutti, 2013; Niang et al., 2014; Seneviratne et al., 2012; Shongwe et al., 2011; Vizy and Cook, 2012), with more intense wet seasons and less severe droughts during October-November-December (OND) and March-April-May (MAM). However these results indicate a reversal of historical trend in these months for eastern Africa regions (Williams and Funk, 2011). For example, regional climate model studies suggest drying over most parts of Uganda, Kenya, and South Sudan in August and September by the end of the 21st century as a result of a weakening Somali jet and Indian monsoon (Patricola and Cook, 2011). Cook and Vizy (2013) indicate truncated boreal spring rains in the mid-21st century over eastern Ethiopia, Somalia, Tanzania, and southern Kenya while the boreal fall season is lengthened in the southern Kenya and Tanzania (Nakaegawa et al., 2012). Moreover regional model studies suggest an increase in the number of extreme rainfall days over West Africa and the Sahel during May and July (Vizy and Cook, 2012) and more intense and more frequent occurrences of extreme rainfall over the Guinea Highlands and Cameroun Mountains (Sylla et al., 2012; Haensler et al.,2013).

2.3. Impact of climate change

Climate change is a complex process which has multiple direct and indirect impacts at different levels in an economy. These climate-induced changes could lead to comparative advantage in crop production across the world, where the diversity in impacts on crop yields reflects not only the spatial heterogeneity of projected climate change, but also the differences in vulnerability to climate change across crop types and also cropping periods. Climate change is very likely to have an overall negative effect on yields of major food security crops across Africa, with strong regional variability in the degree of yield reduction (Liu et al., 2008; Lobell et al., 2008, Schlenker and Lobell, 2010; Lobell et al., 2011; Roudier et al., 2011; Berg et al., 2013; Sultan et al., 2013).

Parrya et al., 2004 (as cited by Asafu-Adjaye, 2014) assessed the effects of climate change on global food production under the IPCC's SRES scenarios. They found that the world would continue to feed itself through this century because production in the developed countries (which mostly benefit from climate change) would compensate for the projected decline in agricultural output in the developing countries. Bosello et al. (2010) undertook an inter-model comparison using five different models that provide a regional break-down of overall climate change impacts as a percentage of GDP, for a temperature increase of 2.5^{0}C. Another study by Barr et al. (2010) also showed African countries to be the most vulnerable in the world, with the highest expected impacts of climate change and the lowest capacity to adapt. Using the Regional Integrated model of Climate and the Economy (RICE) model, Vivid Economics (2011) found that climate damages in Africa (as a percentage of GDP) are expected to be higher than in any other region in the world, more than 10 percentage points higher than the next most exposed region (India) and more than twice as high as in the USA, Russia, Eurasia, and Latin America.

Even though climate change impacts in Africa is projected towards reducing growing season length (Thornton et al., 2011), other studies project the potential for some areas to experience longer growing seasons (Cook and Vizy, 2012). One example is in eastern Africa where maize production could benefit from warming at high elevation locations (Schlenker and Lobell, 2010; Ahmed et al., 2012), although the majority of current maize production occurs at lower elevations, thereby implying a potential change in the distribution of maize cropping. Studies in North Africa by, Drine (2011), and Mougou et al. (2011) also indicate a high vulnerability of wheat production to projected warming trends. In West Africa, temperature increases above 2°C (relative to a 1961–1990 baseline) are estimated to counteract positive effects on millet and sorghum yields of increased precipitation with negative effects stronger in the savannah than in the Sahel, and with modern cereal varieties compared with traditional ones (Sultan et al., 2013).

3. Trade in Africa

Trade is the most potent driver for growth and development, and it also binds countries together. The common trend in African countries and their trading pattern is limited and focused on a sub-regional level like West Africa region, Eastern Africa, Southern Africa and as such rather than a continental trading pattern. This is an indication of the potential to achieve more, and the need to focus on how best to do so. For instance trade can help alleviate the impact of weather volatility by enabling risk spreading and crop surplus areas to offset supply shocks in deficit ones (Ahmed et al., 2012; Brenton et al., 2014; Verma et al., 2014; Shepherd and Maur, 2015; Keyser, 2012; Moctar et al., 2015). Here both regional and extra-regional trade are important, with regional trade accounting for similar dietary preferences, import responsiveness and reduced transport costs, and being especially important for Africa's many landlocked countries, while extra-regional trade provides further stability.

