United Nations
Economic Commission for Africa

ACPC
African Climate Policy Centre

ASSESSING THE IMPACT OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTION, TRADE AND FOOD SECURITY IN THE EAST AFRICA COMMUNITY (EAC).

Final Report

July 2017

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ABBREVIATIONS

ACPC	African Climate Policy Centre
CET	Common External Tariff
CGE	Computable Equilibrium Model
CIF	Cost Insurance and Freight
CPC	Central Product Classification system
EAC	East African Community
FAO	Food and Agriculture Organization
GATT	General Agreement on Trade in Tariffs
GDP	Gross Domestic Product
HS	Harmonized Standards
IFPRI	International Food Policy Research Institute
IPCC	International Panel on Climate Change
ISIC	International Standard Classification of All Economic Activities
KEPHIS	Kenya Plant Health Inspectorate Services
MFN	Most Favored Nation
NTB	Non Tariff Barriers
SAM	Social Accounting Matrix
SPS	Sanitary and Phyto-sanitary Measures
SSA	Sub-Saharan Africa
TAM	Trade Analysis Model
UNECA	United Nations Economic Commission for Africa
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization
WTO	World Trade Organization

1 BACKGROUND

1.1 Introduction

Climate change is the overall change in a region's weather pattern. This includes precipitation, temperature, cloud cover. In Africa, there is a strong link between climate change, agriculture and food security. This is because most African countries heavily rely on climate for their agricultural production. When climate change affects agricultural production, it results in a situation where a country has less food to meet the needs of her people. In order to meet the demands, most nations tend to trade in order to bridge the deficit. But when this deficit is not met, a country becomes food insecure. It is paramount to establish the links between climate change, agricultural production and trade and food security. Unfortunately, there is limited expertise that provides empirical linkage between agricultural production and trade and food security. This can largely be attributed to the multi-disciplinary nature of investigating these three issues together.

Climate change can either affect the production of commodities such as maize, beans, wheat, vegetable, and sugarcane either negatively or positively depending on the climatic conditions that these crops require. At the same time, the supply of these crops is important in determining the food security status of a nation. As already stated, most African economies heavily rely on climate for their agricultural production, therefore change in climatic patterns tend to affect agricultural production, which in turn affects food security. The concept of food security has been used flexibly in research and policy arena. International organizations such as the World Bank, Food and Agricultural Organization (FAO) and World Food Summit have provided contrasting definitions. The study will use the working definition given by FAO (2003):

> *"When all people, at all times have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life"*

Food insecurity exists when people do not have adequate physical, social or economic access to food. Trade policies on the other hand involve a combination of measures such as domestic support measures, export subsidies and tariffs which affect relative prices of both traded and non- traded commodities in any economy, which in turn affects the allocation of resources. These changes tend to alter sectoral and aggregate output, which in turn leads to changes in income levels.

In situations where a nation experiences food shortage or there is an imminent risk of food shortage, governments tend to use a combination of policies to mitigate the risks or increase food supply. There is however limited empirical evidence on the impact of climate change on agricultural production and trade patterns and its impact on food security. Attempting to establish this impact requires a multifaceted approach where climate change simulations are carried out on its impact on agricultural production and how this affects agricultural trade and food security. As a result, the African Climate Policy Centre (ACPC) at the United Nations Economic Commission for Africa (UNECA) has put in place an initiative that will ensure that member states and regional economic blocs mainstream climate change impacts in their development policies, frameworks and plans. ACPC seeks to develop analytical works that seek to inform the linkages between climate change, agriculture production and trade and food security.

The link between climate change and agricultural systems, trade and food security presents three components that are largely interlinked. However, from an analytical perspective, these links can be modeled as different components, which feed into each other in order to establish impact. The ACPC project has three components:

i. The Crop Model- Explores the medium and long-term spatial effects of climate change on agricultural production and food security in the EAC region.
ii. The Economic Policy Model- Explore the Implications on regional agricultural policy across political boundaries, within and across national boundaries.
iii. Trade Analysis Model (TAM) - Examines the potential trade effects of climate change on food security in the EAC region.

This study focuses on the trade effects of climate change on food security, it seeks to establish the evidence on the impact of climate change on agricultural production, trade and food security in order to inform policies that will result in effective climate change adaptation frameworks that ensure food security in the East Africa Community region. From the Trade Analysis Model simulations, it will be possible to establish how the climate change affects agricultural trade and food security. This exercise will provide the appropriate trade policy actions that can be used in mitigating food security challenges arising from climate change.

1.2 Climate Change, Trade and Food Security

Food security is a complex matter and is not solely an agricultural issue. Food security emanates from complex interactions of different sectoral players making it a cross cutting issue. Following the FAO (2003) definition of food security, there are four dimensions to this phenomenon: availability, accessibility, utilization and stability. These dimensions are affected by different factors, for example, climate change has increasingly become a key determinant of agricultural production in most countries in Sub-Saharan Africa (SSA), the changing weather patterns tend to be detrimental to crops such as grains and pulses, which are important for food security. There are also trade policies (in most cases the absence of tariff and non-tariff barriers) that affect the availability of agricultural commodities that may stimulate economic growth through growth in exports which in turn increase incomes, this increases household's capacity to access more food. The presence of tariff and non-tariff barriers result in decreased access to food, which results in food insecurity.

The international panel on climate change (IPCC) (2014) notes that there have been more negative impacts of climate change on crop and terrestrial production than positive impacts. Without adaptation, local temperature increases of 1.0^{c} is likely to negatively impact the yields of key crops such as maize and wheat, resulting in the disruption of agricultural systems and production. The scarcity of grains such as maize and wheat may trigger restrictive trade policies such as quantitative restriction of exports, safe guard or anti-dumping measures and tariff peaks that ensure food security of a nation. These trade restrictive measures are allowed under the World Trade Organization (WTO) multilateral trading framework under conditions where trade is an imminent threat to national food security. The linkage between climate change, trade and food security is important in achieving development at both national and regional level in cases where neighboring countries have a strong integration framework as is the case with the East Africa Community (EAC).

1.3 The East Africa Community (EAC) in Historical Perspective.

The EAC owes its existence to the construction of the Kenya-Uganda railway. Kenya and Uganda formed a customs union in 1917, Tanzania (then called Tanganyika*)* joined in 1927. From 1948 to 1961 there existed the East African High Commission, the East Africa Common Services Organization (1961-1967) and the East Africa Community from 1967 with the final break up taking place in 1977. In 1984 member states of the EAC negotiated and signed a mediation agreement on the division of the Assets and liabilities of the EAC. Subsequent meetings between the three heads of states led to the signing of the agreement that established the permanent tripartite commission for the East African Cooperation on November 30, 1996. The full EAC operations started with the launch of the secretariat in Arusha 14 March 1996. On 7th July 2000, the treaty establishing the EAC came into force, in March 2004, the EAC summit made up of the three heads of states signed the protocol establishing the EAC customs union. The Republic of Rwanda and Burundi acceded to the EAC in June and July 2007 respectively and joined the EAC customs union in July 2009. EAC has made strides in deeper integration by ratifying the common market protocol on July 2010 and the protocol establishing the EAC monetary union in November 2013.

The EAC is made up of five partner states (Kenya, Uganda, Tanzania, Rwanda and Burundi), with common languages and cultures particularly where borders are shared. This implies that there are certain foods that are common in the partner states such as grains, pulses and vegetables among others. The productive sector therefore forms the corner stone of livelihoods of the EAC citizenry since it employs majority of the population. Sustained production of commodities that ensure food security require predictable weather patterns, however, the EAC economies heavy reliance on climate- sensitive natural resources and rain-fed agriculture makes these economies very vulnerable to climate change. The Intergovernmental Panel on Climate Change (IPCC 2007) reports that it is difficult to accurately predict consequences of climate change and the risks associated with it, even though impacts like floods, drought, and decline in crop yields are vividly observed. This study intends to bridge this gap by assessing the effect of climate change on trade and food security.

1.4 Study Objectives

The TAM model will seek to achieve the following objectives:

1. Establish the regional and national agricultural and trade policies within EAC region.
2. Establish the agricultural commodities trade patterns at the regional and national level within the EAC.
3. Establish the impact climate change on agricultural commodity trade patterns and food security with in EAC using Computable General Equilibrium (CGE) and micro simulation models.
4. Provide policy recommendations

1.5 Scope

The TAM component will focus on the four East African Community (EAC) partner states: Kenya, Uganda, Tanzania and Rwanda. Burundi is excluded due to data issues.

2 REGIONAL AND NATIONAL AGRICULTURAL TRADE POLICIES.

2.1 Overview of EAC Economies

The East African Community (EAC) comprises five Partner States namely Kenya, Uganda, Tanzania, Rwanda and Burundi. The region has a total area (including water) of 1.82 million square kilometres and located 5^{0}30"N & 12^{0}S latitude, and 28^{0}45"E & 41^{0}50" E longitudes. Of the total surface area, excluding water bodies, Tanzania occupies 939 thousand square kilometres followed by Kenya (583), and Uganda (241.6) while Rwanda and Burundi are the smallest countries occupying 26.3 and 27.8 thousand kilometres' square respectively.

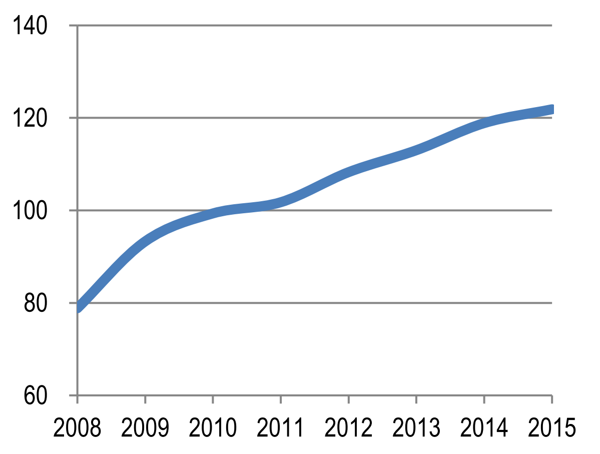
The EAC has a population of 149.7 million people, with Tanzania being the most populous country of the EAC partner states having a population of 48.8 million. Kenya and Uganda have populations of 44.2 and 35.5 million respectively. Rwanda (11.2 million) and Burundi (10 million). In contrast, Rwanda and Burundi have much higher population densities of 445 and 379 people per square kilometre. The other Partner states, Kenya, Uganda and Tanzania have densities of 76, 177 and 55 persons per square kilometre respectively. Uganda's population density is likely to increase faster given the high population growth rate of 3.6 per cent. Kenya's population density is likely to remain low given the low population growth rate of 2.9 per cent per annum.

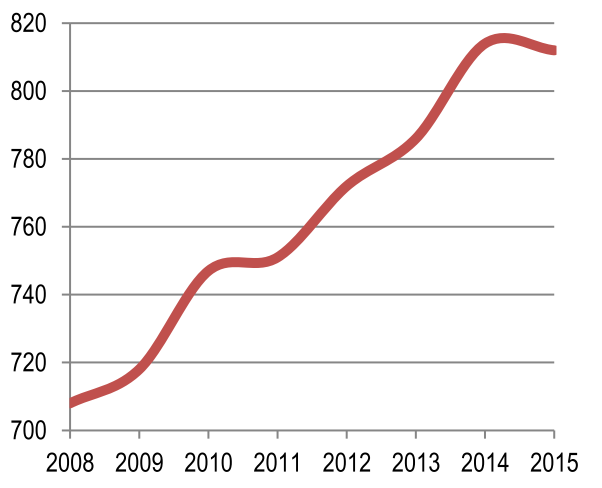
The overall real GDP the EAC has been on the rise showing an upward trend (Figure 2.1a), this was driven by growth in Kenya, Uganda and Tanzania. Real GDP per capita has been on the rise for the EAC and as at 2015, it stood at USD 813 per capita. Real GDP per capita growth is a good indicator of individual incomes and cane be used to forecast future demand, however, distribution of the GDP is also important as it tells where most of the income is concentrated. Real GDP per capita growth has remained mixed in 2009, the EAC had a per capita growth rate of 1.4 per cent, in 2010, the growth rate went up to 3.9 per cent but late declined to 0.6 per cent in 2011 and in 2015, there was a major decline in growth rate to 0.2 per cent.