In addition, trade can also help better design social safety net programs. For example the emergence of Zambia as a consistent surplus producer, particularly for maize, has resulted in changing regional trade patterns in Eastern and Southern Africa (OECD/FAO 2016). Chapoto and Sitko, 2014 in their paper has indicated the positive contribution intra-regional trade plays where neighboring countries are pooling production to stabilize market through cross borders (Mozambique-Malawi, Malawi-Zambia, Uganda-Kenya). Even though there is enormous opportunity for trade within countries and across borders between food surplus and food deficit areas in Africa, such potential is undermined by barriers to trade along the whole value chain (World Bank, 2012; USAID, 2013).

Informal trading charges, burdensome border regimes and limited transportation infrastructure have all been identified as trade impediments (Morrison and Sarris, 2016; OECD/FAO 2016). For example, according to a report from OECD (Lesser, C. and E. Moisé-Leeman, 2009), in 2006, Uganda's informal exports of agricultural goods to its five neighboring countries represented 75% of official agricultural export flows. In the Horn of Africa (Sudan, Ethiopia, Eritrea, Djibouti and North-East Kenya), Little (2005) notes that for some agricultural commodities — like livestock and grain — unofficial exports to neighboring countries in fact exceeded at times official trade by a factor of 30 or more, hence constituting over 95% of total trade in these commodities. The growing unregistered cross-border trade in agricultural products between neighboring countries in Africa proves the impracticality of the official intra-regional barriers, and highlights the need for deeper regional integration and effective regional policy (Araujo and Brunelin, 2013; Keyser, 2012; Versailles, 2012).

4. Trade Approaches in Africa

Trade can perform a valuable role in addressing increasing food insecurity associated with climate change in Africa. Despite the considerable importance of trade, only a very limited number of studies have investigated the interaction between trade, climate change and agriculture in Africa. Important studies in this area utilise Computable General Equilibrium (CGE) modelling to analyse the interaction between biophysical models of climate change and market-based responses, such as international trade. Yet many of these models are calibrated on assumptions which are more appropriate for high income, industrialized economies with greater adaptive capacity (Hertel and Lobell, 2014). A second approach uses qualitative analysis, for instance to build an understanding of how trade can help African countries access inputs and technologies required for improved climate change adaptation (Keyser, 2012; Shepherd and Maur, 2015). A third utilises empirical models and econometrics to present the case for improved trade as a solution to climate-induced weather volatility, by looking at the co-occurrence of supply-side shocks and market access. Even though these models are rather broad categories, yet they provide a useful structure through which to think about the various approaches to this complex topic.

4.1. Computable General Equilibrium (CGE)

CGE models are useful in such analysis as they have the capacity to incorporate a wide array of complex interactions, such as between biophysical models of climate, crop productivity models and those of the economy. In this context, CGE models can be further split into three subcategories: i) Integrated Assessment Models, which holistically tie together biophysical climate and economic interactions into a single modelling framework, ii) Linked Integrated Assessment Models, in which separate models for the biosphere produce estimates which are fed into economy models, thus linking the two together, and iii) economy models, comprising only economic interactions, such as those of international trade, factor prices, and crop prices, and drawing from pre-estimated values for climate change, such as estimates on agricultural productivity changes. As with all CGE modelling, these approaches provide considerable value in attempting to predict the future, and are calibrated on empirical findings, yet necessarily require the employment of substantial assumptions See McKibbin et al., 2011; Asafu-Adjaye and Mahadevan, 2013).