The combined Gross Domestic Product (GDP at current prices) for the EAC region is $122 billion of which Kenya has US$ 41.2 billion, Tanzania US$ 42.3 billion, Uganda US$ 28.3 billion, Rwanda US$ 8.2 billion and Burundi US$ 1.7 billion. In terms of GDP growth trends (Fig 2.2) Tanzania, Uganda and Rwanda growth trends are increasing as compared to Kenya and Burundi. However the growth rates remain mixed and not consistent as shown in figure 2.4. Tanzania, Uganda and Rwanda are showing consistent real GDP per capita growth rates as compared to Kenya and Burundi, whose growth trends remain (Figure 2.3).

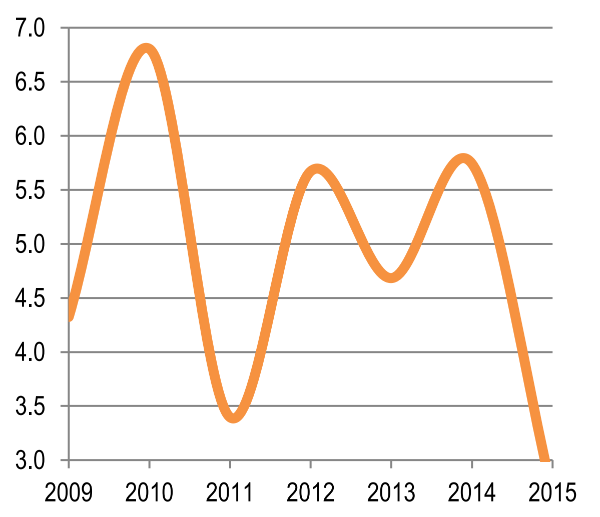
Figure 2.1: Real GDP Indicators East Africa Community

(a) Real GDP (Billion USD)	(b) Real GDP Per Capita (USD)

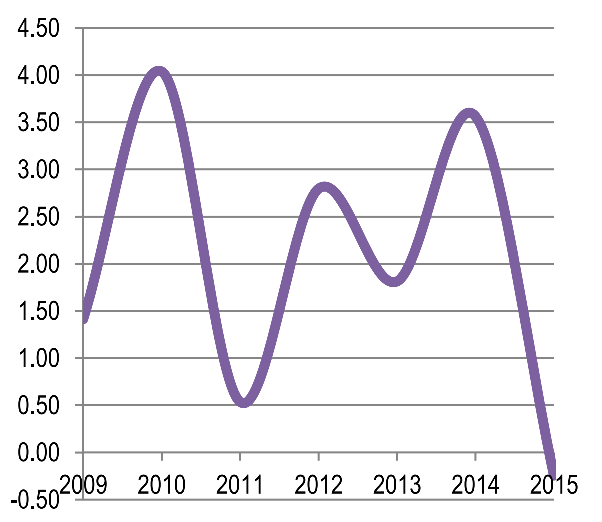




(c) Real GDP Growth Rate

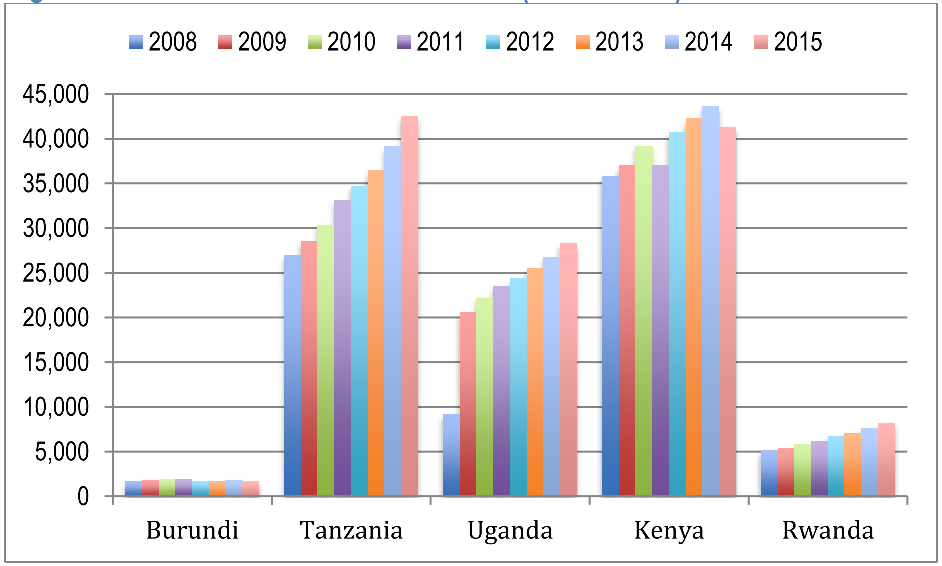


(d) Real GDP Per Capita Growth Rate



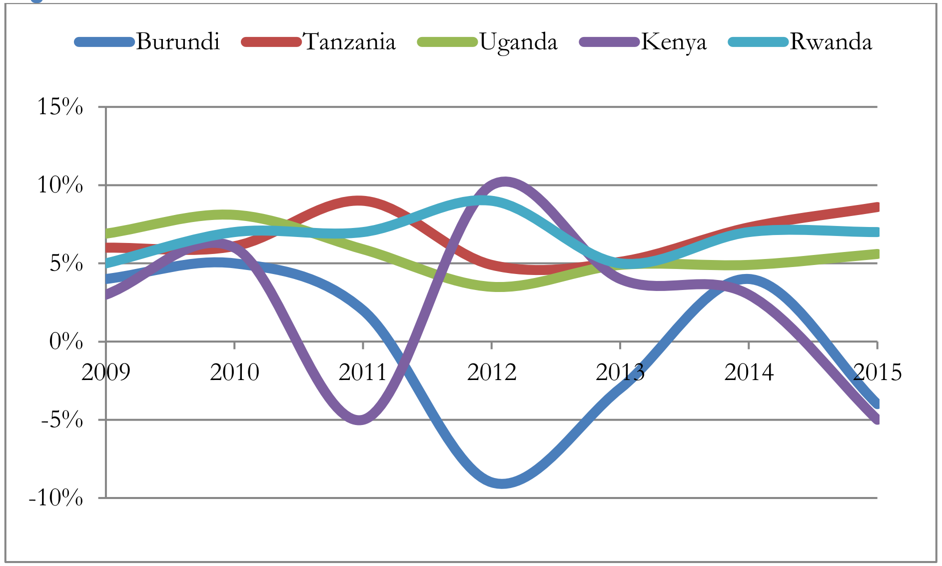
Source: EAC 2016

Figure 2.2: Real GDP EAC Partner States (Million USD)



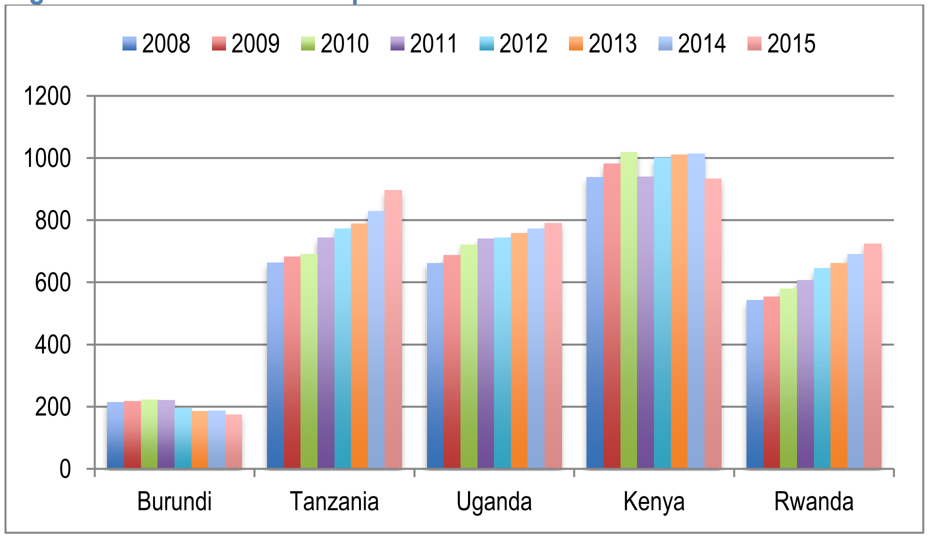
Source: EAC 2014

Figure 2.4: Real GDP Growth Rate



Source: EAC 2016

Figure 2.3: Real GDP Per capita



Source: EAC 2014

2.2 Trade Policies and Programmes Relating to Agriculture in the EAC

Trade policies in the EAC can be largely categorized as tariff and non-tariff policies. These policies are ratified at the regional level (EAC) and implemented by each partner state. The protocol that established the EAC customs union was signed in 30 November 2004 and came into force on 1 January 2005. The objectives of the customs union as set out in article 3 are:

- Further liberalize intra-regional trade in goods on the basis of mutually beneficial trade arrangements among the Partner States;
- Promote efficiency in production within the Community;
- Enhance domestic, cross border and foreign investment in the Community; and
- Promote economic development and diversification in industrialization in the Community.

Article (4) defines the activities under which the protocol will apply, this include: Trade liberalization-removal of tariff and non-tariff barriers; Trade related aspects- largely simplification of customs procedures; trade remedies; national and joint institutions training programmes; production and sharing of customs statistics and export promotion. Article 4(2) stipulates the areas of cooperation in the customs union, which includes harmonization of tariffs, standards and customs procedures.

2.3 Internal Tariff Elimination

Article (11) provides for the elimination of internal tariffs among the Partner states. At that time since there were only 3 countries, Kenya Uganda and Tanzania, it was agreed that for the purpose of transition into a customs union while taking cognizance of the principle of asymmetry, goods from Uganda and Tanzania into Kenya shall enter duty free, while goods from Kenya into Uganda and Tanzania would be categorized as those eligible for duty free treatment (category A) and those eligible for gradual tariff reduction (Category B). These goods (Category B) would be eliminated for a period of five years as follows:

- 10 percent first year
- 8 percent second year
- 6 percent third year
- 4 percent during the fourth year
- 2 percent during the fifth year
- 0 percent thereafter

These tariff reductions were implemented from 2005 to 2010. Currently the EAC partner states have been able to eliminate internal tariffs among themselves.

2.4 The EAC Common External Tariff

Article 12(1) established a three-band common external tariff with a minimum rate of 0 percent (raw materials), middle rate 10 percent (intermediate goods) and 25 percent (manufactured or processed goods). These CET tariffs are charged on third countries importing to the EAC. There are exemptions to the CET, where thirds countries importing to the EAC are charged above the set CET. These products are known as the sensitive products, they are products, which are of special interest to a country since they allow a country to protect their local industries at nascent stage of development, food security or because of their importance as a source of national revenue. Development of the sensitive list of products has remained controversial for the partner states since it has also been used as a non-tariff barrier. Some of the common sensitive products include maize, beans, rice, milk, tea, and coffee among others. A conclusive sensitive list of products has not been fully attained in the EAC. Article (13) of the protocol stipulates the immediate removal of all forms of non-tariff barriers (NTBs) to importation of goods originating from Partner states. Elimination of NTBs remains a challenge as new barriers come into play while old ones are removed. By end of 2012, EAC had 22 unresolved NTBs, 8 new NTBs and 69 resolved NTBs, EAC (2014). Summaries of the key trade policies (and key features) that affect agricultural production and trade that are being implemented at the regional level are presented in table 3.1.

Table 2-1: Trade Policies Affecting Agriculture Trade at the EAC.

Trade Policies	Features
Customs Procedures and Documentation	• Addressed in the Customs Management Act. • The objective is to standardize and harmonize the customs formalities (documentation and procedure) in the member states for all commodities or products. • Customs Procedures Manual was adopted by EAC council of ministers and application commenced in 2012/13
Customs Valuation	• Procedure applied to assign monetary value to goods or service for the purposes of import or exports. • Incorporated in the EAC Customs Management Act, 2004 • Based on the implementation of the WTO Agreement on the implementation of Article VII of GATT 1994 on customs valuation.

Rules of Origin	• Used to determine the country of origin of a product within multilateral or regional trade framework.
	• Set up in Annex III of the Protocol on the Establishment of the EAC Customs Union.
	• Goods are defined as originating from a country if
	    o They are wholly produced or
	    o Undergo substantial transformation- import content of good is no more than 60% of c.i.f value of material used for value added.
	    o Change in tariff heading

Tariffs and Other duties	• MFM Applied Tariff structure
	    o EAC Common External Tariff (CET)-
	        ▪ Raw materials and capital goods are zero-rated.
	        ▪ Intermediate goods is 10%
	        ▪ Finished goods 25%
	        ▪ Sensitive products apply 35-100%, this apply to 58 tariff lines
	    o CET Contains 5,274 lines at HS8-digit level. 99.8 % carry ad valorem while the rest have mixed tariffs

Tariff Preferences	• EAC members can grant tariff preferences on reciprocal basis under bilateral agreements.
Tariff and tax exemptions and concessions	• Under customs union protocol, members have agreed to harmonize their duty and tax exemptions and concessions. • The EAC Council on a case-by-case basis also grants country specific waivers.

Trade Policies	Features
Internal Taxes	• Under EAC Common Market Protocol, members have agreed to harmonize their tax policies and laws on domestic taxes. • This will remove tax distortion and facilitate free movement of goods, services and capital in order to promote investment in the community.
Contingency Measures	• Contingency Measures found in Article 16-20 and 24 on the Protocol Establishing the EAC customs union. • These contingencies include anti-dumping, countervailing and safeguards measure.
Import Prohibitions, restrictions and licensing	• Provided under the Second Schedule of the EAC Customs Management Act, 2004. • EAC member states have a schedule of prohibited products. • Import permit is required for 31 product groups under the second schedule.
Standards and Technical Requirements	• Article 13 on Protocol Establishing the EA Customs union urges removal of non-tariff barriers (NTBs). • Catalogue of East African Standards provides a comprehensive list of harmonized standards applicable to EAC.
Sanitary and Phytosanitary Measures (SPS)	• Addressed in Article 108 of Treaty establishing the EAC. • Provides for harmonization of SPS measures. • This agreement adheres to the WTO- SPS agreement.
Documentation taxation and restrictions	• These documentation requirements for exports. • Addressed in the Customs Management Act
Competition and Regulatory Issues	• Article 21 of Customs Union Protocol obliges EAC member states to prohibit anti-competitive behaviors. • EAC Competition Act was enacted in 2006 and established the EAC Competition Authority.
Intellectual Property Rights	• Addressed in Article 103 of the EAC Treaty and Art. 104 of the EAC Common Market Protocol • This sets up the framework for the harmonization of EAC intellectual Property Rights Policies.

Agriculture	• The treaty establishing the EAC emphasized the importance of agriculture and food security, and made it a key cooperation area.
	• Several regional policies have been developed:
	  • Agriculture and Rural Development Policy
	  • Agriculture Rural Development Strategy
	  • EAC Food Security Action Plan
	  • Regional Protocol on Environment and Natural Resource Management (2006).

Source: Authors Compilation from WTO EAC Policy Review (2012)

2.5 Trade Related Aspects

Trade related aspects deal with different issues that affect trade or trade facilitation. Key among them that affect agricultural trade include:

- Rules of origin- this is a criterion for selecting goods that are eligible for community tariff if they originate from the partner states. Article (14) specifies the criteria set out to establish the rules of origin.
- National treatment- the partner states must ensure equal treatment of like products of other partner states.
- Trade remedies- these include antidumping, subsidies and countervailing and safeguards measures and how partner states should handle them in relation to third countries and among themselves.

2.6 Export Promotion Schemes

The export promotion scheme under the EAC are meant to accelerate development, promote and facilitate export oriented investments, production of export competitive goods, developing an enabling environment for export promotion schemes and attracting foreign direct investment. There are several schemes in place to promote the set-out objectives these include: duty draw backs, tax remission, manufacturing under bond and export processing zones.

2.7 Implications of Trade Policies on Agricultural Trade and Food Security

The most common policies that have been used in the EAC are export/import bans/lift. In May 2011, the Government of Tanzania issued export restrictions on grains in order to safeguard the economy from depleting the existing stock that was causing inflation in the country. Several parts of the country lacked food supply hence this move was to divert cereals into the domestic market so that excess supply would lead to reduced prices. Compete (2011) note that this ban did not effectively curtail cross border trade due to parallel markets through Democratic Republic of Congo, Malawi, Zambia and Kenya borders. This approach by Tanzania can be termed as a self-sufficiency approach to food security since the country was tempting to be able to meet consumption needs (particularly of staple foods) through buying rather than importing (IFPRI, 2010). In 2009, Kenya experienced food shortage following the 2008 drought; the government initiated a lift on maize import ban in order to meet the local demands through importation and subsidizing maize milling prices. This approach to food security where food is imported from the world market when prices are cheaper that growing it at home is termed as self- reliance, Deb *et al* (2009) ensure that countries produce where they have comparative advantage tends to promote importation and cross border trade in general. Consequently, in 2008 and 2009, Kenya was the largest maize importer from the EAC region. Trade policies that promote cross border trade, in order to ensure food security as was the case with Kenya, have resulted in more increased trade as compared to restrictive trade policies geared towards food security as was the case of Tanzania. While cross border trade was not hinder, this restriction still resulted in higher prices of staple foods and worsened inflation.

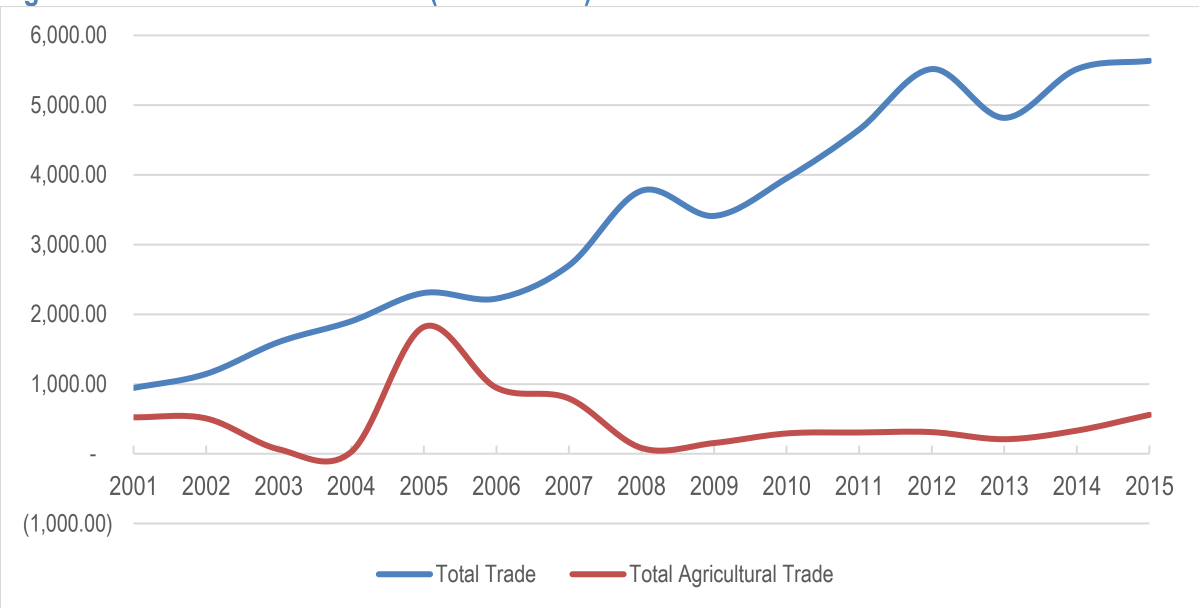
Sanitary and Phytosanitary (SPS) measures are normally put in place to protect plants and animals from the risks of entry or spread of pests, diseases, disease-carrying organisms or disease causing-organisms or protect human or animal life from risks of additives, contaminants, toxins or disease-causing organisms in foods, beverages or feedstuffs or any other damages. These standards tend to restrict trade since they are not easy to administer when there are not clear standard or standards are seasonal. SPS become trade restrictive when they are administered in a non- transparent manner or when used by country authorities to prohibit imports of certain commodities without providing the scientific evidence that are required to when doing so. Standards and technical requirements are non- tariff barriers that are also used to ensure that commodities that enter a country meet a certain criterion for standards. Like SPS, they can also be abused by countries and become a hindrance to trade. Currently, Kenya through KEPHIS (Kenya Plant Health and Inspectorate Services) has imposed charges has imposed of plant import permit at Malaba border posts for teas from Uganda and Burundi that are destined for auction at the Mombasa port. While this is a legal requirement (national level) for teas destined for Mombasa auction, this raises the cost of doing business for the exporters from Uganda and Burundi. Consequently, lower profit margins result in lower incomes for tea farming households, which increases the risk to food insecurity since these households are selling their tea at much lower prices. At the same time, the Ministry of Agriculture in Kenya does not recognize the SPS certificates issued by Ugandan authorities for tea destined from Mombasa. This equally raises the cost of doing business since more certification is required; the ultimate outcome is reduction in prices received by farmers

The EAC customs union has a common external tariff for commodities with three tiers (0 (raw), 15 (intermediate) and 25 (manufactured) percent). The implementation of this CET has seen the increase in EAC intra- EAC trade (figure 4.1). Total intra EAC trade has gradually been on the rise since 2005 in terms of value- Increased trade of cereal, which are important for food security, brings in the element of self-sufficiency since partner states buy commodities where they have comparative advantage

3 TRADE IN AGRICULTURAL PRODUCTS

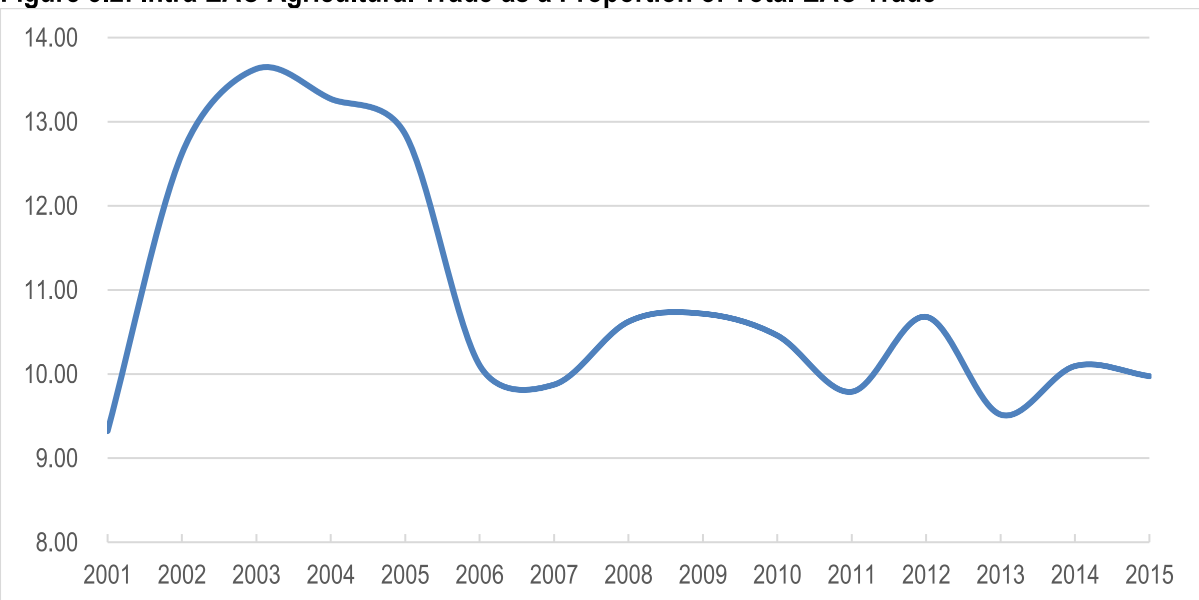
Total trade (exports and imports) has been on the rise within the EAC, in 2001, total intra- EAC trade was valued at USD. 944 thousand, this value increased to 1.9 million in 2004. After the coming into force of the customs union, intra EAC trade increased to USD 2.3 million. After 2006, intra EAC trade has been gradually rising and in 2015 it was valued at USD 5,636million. Intra EAC trade in agricultural commodities has been rising, in 2001, agricultural commodities trade was USD 523 million, this trade value rose to USD 948 million in 2006 and currently stands at USD 558 million.