4.1.1. Integrated Assessment Models

Integrated Assessment Models aim to capture, within a single modelling framework, the main features of climate and earth systems alongside social and economic behaviours in order to provide a holistic model of climate change. Such models include AD-DICE which is designed to derive an intertemporally optimal global carbon price path. The similar AD-WITCH model additionally breaks the world into 12 geographic regions and differentiates impacts and adaptation rates by whether regions are "North" or "South". Each provides a comprehensive, but highly aggregated treatment of climate change, especially for subcomponents of interest, such as African agriculture and trade. As such these models provide valuable estimates that factor into the broader climate change research, but which do not in themselves especially help address questions of trade in climate change and agriculture in Africa.

4.1.2. Linked Integrated Assessment Models

Linked Integrated Assessment Modelling Frameworks differ in that they provide improved focus on specific modelling issues of interest, at the expense of being less comprehensive. Yet models need not necessarily be comprehensive in order to provide useful insights and such additional focus can provide further detail to aspects of interest, such as agricultural and trade. Such models typically combine a biophysical model of climate change, based on biophysical, biochemical or hydrological processes, and emission scenarios from the IPCC, with additional modules that focus on subcomponents of interest, such as farm management and technology responses or market-oriented reactions. Interactions allowed by such models include changes in trade; consumption adjustments; substitution between capital, labour and other inputs, with land; crop varieties; growing periods; and irrigation intensity.

A good example of such a model is the

IMAGE-MAGNET, in which shocks concerning climate, carbon and nitrogen cycles are produced in the biophysical IMAGE model before being passed over as exogenous productivity shocks to the MAGNET model, which in turn stimulates economic responses in land area use, intensification of production, changes in crop mixes and livestock activity, price-sensitive consumption behaviour and international trade (Bouwman et al. 2006; Eickhout 2008; Van Meijl et al. 2006). Hertel and Lobell (2014) provide a useful summary of such models and their capacity for analysing both biophysical and economic adaptations to climate change in agriculture.

4.1.3. Economy Models

A third form of CGE models simply take the biophysical estimates of climate change as given, drawing values for agriculture productivity shocks from the pre-existing literature and inputting these into economic models. A good example here is However, like quantitative Analysis, empirical models necessarily concern information that is historical, or at most that of Hertel et al. (2010), which feeds a range of climate change estimates, based on Christensen et al. (2007) and Ainsworth et al. (2008), into the GTAP model as agricultural productivity shocks.

4.2. Qualitative Analysis

Qualitative Analysis are highly complementary to CGE modelling approaches, buttressing the predictive capacity of the latter with further detail and depth. They are especially valuable in assessing policy requirements and constraints, which may not always be easily quantifiable.

4.3. Empirical models

Empirical models place a quantitative lens over historical data to tease out the relationship between variables of interest, such as agricultural exports between trading partners with the co-occurrence of dry and non-dry years (Ahmed et al., 2012).

current, and as such are less adept at complex future predictions and estimations.

Table 1: Methodological Summary of Literature on Trade in Climate Change and Agricultural Production in Africa

Analytical Methods		Examples	Advantages	Disadvantages
CGE Models	Integrated Assessment Models	AD-DICE *Aragwala et al., 2011; Nordhaus, 2008* AD-WITH *Aragwala et al., 2011; Bosello et al., 2010*	• Interactions between variables feedback throughout model • Forward looking economic agents	• Highly aggregated • Little scope to focus on Africa, and intra-Africa trade • Reliance on assumptions
	Linked Integrated Assessment Models	IMAGE-MAGNET *Bouwman et al., 2006; Eickhout, 2008; Van Meijl et al., 2006* IMPACT-GTAP-W *Calzadilla et al., 2009; Calzadilla et al., 2014* CMIP3-GTAP *Ahmed et al., 2012* SIMPLE *Baldos and Hertel, 2015*	• Scope for focus on specific issues of interest • Can specify biophysical shocks to relate to the issues of interest	• All variables do not feedback throughout model • Reliance on assumptions
	Economy models	GTAP *Hertel et al. 2010* *Costinot et al. 2014*	• Take biophysical estimates from pre-existing literature to simplify analysis	• Cannot tailor biophysical shocks to questions of interest
Qualitative Analysis		*Keyser, 2012* *Maur and Stepherd, 2015*	• Useful for non-qualitative information	• Less adept at climate-related predictions
Empirical Models		*Badiane et al., 2013* *Moctar et al., 2015* *Ahmed et al., 2012*	• Based on actual observed relationships between variables	• Less adept at climate-related predictions