Figure 3.1: Total Trade in the EAC (Million USD)



Source: ITC Database

Figure 3.2: Intra EAC Agricultural Trade as a Proportion of Total EAC Trade



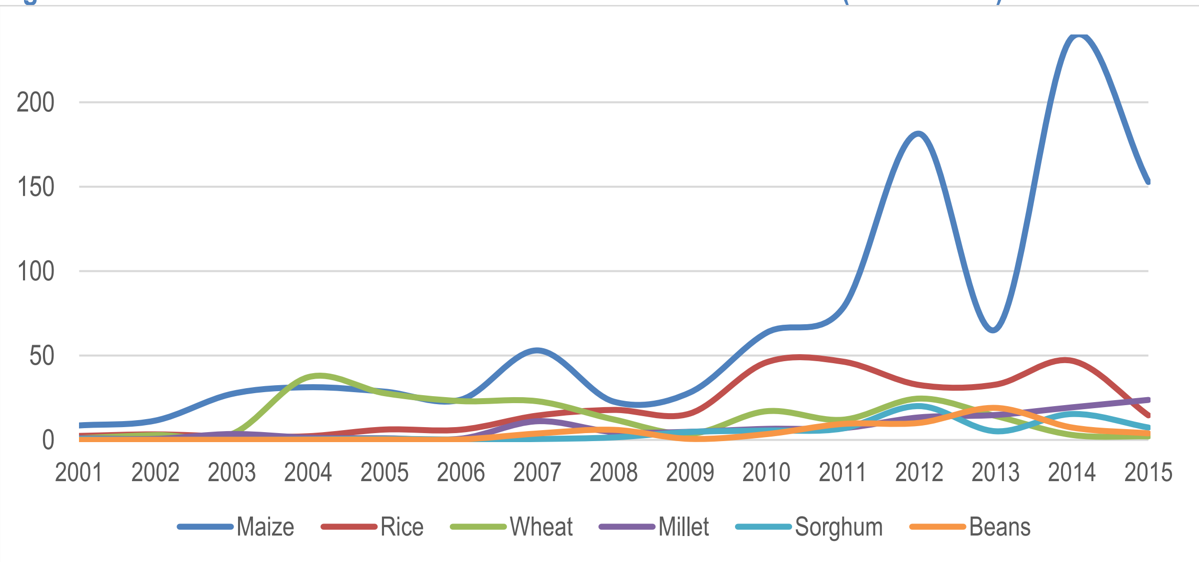
Source: ITC Database

Total EAC agricultural trade as a proportion of total EAC trade has remained mixed ranging between 13 percent in 2006 to 10 percent in 2015 (Figure 3.2). One of the main factors that affected agricultural trade was drought that was experienced in 2008. Appendix tables 1 and 2 further provide disaggregated data for tables 3.1 and 3.2 each of the partner states.

4.1.2 Trade Patterns in Selected Commodities

Maize, millet and rice are the most traded commodities in the EAC as shown in figure 3.3. The value of total trade (export + imports) has been rising for maize, but with a series of fluctuations particularly in 2013. Wheat on the other hand is the lowest rank commodity traded within the EAC when one reviews cereals under 2-digit HS heading 10. Appendix tables 1-4 provide exports and imports (respectively) that each EAC partner state trades within the EAC.

Figure 3.3: EAC Partner State Total Trade in Selected Commodities (Million USD)



Source: ITC Database

4 METHODOLOGY

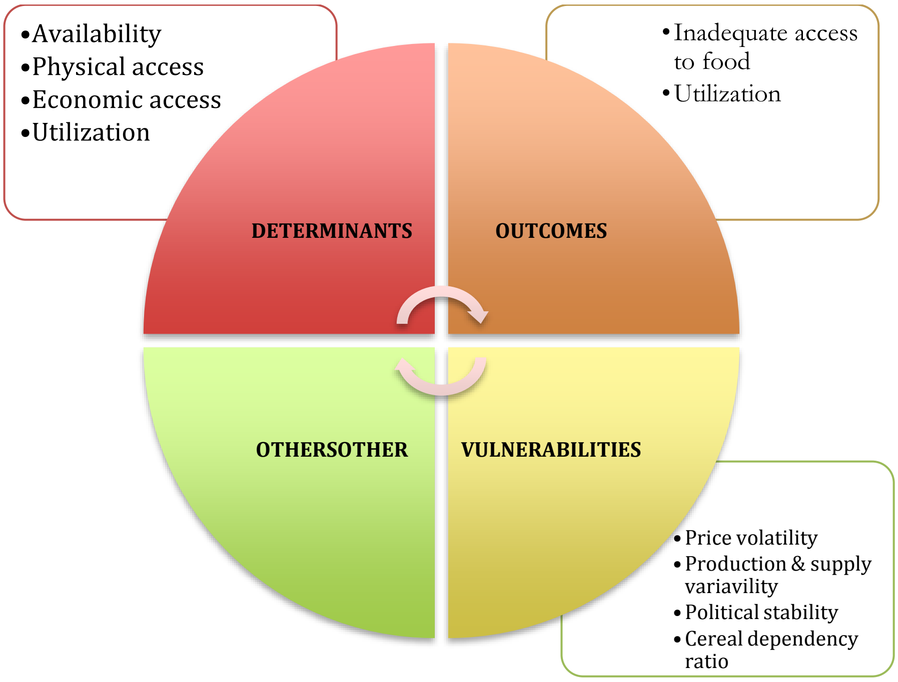
4.1 Introduction

The section presents the theoretical framework that is used to analyze the impact of climate change on agricultural trade and food security. Here, we review food security indicators and how they link to climate change and national policies. The methodological framework provides a step-by-step process of how to move from climate change to agricultural production, trade and lastly how food security is affected. This involves the use of farm household analysis to obtain productivity impacts of climate on key crops identified by partner states as important for food security, simulating the impacts of the productivity on consumption using a CGE model and last simulating the impacts of consumption on food security using a micro- simulation model.

4.2 Conceptual Framework

Food insecurity exists when people do not have adequate physical, social or economic access to food. Trade policies on the other hand involve a combination of measures such as domestic support measures, export subsidies and tariffs which affect relative prices of both traded and non- traded commodities in any economy, which in turn affects the allocation of resources. These changes tend to alter sectoral and aggregate output, which in turn leads to changes in income levels. Positive changes in income levels will result in food security while negative changes in income will result in food insecurity.

Figure 4.1: Food Security Indicators



Source: FAO 2012

Following the FAO (2003) definition of food security, there are four dimensions to this phenomenon: availability, accessibility, utilization and stability. FAO (2012) launched a set of indicators that can be used to establish the status of food security in the country. The indicators are largely grouped into two distinct dimensions: First, are those that describe the determinants of food security, these indicators describe the structural conditions of a country that worsened food security; these conditions can be improved by appropriate public policies. These include food production indices, physical access to foods through road or rail networks, food price indices and access to water and sanitation services.

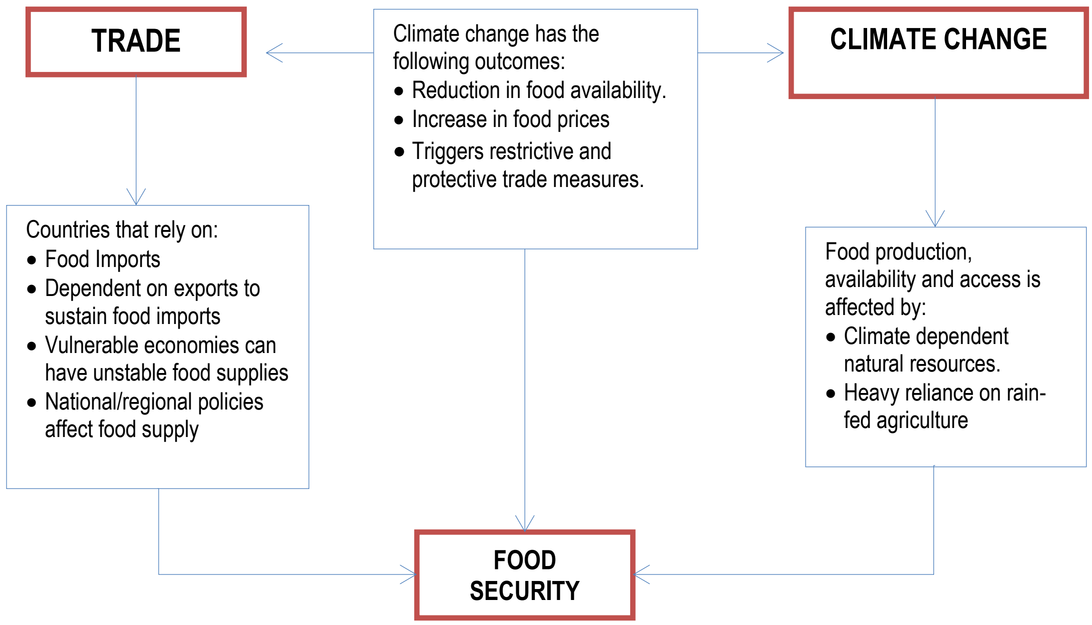
The second dimension is the outcome which tend to capture the consequences of food insecurity irrespective of the policies in place- these include undernourishment, share of food expenditure of the poor, percentage of children under 5 with stunted or wasted growth among others. The final set of indicators captures conditions that capture future food insecurity vulnerabilities- these include food price volatility, food production and supply variability and food dependency ratios among others.

4.2.1 Linking Climate Change, Agricultural Trade and Food Security

Climate change has direct impact on agricultural trade policies as can be seen in situations where there is a food crisis due to change in weather patterns. Trade measures such as safeguards mechanisms tend to be used to protect a country against the imminent threat of food insecurity.

Figure 4.2: Climate Change, Trade and Food Security Conceptual Framework

Climate change has direct impact on agricultural trade policies as can be seen in situations where there is a food crisis due to change in weather patterns. Trade measures such as safeguards mechanisms tend to be used to protect a country against the imminent threat of food insecurity.



Source: Adopted fromScavione 2010

Secondly, the United Nations Framework Convention on Climate Change (UNFCCC) and the World Trade Organization governs climate change and agricultural trade. The 1997 Kyoto protocol seeks to improve human welfare, similarly, the WTO also seeks to improve human welfare through international trade. Food security is a common expected outcome for both climate change mitigation initiatives under UNFCC and the WTO agricultural trade negotiations. The international panel on climate change (IPCC) (2014) notes that there have been more negative impacts of climate change on crop and terrestrial production than positive impacts. Without adaptation, local temperature increases of 1.0^{c} is likely to negatively impact the yields of key crops such as maize and wheat, resulting in the disruption of agricultural systems and production. The scarcity of grains such as maize and wheat may trigger restrictive trade policies such as quantitative restriction of exports, safe guard or anti-dumping measures and tariff peaks that ensure food security of a nation.

There are also trade policies (the absence/presence of tariff and non-tariff barriers) that affect the availability of agricultural commodities. These policies may stimulate economic growth through growth in exports, which in turn increase incomes. Increases in incomes of households has the direct impact of increasing household expenditure on food hence a household has capacity to access more food. The presence of tariff and non-tariff barriers result in decreased access to food, which results in food insecurity. Trade restrictive measures are allowed under the World Trade Organization (WTO) multilateral trading framework under special conditions where trade becomes an imminent threat to national food security. The trade policy tools that have largely been used in the EAC are the export/import bans (restrictions) /lifts. Export ban has a direct implication on food self-sufficiency, since it encourages local production to meet consumption needs. Lifting of import/export bans encourages trade and importation of cheaper commodities to meet local demand; this encourages production where there is comparative advantage. It brings out the self-reliance approach to food security. The linkage between climate change, trade and food security is important in achieving development at both national and regional level in cases where neighboring countries have a strong integration framework as is the case with the East Africa Community (EAC).

4.3 Empirical Models

4.3.1 Farm Household Analysis

Most farm households in developing countries rely heavily on the weather conditions for their agricultural production as a major input; hence climate determinants such as temperature, humidity are the key inputs to agricultural production. Variability in climate therefore affects both animals and crop production, which in turn affects productivity. The relationship between households and agricultural productivity can be stated as a production function (1).

$$q_i = f\left(x_i, b_i\right) + e_{ij} \qquad (1)$$

Where q is a vector of outputs and x is the vector of inputs, which include climate change variables, b_j is a vector of coefficients to be estimated while e_{ij} is the error term. Equation (1) is therefore an increasing function with respect to output and a decreasing function with respect to inputs. Molua and Lambi (2007) used a structural approach that links the crop model, which measures crop yield changes under different climatic conditions to economic model of the agricultural sector, which estimates the changes in acreage and supply and its impact on market clearing prices and consumer and producer welfare. In their model, agricultural production capability is assumed to be restricted to exogenous climate and other socio-economic variables; therefore, the farmers maximize their returns subject to critical outputs and environmental factors. They regress farm value on climate and other socio-economic variables with a non- linear function.

Matovu (2013) used a similar model to that of Molua and Lambi (2007) in establishing climate change impacts, they regressed yield in tonnes per hectare on both climate and socio-economic variables which include rainfall, temperature, rainfall and temperature variation, and physical inputs such as family labour. In their case, they used a linear functional model. Temesgen *et al* (2009) used a different approach in establishing the climate impacts on households. In their model, the welfare of a household is measured by farm income and is affected by observable household characteristics (household size, location, educational attainment of the household head, etc.) and climatic shocks (droughts, floods and hailstorms). The main assumption in their model was that when a household experienced climatic shocks such as drought, flood and/or hailstorms, there was an increased probability of this household falling below a given consumption/income level, or forced it to stay under such a level if already below it.

Matovu (*ibid*) in establishing the climate change effects on yield, used equation (2).

$$Y_{ij} = \alpha_0 + \alpha_1 R_{ij} + \alpha_2 T_{ij} + \alpha_3 Rv_{ij} + \alpha_4 Tv_{ij} + \beta_1 L_{ij} + \beta_2 M_{ij} + \beta_3 K_{ij} + \varepsilon_{ij} \qquad (2)$$

Where y_{ij} is yield in tons per hectare (t/ha) for crop *j* for farmer *i*. R- Mean rainfall in millimeters, T- is mean temperature in degrees Celsius, these were obtained from world metrological organization (WMO). Rv- rainfall variation, Rt- temperature, both Rt and Rv were measured as the standard deviation from the mean, following evidence from literature by Skoufias *et al* (2011) and Matovu (2013), this data was also obtained from WMO. The letters L, M and K represent the physical inputs of family labour –measured in person days, manure in kilograms and capital –which is an aggregation of the cost of purchased inputs (for example land rent, seed, fertilizer, and pesticides) used in production of a particular crop. In case the crop is produced under the intercropping system, the inputs are determined according to the proportion on area under the crop.

The choice of dependent variables and functional forms depend on the question under study, in this study, the objective was to establish the effect of climate variables temperature, rainfall, temperature and rainfall variation on yield. In order to obtain changes that could be simulated in a CGE model, equation (2) is transformed into a log- linear model (equation 2.5), in order to obtain the percentage changes in yield associated with the climate variables. The percentage changes in the yield were used to shock the efficiency variable in the production function of the CGE model, this is explained in the subsequent section.

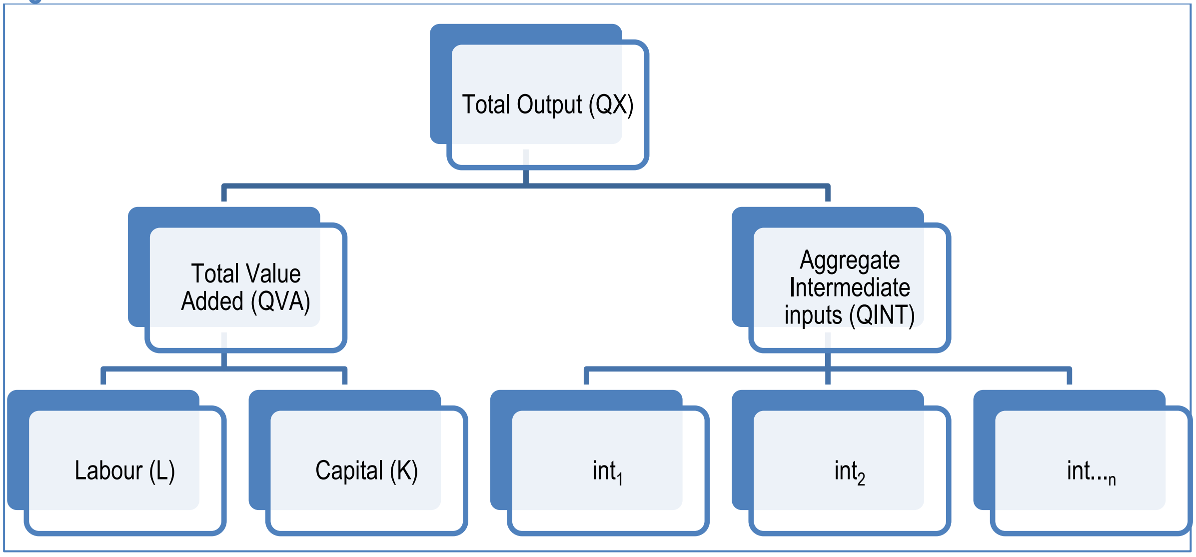
$$Log(Yield_{ij}) = \alpha_0 + \alpha_1 R_{ij} + \alpha_2 T_{ij} + \alpha_3 Rv_{ij} + \alpha_4 Tv_{ij} + \beta_1 L_{ij} + \beta_2 M_{ij} + \beta_3 K_{ij} + \varepsilon_{ij} \qquad (2.5)$$

4.3.2 The Computable General Equilibrium (CGE) Model

CGE models provide an analytical approach that views the economy as a system of interdependent sectors of the economy. In this framework, economic shock emanating from one sector creates ripples in other sectors, secondly, it is possible to undertake quantitative analysis by solving the general equilibrium numerically, hence one can undertake economy wide analysis at global or even regional level. The CGE model can handle a broad spectrum of issues such as taxation, trade, pollution, welfare etc., it is equally possible to establish forward and backward linkages between sectors. This model is therefore appropriate for establishing the climate change, agricultural production and trade impacts on food security, this is because the model will be able to simulate the functioning of the economy under certain climatic conditions which affect productivity and total production. These effects are transmitted through price and quantity adjustments in the various markets , secondly , given that a CGE is based on a social accounting matrix, it will be possible to establish the effects of climate change on different sectors of the economy, linking the model to household survey enables an in depth assessment of household welfare effects due to climate change, it is from here that the policy implications are drawn.

The CGE model will follow the works of Löfgren *et al.* (2001). There are four blocks of equations: prices, production and trade, institutions and the systems constraints block. Calibration of the model will be based on working by Lofgren *et al.* (2002). In the CGE model, there are parameters, variables and equations that are defined. In this paper, the key equations that are affected by climate change are presented and discussed. It is important to show the structure of production and how it is affected by changes in yield.

Figure 4.3: Nested Structure of Production



Production takes a nested structure as presented in figure 4.3, total output is a CES function of total value added and aggregate intermediate inputs.

$$QX_a = \alpha_a^a * \left(\delta_a^a * QVA_a^{-\rho_a^a} + (1 - \delta_a^a) * QINT_a^{-\rho_a^a}\right)^{-\frac{1}{-\rho_a^a}} \qquad (3)$$

At the second level, QVA is a CES function of capital and labour.

$$QVA_a = A[\delta K^{-\rho} + (1 - \delta)L^{-\rho}]^{-1/\rho} \qquad (4)$$

A is the efficiency parameter, (A>0; 0< δ <1; -1< $\rho \neq 0$) the variables *K* and *L* are capital and labour, respectively; δ is the distribution parameter ρ is the substitution parameter which determines the value of the (constant) elasticity of substitution. The CES is homogeneous of degree one, displays constant returns to scale with a negative slope. A Leontief function also combines intermediate inputs in fixed proportions in order to produce aggregate intermediate input. The changes generated from the crop yield associated climate change (derived from equation 2.5) resulted in equation (4) changing to (4.5), in this case, A^* has incorporated the changes in yield associated with climate change. This change affects QA and QINT on the supply side. In the case of maize, because the effect of climate change on production has been estimated by WMO, the changes in production will be simulated on QX as presented in equation (3)

$$QVA_a^* = A^*[\delta K^{-\rho} + (1 - \delta)L^{-\rho}]^{-1/\rho} \qquad (4.5)$$

On the demand side, the total output (QX) is allocated between domestic sales and exports so that suppliers maximize their sales revenue subject to imperfect substitution between exports and domestic sales based on the constant elasticity of transformation (CET).

$$QX = at(\gamma QE^{\rho_t} + (1-\gamma)QDS^{\rho_t})^{\frac{1}{\rho_t}} \quad (5)$$

At the same time, a CES production function is used to produce a composite commodity made of domestic sales and imported goods.

$$QQ = ac(\delta QM^{-\rho_c} + (1-\delta)QDS^{-\rho_c})^{-\frac{1}{\rho_c}} \quad (6)$$

The parameters for CET, CES and the Armington functions are exogenously determined. The trade flows in the economy (QM and QE) are of interest since we are keen to establish how changes in aggregate output is affected by changes in yields due to climate change, and in turn, how it affects trade flows i.e. imports and exports. With changes in QX_a due to climate change, then QM

This composite commodity (QQ) is consumed between households, government, investment and intermediate use. For food security analysis, household consumption in this model becomes of interest. The household is assumed to maximize a 'Stone-Geary' utility function, subject to a consumption expenditure constraint. This model does not assume unitary elasticity of substitution and minimal and discretionary components of consumption (Löfgren *et al.,* 2002).

$$C_i = C_{\min i} + \frac{\alpha_i}{p_i}\left[Y - \sum P_j C_{\min j}\right] \quad (7)$$

C_i is consumption for good *i* and $C_{\min i}$ is the minimum consumption for each commodity *i*. *Y* is income and $Y - \sum P_j C_{\min j}$ represents the supernumerary or residual income. $\frac{a_i}{p_i}$ - The marginal share of good *i* in the household consumption budget.