5. Case study

IMPACT OF CLIMATE CHANGE ON AGRICULTURAL TRADE FLOWS AND FOOD SECURITY IN ECOWAS

The United Nations University Institute for Natural Resources in Africa (UNU-INRA) in collaboration with the African Climate Policy Centre (ACPC) of the United Nations Economic Commission for Africa (UNECA) implemented a two-year research titled: "Climate Change, Agricultural Trade and Food Security in ECOWAS". The main objective of the project is to evaluate the impacts of climate change on agricultural trade flows in the fourteen ECOWAS countries of Benin, Burkina Faso, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo. The project employed agricultural land use observations of 2004 and simulated up to 2100. The project focused mainly on the yields and prices of some priority crops under various climate and socio-economic scenarios in intra West African agricultural trade as a response to changing climate.

Pathways[3] and four prevailing socio-economic conditions (SSP)[4].

This research uses a bio-economic model with a representative risk-neutral and profit maximization economic agent. The model integrates a biophysical-geographic information system (GIS) in a regional

3 **RCP 4.5** (Global temperature ranging between 0.90c – 2.6 0c)and RCP 8.5 (Global temperature ranging between 1.40c – 4.8 0c)

4 **(SSP1),** State Actors are dominants meaning that strong institutions exist but the governments are short sighted by short-term gains leading to an extensive need of cash. As a result, inflation is a little above the average.

(SSP2), State Actors are focused on long-term priorities with a slow and painful transition to sustainable development. As a result, general price levels are well controlled with low inflation.

(SSP3), Non-State actors such NGOs and the civil society are mature and are in control of the state business. As a result, there is a struggle between civil society and the private sector that is ultimately productive. We predict medium inflation levels in this scenario.

(SSP4), Non-State actors are dominants with short sighted priorities. Institutions are week and the countries are not governed and the resources of the country are used to solve crisis instead of investing in the future. As a result, inflation levels are high

Summary of the project

This project takes advantage of agro-climatic zones to investigate the impacts of climate change on land allocation and crop production in the Economic Community of West African States zone. A regional mathematical programming model is used to simulate the implications of climate change on crop acreage and crop production following two Representative Concentration

economic mathematical programming model (hereafter ECOLAND). ECOLAND is a strictly supply-oriented model which considers climate and atmosphere factors such as temperature, precipitation, and CO_2 as well as non-climate factors such as soil fertility, demography and output prices as exogenous variables

The project also used to generate baseline and climate change data for ECOWAS is a Regional Climate Model (RCM). The regional climate modelling technique consists of using initial conditions, time-dependent lateral meteorological conditions and surface boundary conditions to drive high-resolution limited area models. The driving data is derived from CMIP5 Global Climate Models (GCMs) or Earth System Models (ESMs) and can include greenhouse has (GHG) and aerosol forcing.

This project also investigates the impact of climate change on agricultural trade flows inside and outside the ECOWAS region. To reach its objectives, the project uses a trade module of trade cost minimization built within a bioeconomic optimization model of crop land allocation. The results show that the pattern of trade in ECOWAS induced by climatic factors will depend on socio-economic conditions that may prevail during the century. No specific pattern of trade flow is predicted but there are some countries that may export some years and may become importers some other years. Furthermore, several countries may become dependent on outside ECOWAS trade to meet their domestic food demands.