Equilibrium must be achieved in the labour , product , government budget , foreign trade and in savings and investments. The macro closure consists of the external balance, government balance and the savings investment balance. Investment is taken as exogenous in order to align to the reality of governments or policy makers wanting to achieve a certain investment objective. Given that the price for investment is endogenously determined in the model while foreign and public savings are exogenous, savings will equal the fixed investment quantities when the base year of non-government institutions savings rate adjust to achieve equilibrium. This is therefore an investment driven closure.

Simulation Scenarios

The simulation scenarios undertaken were derived from equation (2), where the $Yield_{ij}$ was used to shock the model in equation (4), which then becomes (4.5). Several other equations were affected in this process these are (5) (6) and (7) depending on the magnitude of yield for the following three scenarios:

1. The base scenario replicated the original data and was a situation of no climate change (i.e. temperature and rainfall changes) associated in productivity i.e. equation (4) are not affected.
2. Scenario 1: where there are productivity changes associated with changes in rainfall and temperature mean.
3. Scenario 2: where there are productivity changes associated with rainfall and temperature variations.
4. Scenario 3: where there are productivity changes associated with changes in rainfall and temperature mean and variation.

4.3.3 The Micro-Simulation Model: Food Security

Foster *et al.* (1984) using the common measure of overall poverty commonly known as the FGT index, which is used to quantify three elements of poverty, namely: level, depth and severity, which are also, respectively, known as incidence, inequality and intensity of poverty. The FGT index is defined as:

$$P_\alpha(y \mid z) = \frac{1}{n}\sum_{i=1}^{q}\left[\frac{g_i}{z}\right]^\alpha \qquad (8)$$

$y = (y_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots y_n)$ the individual income

q = q (y; z) number of poor households with income no greater than z

n = n (y) total number of households

α can take the value 0, 1 or 2.

Z > 0 is the predetermined poverty line

g_i = Z - y_i income shortfall in i^th household

When α =0, then $p_0 = \frac{q}{n}$ this is the headcount ratio and is the proportion of the population below the specified poverty line. α_0 Measures the level or incidence of poverty. When α =1, this gives the income short fall for a household to move out of poverty, when α =2, this measures the poverty severity.

In measuring food security impacts, some adjustment was made to the definition of poverty line (z). While most studies define a poverty line using total consumption expenditure of both food and non- food commodities, this study defined the poverty line using food expenditure only, hence transforming the poverty line to a food poverty line. With this definition, it was possible to establish those households that are food poor and hence food insecure due to non- availability of food. The definition of following variables in equation (8) changed:

$y = (y_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots y_n)$ the individual food expenditure

Z > 0 is the predetermined food poverty line

g_i = Z - y_i food expenditure shortfall in i^th household

In this section, household consumption changes associated with equation (7) affected g_i in equation 8. With α =0, then poverty headcount would also change. The changes in household consumption would enable the establishment of how changes in household consumption associated with climate change affected the headcount ratio, it was therefore possible to establish how many people/households fell below/rose above the food poverty line z.

4.4 Data

The two main data sources for the analysis are the household survey data and the social accounting matrix (SAM). One major distinction between these two data sources is the classification used for the commodities. In the SAMs for the four EAC countries under study, the International Standard Classification of All Economic Activities (ISIC Rev.4) while the household survey datasets use Central Product Classification (CPC) system. In order to conduct the analysis, the data was harmonized to ISIC Rev.4 system of classification. Thirdly, the household survey data sets and SAMs are for different years: Kenya (2005/06), Uganda (2009/10), Tanzania (2008/09) and Rwanda (2010/11). The SAMs for the four countries are as follows: Kenya (2003), Uganda (2007), Rwanda (2006) and Tanzania (2009). These datasets can still be used for analysis even though the years of data production do not match since the structure of economies tend not to change much within a span of five years.

In the case of impact of climate change on maize production, data obtained from the WMO for simulating these changes. Table 4.1 simulating the impact of climate change on maize production.

Table 4-1: Percentage Change in Maize Production Due to Climate Change (APSIM)

	Burundi	Kenya	Rwanda	Uganda	Tanzania
RCP 4.5	-0.150	-2.240	-0.100	-1.900	-0.200
RCP 8.5	-0.150	-1.820	-0.880	-1.200	-0.500

Source: WMO Simulations

4.4.1 Household Survey.

Farm household data was collected from household surveys of the various countries under study. Household survey data was collected by the various governments of the partner states with the main objective of obtaining a wide spectrum of socio-economic indicators required to measure, monitor and analyse the progress made in improving living standards in a single integrated household survey. This data contains information on demographics, housing, education, health, agriculture and livestock, enterprises, expenditure and consumption, household social amenities and community perspectives.

From the household data, the dependent variable (yield) measured by tonnes per hectare (t/ha) for the following crops: beans, rice, millet, sorghum and wheat, that ensure food security in the four EAC countries was obtained. The dependent variables included mean rainfall (mm), mean temperature (^{O}C), rainfall and temperature variation measured using standard deviation (^{O}C), physical inputs (labour – wages/ person days, manure (kg) and capital was measured using cost of purchased inputs such as land rent, seed, fertilizer, and pesticides, used in production of a particular crop production. Table 4.2 presents the descriptive Statistics for the four EAC countries.

Table 4-2: Descriptive Statistics

Country	Description	Obs.	Mean	Std. Dev.	Min	Max
KENYA	**Wheat**					
	Crop Area (ha)	38	2	3	0	16
	Labour (KES)	38	11	49	0	300
	Capital (KES)	38	14,910	27,719	0	156,000
	Yield (t/ha)	38	1,622	1,676	0	8,340
	Rice					
	Crop Area (ha)	30	1	0	0	2

	Labour (KES)	30	38	72	0	300
	Capital (KES)	30	1,095	1,481	0	4,700
	Yield (t/ha)	30	3,580	4,700	0	20,850
	Millet					
	Crop Area (ha)	294	0	0	0	3
	Labour (KES)	296	5	18	0	180
	Capital (KES)	296	570	2,753	0	39,600
	Yield (t/ha)	294	674	978	0	7,413
	Beans					
	Crop Area (ha)	4,035	0	1	0	40
	Labour (KES)	4,095	7	83	0	4,200
	Capital (KES)	4,095	1,316	4,063	0	108,220
	Yield (t/ha)	4,035	496	1,927	0	80,062
TANZANIA						
	Cassava					
	Crop Area (ha)	206	0	0	0	2
	Labour (TZS)	308	4	9	0	60
	Capital (TZS)	308	761	3,982	0	49,000
	Yield (t/ha)	205	2,054	2,362	0	13,591
	Rice					
	Crop Area (ha)	501	0	0	0	3
	Labour (TZS)	539	10	29	0	396
	Capital (TZS)	539	3,569	9,380	0	70,000
	Yield (t/ha)	497	1	2	0	15
	Sorghum					
	Crop Area (ha)	272	1	1	0	8
	Labour (TZS)	297	4	14	0	142
	Capital (TZS)	297	4,532	29,555	0	480,000
	Yield (t/ha)	269	1	4	0	62
	Millet					
	Crop Area (ha)	108	1	1	0	2
	Labour (TZS)	114	7	19	0	134
	Capital (TZS)	114	1,869	8,347	0	70,000
	Yield (t/ha)	107	1	1	0	3
	Beans					
	Crop Area (ha)	557	0	0	0	4
	Labour (TZS)	609	7	17	0	210
	Capital (TZS)	609	5,046	9,899	0	103,200

	Yield (ha)	550	0	0	0	4
UGANDA						
	Matoke					
	Yield (t/ha)	1,198	6,745	27,793	0	741,316
	Capital (UGS)	1,243	4,084	64,831	0	2,241,000
	Labour (UGS)	1,243	1	8	0	231
	Family Labour (mdays)	1,243	37	48	0	579
	Crop Area (ha)	1,198	0	1	0	16
	Rice					
	Yield (t/ha)	74	5,693	34,462	0	296,526
	Capital (UGS)	75	20,399	38,001	0	240,000
	Labour (UGS)	75	13	34	0	210
	Family Labour (mdays)	75	57	66	0	320
	Crop Area (ha)	74	0	0	0	2
	Millet					
	Yield (t/ha)	373	979	3,926	0	49,421
	Capital (UGS)	384	1,468	3,868	0	50,000
	Labour (UGS)	384	4	15	0	228
	Family Labour (mdays)	384	38	34	0	198
	Crop Area (ha)	374	0	0	0	3
	Sorghum					
	Yield (t/ha)	593	626	1,757	0	29,653
	Capital (UGS)	611	2,005	6,352	0	125,002
	Labour (UGS)	611	2	11	0	140
	Family Labour (mdays)	611	29	27	0	240
	Crop Area (t/ha)	593	0	2	0	40
	Beans					
	Yield (t/ha)	1,845	1,479	7,446	0	148,263
	Capital (UGS)	1,924	10,069	34,742	0	1,250,000
	Labour (UGS)	1,924	2	10	0	240
	Family Labour (mdays)	1,924	45	67	0	880
	Crop Area (ha)	1,848	0	1	0	40
RWANDA						
	Beans					
	Yield (t/ha)	15,132	0	0	0	6
	Capital (RWF)	15,132	4,489	10,106	0	166,133
	Labour (RWF)	15,132	3,398	9,422	0	150,000
	Crop Area (ha)	15,132	71	148	0	6,600

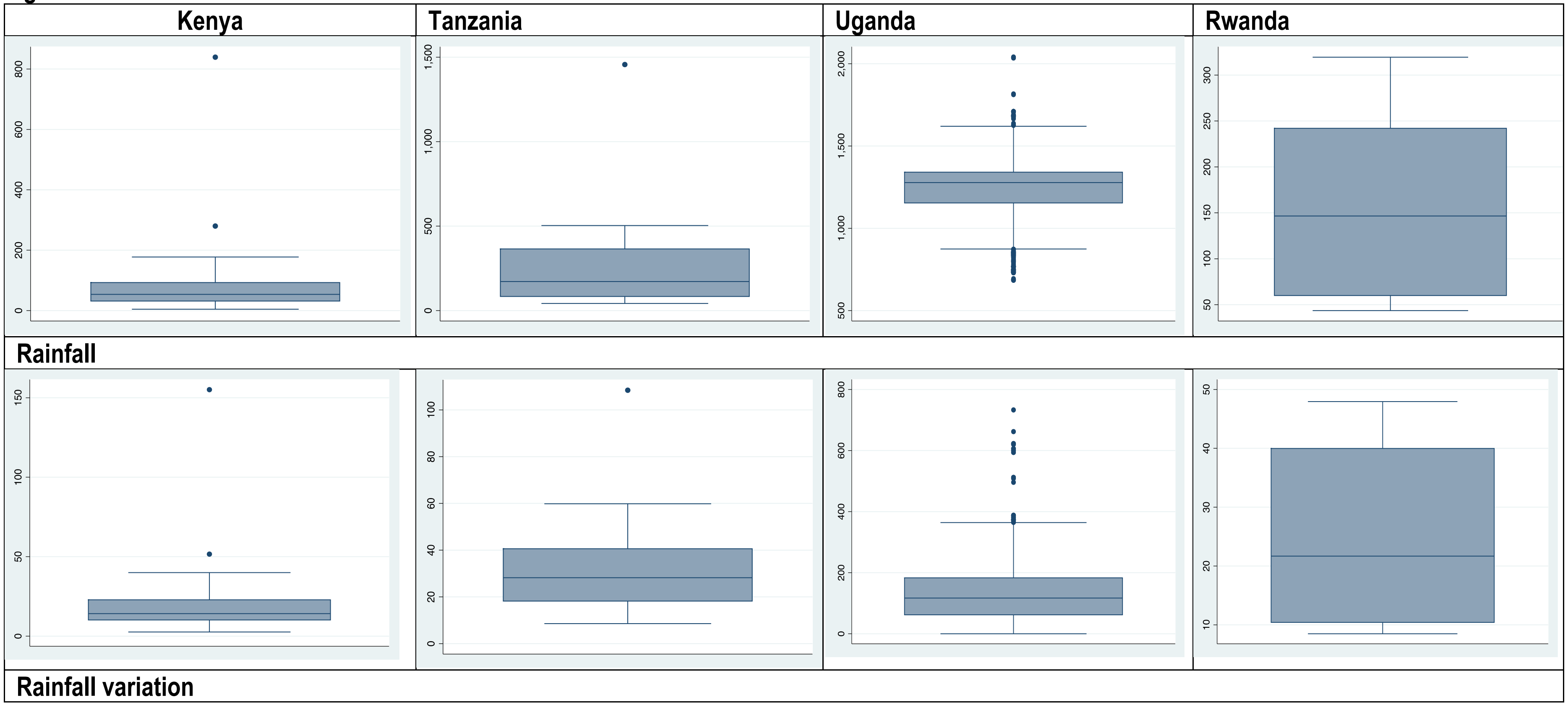
	Sweet Potato					
	Yield (t/ha)	2,518	19	33	0	566
	Capital (RWF)	2,518	2,995	4,723	0	104,800
	Labour (RWF)	2,518	3,111	9,116	0	150,000
	Crop Area (ha)	2,518	74	159	2	6,600

Source: Household Surveys Kenya, Uganda, Tanzania, and Rwanda

4.4.2 Rainfall and Temperature

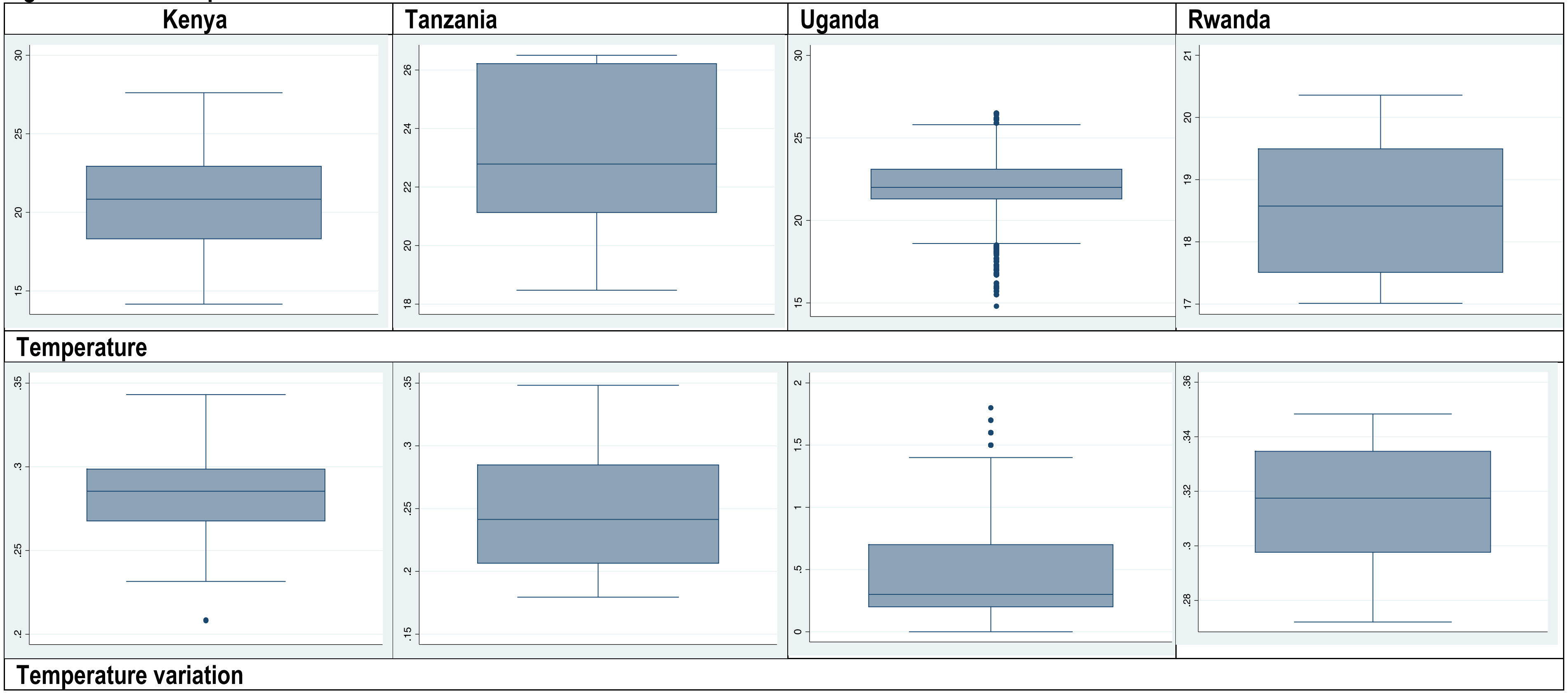
Rainfall and temperature data was collected at the station/district level, for each country, from the WMO, under this section; the data is summarized and presented at the national level. Figures 11 and 12 present the average rainfall and temperature (mean and variability) respectively for the periods under analysis, for each of the EAC countries. The box plots provide the interquartile range (i.e. the width of the box Q3 minus Q1) of the distribution. The lower whiskers provide the smallest non- outlier while the whiskers after Q3 goes to the largest outliers. Uganda has more temperature and rainfall outliers as compared to the other three counterparts (Kenya, Tanzania and Rwanda). Uganda has the highest annual mean rainfall of approximately 1,300mm; with a range (spread without outliers) of 850 mm. Figure 12 shows the average annual temperature for each of the four EAC countries. Rwanda has the lowest mean annual temperature of approximately 18.7^{0}C but with the highest mean variability of 0.32^{0}C. Tanzania has a mean temperature of 23.0^{0}C with a mean temperature variability of 0.17. Matovu (2014) note that high low rainfall coupled with high variation in both rainfall and temperature has grave implications on the yield of farmers who solely depend on rainfall for crop production. Alexandrov and Hoogenboom (2000) also note that crop yields are affected by variations in climatic factors such as air temperature and precipitation, and the frequency and severity of extreme events like droughts, floods, hurricanes, windstorms and hail.

Figure 4: Mean Rainfall and Variation for EAC Countries



Source: Author's calculations from Kenya, Uganda, Tanzania and Rwanda World Meteorological Organization (WMO) weather data

Figure 5: Mean Temperature and Variation for EAC Countries



Source: Author's calculations from Kenya, Uganda, Tanzania and Rwanda World Meteorological Organization (WMO) weather data

4.4.3 The Social Accounting Matrix (SAM)

The SAM provides a summary of the national accounts and traces out the flow of incomes from production activities, to factor payments, to incomes of institutions and back to demand of commodities Most of these SAMs have at least 30 activity-commodity mapping which can be broadly categorized into agriculture, manufactures and services. The activity/commodities are further classified using ISIC (International Standard Industrial Classification). The disaggregated model enables one to understand the differences in sectors and can enable one to distinguish the impact of more vulnerable sectors.

Agricultural Commodity Production

Agricultural commodity production derived from the social accounting matrices for Kenya, Uganda, Tanzania and Rwanda (Table 4.3). The top ten agricultural commodities with the highest gross output in Kenya are maize tea, dairy, vegetables, oils, beef, cut flowers, fruits, roots and tubers and poultry. These commodities make up 82 percent of all agricultural commodities produced. The agricultural commodities produced make up 20 percent of gross output, with maize and tea contributing more than ten percent respectively to total agricultural output. In the case of Tanzania, agricultural output constitutes approximately 23 percent of gross output, with maize and mining being the top two agricultural commodities, while rice ranks third. The other agricultural commodities produced are forestry, vegetables, cattle, pulses, fisheries, cassava and poultry. The top ten agricultural commodities produced in Tanzania make up 74 percent of total agricultural output. Given that agricultural commodities are priced in different currencies for the four EAC partner states, comparisons can only be made using proportions/ ratios. In both countries, agricultural commodity production is around 20 percent of gross output; infact Tanzania has a higher gross output ratio of 23 percent. The proportion of the top ten agricultural commodities produced as a proportion total agricultural commodity production is higher for Tanzania (84 percent) as compared to Kenya (71 percent).

In Uganda, total agricultural commodity output constitutes 18 percent of gross output. The top ten agricultural commodities produced are forestry, pulses and oilseeds, fishing, roots, Matoke, livestock, cassava, coffee, other cereals and maize. These commodities constitute 91 percent of agricultural commodity outputs. In the case of Rwanda, agricultural commodity output constitutes 33 percent of gross output. The top ten commodities produced include banana/ plantain, Irish potatoes, sweet potatoes, pulses, cassava, forestry, sorghum, maize, mining and fruits. These commodities make up 82 percent of total agricultural commodity output. In terms of agricultural commodity production diversification, Kenya can be considered more diversified in terms of production since it has a lower percentage proportion of the top ten produced commodities.

Table 4-3: EAC Agricultural Commodity Production

Commodity	Total	(%) Agric. Output	Rank	(%) of Gross Output
Kenya (Million KES)				
Maize	56,109	14.9	1	3.0
Tea	51,419	13.6	2	2.7
Dairy	35,019	9.3	3	1.9
Vegetables	32,256	8.6	4	1.7
Oils	30,710	8.1	5	1.6

Commodity	Total	(%) Agric. Output	Rank	(%) of Gross Output
Beef	24,398	6.5	6	1.3
Cut flower	21,668	5.7	7	1.1
Fruit	21,651	5.7	8	1.1
Roots & Tuber	18,804	5.0	9	1.0
Poultry	18,223	4.8	10	1.0
Total Agric.	**377,199**			**20.0**
Gross Output	**1,886,249**			
UGANDA (Million UGS)				
Forestry	1,151	18.8	1	3.4
Pulses& oilseeds	808	13.2	2	2.4
Fishing	675	11.0	3	2.0
Roots	568	9.3	4	1.7
Matoke	522	8.5	5	1.6
Livestock	518	8.5	6	1.5
Cassava	495	8.1	7	1.5
Coffee	277	4.5	8	0.8
Other cereals	274	4.5	9	0.8
Maize	270	4.4	10	0.8
Total Agric.	**6,130**			**18.3**
Gross Output	**33,559**			
Commodity	**Total**	**(%) Agric. Output**	**Rank**	**(%) of Gross Output**
Tanzania (Billion TZs)				
Maize	1,253,464	13.3	1	3.1
Mining	1,151,001	12.3	2	2.9
Rice	802,655	8.5	3	2.0
Forestry	741,873	7.9	4	1.8
Vegetables	638,521	6.8	5	1.6
Cattle	585,309	6.2	6	1.5
Pulses	491,685	5.2	7	1.2
Fisheries	464,754	4.9	8	1.2
Cassava	460,075	4.9	9	1.1
Poultry	381,517	4.1	10	0.9
Total Agric.	**9,391,114**			**23.3**
Gross Output	**40,250,130**			
Rwanda (Million RWF)				
Bananas/plant	123,114	17.8	1	5.9
Irish potatoes	111,285	16.0	2	5.3
S. potatoes	76,560	11.0	3	3.6
Pulses	75,459	10.9	4	3.6

Commodity	Total	(%) Agric. Output	Rank	(%) of Gross Output
Cassava	53,861	7.8	5	2.6
Forestry	41,594	6.0	6	2.0
Sorghum	26,767	3.9	7	1.3
Maize	21,178	3.1	8	1.0
Mining	17,967	2.6	9	0.9
Fruits	16,637	2.4	10	0.8
Total Agric.	**693,566**			**33.0**
Gross Output	**2,100,768**			

Source: Kenya SAM 2003, Tanzania SAM 2007, Rwanda SAM 2006, Uganda SAM 2007

Household Agricultural Commodity Consumption

Household commodity consumption for the four EAC partner states is presented in table 4.4. For Kenya, the top ten commodities consumed by households are maize, beef, vegetables, oils and pulses, roots, forestry, rice, fruits dairy and fish. These commodities constitute 17 percent of total commodities consumed. The rest of the 83 percent are shared between exports, intermediate consumption and consumption by other non- household institutions. These top ten commodities consumed by the Kenyan households make up 93 percent of total commodities consumed by households in Kenya. The top ten commodities consumed in Tanzania are maize, mining, rice, forestry, vegetables, cattle, pulses, fisheries, cassava and poultry. Tanzania's total household consumption of agricultural commodities make up 23 percent of total consumption while the top ten commodities make up 74 percent of total agricultural commodities by households. For Uganda, total household agricultural commodity consumption makes up 25 percent of total consumption, the top ten commodities include: forestry, pulses and oil seed, Matoke, cassava, roots, fishing, other cereals, livestock, horticulture and maize. These commodities make up 98 percent of total agricultural commodities consumed by households.