Gaps Observed in the project

- The project focused mainly on robust climate change research's and its predicted impact in the agricultural production and yield than to focus on intra-West African agricultural trade integration
- Individual countries data for some variables were not available therefore some of the countries were omitted from the overall analysis
- The project integrated five different models where individual analyses had to be implemented and then aggregated to produce a final result. That seemingly makes the methodology prone to be sensitive to errors that may have variable spillovers
- The project used agro-climatic zones to investigate the impacts of climate change on land allocation and crop production, the findings do not provide a detailed analysis on the pattern of those acreages change and for which crop type was not specified
- The research deployed ECOLAND model which does not consider the relationship between price responses and induced supply changes (due to import from outside the region)
- The research used agricultural land use to forecast crop yields, it did not employ crop suitability mapping that could be more appropriate in identifying new agro-ecology for the priority crops under climate shifts. This is important because different studies have highlighted the impact of climate change in terms of reducing suitable areas for range of crops mainly in sub-Saharan Africa and the Caribbean areas that has the least capacity to cope
- The research's finding was not able to show any specific pattern of trade flow that was induced by climatic factors
- The current status of agricultural trade in the ECOWAS region was not captured in the project

Way Forward/ Recommendations

- It is important to identify and use a suitable models that captures all the necessary variables of climate change, agricultural production and trade. Models such as GTAP[5] could be used to fully understand the impact of climate change on agricultural trade flows in the ECOWAS region
- It is important to have an integrated understanding of how decadal climate developments will impact both the international and continental market since the rules may change and it have a profound implication for Africa's food security and the continents exportable crops
- In doing such kind of project all the available arrays of variables including adaptation measures like irrigation, biotechnology and other sustainable methods of crop yields increase as well as supply induced price changes due to climate change needs to be take in to account
- A deeper look on how trade can operate as an insurance against climate change is important, in order for regions that are affected by reduced agricultural productivity can import from other region where food is available
- Suitability mapping also plays a big role to assist policymakers and the private sector in forward planning and adapting to changes in country comparative advantage induced by climate change

6. Conclusion

There is substantial evidence that the frequency and intensity of extreme climate events may change in the coming decades, with these changes being particularly important for agriculture. African countries, are particularly sensitive to climate extremes due to their reliance on rain-fed subsistence agriculture. However, there is considerable heterogeneity in the impacts of climate change across countries, and so international agricultural markets may allow for pooling of the risk posed by local (or national) climate extremes. Farmers in countries that are less severely affected by particular weather outcomes may be able to sell excess supply to meet the excess demand from consumers in the more severely affected regions. In the medium to long run, declines in agricultural production arising from climate change in some

[5] The standard GTAP (Global Trade Analysis Project) Model is a multi-regional, multi-sectoral, computable general equilibrium model, with perfect competition and constant returns to scale. Some of the specific model that can be used in this kind of report includes: GTAP-E is an extension of the GTAP framework (data base and model) used to evaluate costs of abatement and to assess the spill-over effects of greenhouse gases (GHG) abatement policies via international trade and sectoral interaction. GTAP-AEZ modifies the GTAP framework to incorporate different types of land (Agro Ecological Zones). Global Land Use and Global Land Cover Data Base includes global forestry data.

countries might be offset by increases in production in other regions. Whereas for countries that are negatively affected by climate change in their production could use a diversified sources of imports to help mitigate the effects of a negative supply shock. Conversely, having diverse destinations for exports can allow for export increases when negative supply shocks affect the partners' dominant sources.

A major element of the analytical process comprised review of different literature on climate change adaptation, agricultural production and trade in Africa. The review itself suggested that there are lack of literatures that capture the important role trade plays in climate change, agriculture and food security nexus, and with the right policy framework can help in mitigating food security challenges in Africa. This study is thus a suitable point of departure for further study. Further research on these three areas would be of particular value:

Firstly, an improved understanding of how projected climate changes will impact the international market for Africa's food security. Secondly, improved estimates of the impact of increased weather volatility on African crops for a broader range of African countries, and the implications of such unpredictability, would help underline the case for agricultural trade openness both regionally and globally with Africa. Thirdly, identifying a country's comparative advantage due to climate change would help policymakers and the private sector in forward planning and adapting to changes through exporting food security crops.

7. Reference

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