Lastly for Rwanda, agricultural commodities make up 44 percent of total commodities consumed by households. The top ten commodities consumed by households are Irish potatoes, sweet potatoes, pulses, bananas/plantains, cassava, forestry, maize, vegetables, sorghum and other roots. These agricultural commodities make up 39 percent of all agricultural commodities consumed by households. Kenya and Uganda have a less diversified agricultural commodity consumption basket since the top ten commodities consumed by their households are more than 90 percent (93 and 98 percent respectively), as compared to Tanzania with 94 percent. Rwanda has a more diversified agricultural commodity consumption basket since the top ten commodities constitute 39 percent of total agricultural commodities consumed by the households.

Table 4-4: EAC Agricultural Commodity Consumption

Commodity	Total	(%) of Agric. Commodity	Rank	(%) of Total Consumption
Kenya (Million KES)				
Maize	21,114	16.8	1	2.8
Beef	20,134	16.0	2	2.7
Vegetables	17,023	13.5	3	2.3
Oils &Pulses	12,886	10.2	4	1.7

Commodity	Total	(%) of Agric. Commodity	Rank	(%) of Total Consumption
Roots	9,564	7.6	5	1.3
Forestry	8,921	7.1	6	1.2
Rice	8,670	6.9	7	1.1
Fruits	6,756	5.4	8	0.9
Dairy	6,482	5.1	9	0.9
Fish	5,278	4.2	10	0.7
Agric. Cons.	**125,962**			**16.7**
Total Cons.	**1,886,249**			
UGANDA (Million UGS)				
Forestry	1,256	26.8	1	6.7
Pulses , oilseed	671	14.3	2	3.6
Matoke	651	13.9	3	3.5
Cassava	560	11.9	4	3.0
Roots	559	11.9	5	3.0
Fishing	418	8.9	6	2.2
Other cereals	187	4.0	7	1.0
Livestock	118	2.5	8	0.6
Horticulture	98	2.1	9	0.5
Maize	65	1.4	10	0.3
Agric. Cons.	**4,694**			**25.0**
Total Cons.	**18,743**			
Tanzania (Billion TZS)				
Commodity	**Total**	**(%) of Agric. Commodity**	**Rank**	**(%) of Total Consumption**
Maize	579,672	15.8	1	3.9
Other cereals	396,330	10.8	2	2.7
Vegetables	386,153	10.5	3	2.6
Mining	381,448	10.4	4	2.6
Forestry	340,337	9.2	5	2.3
Poultry	288,353	7.8	6	2.0
Cassava	204,267	5.6	7	1.4
Rice	190,442	5.2	8	1.3
Pulses	147,992	4.0	9	1.0
Cattle	113,389	3.1	10	0.8
Agric. Cons.	**3,679,410**			**25.0**
Total Cons.	**40,250,130**	**23.3**		
Rwanda (Million RWF)				
Commodity	**Total**	**(%) of Agric. Commodity**	**Rank**	**(%) of Total Consumption**
Irish potatoes	114,267	19.9	1	8.7
S. potatoes	89,334	15.6	2	6.8

Commodity	Total	(%) of Agric. Commodity	Rank	(%) of Total Consumption
Pulses	76,942	13.4	3	5.9
Bananas/plant	56,543	9.9	4	4.3
Cassava	48,985	8.5	5	3.7
Forestry	38,556	6.7	6	2.9
Maize	25,725	4.5	7	2.0
Vegetables	19,885	3.5	8	1.5
Sorghum	18,221	3.2	9	1.4
Other roots	16,746	2.9	10	1.3
Agric. Cons.	**573,219**			**43.7**
Total Cons.	**1,312,273**			

Source: Kenya SAM 2003, Tanzania SAM 2007, Rwanda SAM 2006, Uganda SAM 2007

5 RESULTS AND DISCUSSION

5.1 Farm Household Analysis

The objective of the farm household analysis is to obtain the coefficients of the temperature variables that will be used to simulate the productivity data in the CGE model. While temperature, rainfall, capital and labour data is presented in the country results. Only results for rainfall, temperature and their respective variation will be the focus for this section. Ray *et al* (2014) found that over 60 percent of yield variations in crops are explained by temperature variation, making temperature variation a very significant component for establishing the productivity effects in yield. The yield results show that climate variation (rainfall and temperature) have adverse effects on most of the crops, this is consistent with results by Rimi *et al.* (2009) who found that temperature variations decreased rice production significantly. For all the regressions undertaken for each country for the selected crops, the models were all significant and one percent even though the respective models had low percentages for the R^2 statistics. It was expected that increase in crop area would increase crop yields, however for the crops examined, there was a decrease, this can be due to the quality of land and its suitability for the crop in question. The relationship between crop yields and crop areas would require further investigation, however, this does not fall within the scope f this research.

Kenya

The dependent variable in the analysis was log of yield regressed on weather variables, capital and labour. For Kenya (table 5.1), a unit (mm) increase in rainfall reduced the yield of millet, sorghum and beans. A unit increase in rainfall variation increased yields for millet (0.071), sorghum (0.232), while for beans the yield would decrease by 0.038. Rainfall variation was found to adversely affect sorghum. A unit increase in temperature reduced millet yields, but increased yields of beans by 0.032. Temperature variation had adverse effects on most of these crops, millet yields would reduce 7 times with increase in temperature variation, and while beans yields would reduce almost 8 times. Wheat would be adversely affected by temperature variation since the yields would reduce 42 times.

Table 5-1: Results of Yield Change due to Unit Change in Temperature and Rainfall (Kenya)

	Rice	Millet	Sorghum	Beans	Wheat
Rainfall (mm)	-0.039	-0.012**	-0.031*	-0.031*	0.009
Temperature (^{0}C)	0.016	-0.120**	0.032	0.032*	0.115
Rainfall Variation (mm)	0.435	0.071***	0.232*	-0.038*	-0.033
Temperature Variation (^{0}C)	0.000	-7.675***	2.432	-7.455*	-42.423**
Capital (KES)	0.001	0.000*	0.000	0.000**	0.000
Labour (man days)	0.004	0.007***	0.000	0.000	0.002
Crop Area (hectares)	-1.668	-0.988*	-0.355*	-0.249*	-0.103
Constant	1.635	11.341*	3.926*	8.824*	15.883*
R-adjusted	0.364	0.169	0.087	0.088	0.176
No. of observations	23	244	582	3,104	23

*1 %, **5% and ***10% significance level

Source: Author's Calculations from Kenya Household Survey Data 2005/06

Tanzania

A unit increase in rainfall had a positive effect on the yields, rice and cassava yields each reduced by 0.001. Variation in rainfall reduced the yields of maize, millet and cassava. A unit increase in temperature was found to reduce the yields of rice, beans, sorghum, millet and cassava. A unit increase in temperature variation increased the yields of millet almost five times, while that of beans increased 3 times, while this change was found to reduce the yields of sorghum almost 4 times. Like Kenya the question of land quality and impact on crop yields should be an area for further research.

Table 5-2: Results of Yield Change due to Unit Change in Temperature and Rainfall (Tanzania)

	Rice	Sorghum	Millet	Cassava	Beans
Rainfall (mm)	-0.001*	0.000	-0.001	-0.005*	0.000
Temperature (^{0}C)	-0.262*	-0.087***	-0.401*	-0.414*	-0.017
Rainfall Variation (mm)	-0.002	-0.001	-0.025**	-0.010*	-0.001
Temperature Variation (^{0}C)	0.401	-3.572***	4.867**	3.506	3.435*
Capital (TZS)	0.000	0.000	0.000	0.000	0.000*
Labour (man days)	0.004*	0.006	0.001	0.018	0.010*
Crop Area (hectares)	-0.640*	-0.173**	-0.145	-1.043*	-1.092*
Constant	6.458*	1.898**	7.289**	18.150*	-1.740*
R-adjusted	0.187	0.057	0.088	0.317	0.317
No. of observations	495	268	107	204	550

*1 %, **5% and ***10% significance level

Source: Author's Calculations from Tanzania Household Survey Data

Uganda

In Uganda, change in rainfall was found to reduce the yields of sorghum, though by a small amount (0.001 times). Rainfall variation also increased yields of beans only. Change in temperature, reduced the yields of sorghum and millet, but increased the yield of beans. Temperature variation was found to adversely affect rice yields by 1.3 decrease in output per hectare, beans yields were also decreased (0.378 times).

Table 5-3: Results of Yield Change due to Unit Change in Temperature and Rainfall (Uganda)

	Rice	Sorghum	Millet	Matoke	Beans
Rainfall (mm)	0.005***	0.001**	0.001	0.000	0.000
Temperature (^{0}C)	-0.259	-0.004***	-0.259*	-0.113	0.066**
Rainfall Variation (mm)	0.002	0.002	0.000	0.001	0.001***
Temperature Variation (^{0}C)	-1.299***	-0.116	-0.239	-0.364	-0.378*
Capital (UGS)	0.000	0.000*	0.000	0.000	0.000**
Hired Labour (UGS)	0.012**	0.001	0.017**	0.004	0.002
Family Labour (Man Days)	0.001	-0.001	0.010*	-0.001	0.001**
Crop Area (hectares)	-1.310*	-0.147*	-1.590*	-0.410	-0.214*
Constant	4.988	4.923*	11.092*	10.267	4.432*
R-adjusted	0.086	0.077	0.229	0.061	0.055

	Rice	Sorghum	Millet	Matoke	Beans
No. of observations	61	374	281	1,048	1,528

*1 %, **5% and ***10% significance level
Source: Author's Calculations from Uganda Household Survey Data

Rwanda

In Rwanda, a unit increase in rainfall decreased the yields of beans and sweet potatoes. Variation of rainfall on the other hand increased the yields of the same crops, with a magnitude of less than one. A unit increase in temperature also increased the yields of beans while decreasing the yields of sweet potato. Temperature variation was found to have adverse but positive effects for beans, whose yields increased 13 times.

Table 5-4: Results of Yield Change due to Unit Change Temperature and Rainfall (Rwanda)

	Beans	S. Potato
Rainfall (mm)	-0.023*	-0.028*
Temperature (^{0}C)	0.143*	-0.350*
Rainfall Variation (mm)	0.158*	0.173*
Temperature Variation (^{0}C)	13.210*	2.493
Capital (RWF)	0.000	0.000
Labour (man days)	0.000*	0.000
Crop Area (hectares)	-0.004*	-0.003*
Constant	-14.382*	8.119
R-adjusted	0.261	0.172
No. of observations	15,132	2,518

*1 %, **5% and ***10% significance level
Source: Author's Calculations from Rwanda Household Survey Data

5.2 Agricultural Production

The productivity changes associated with the rainfall and temperature changes obtained from the econometric regressions were applied in the CGE model by altering the total factor productivity. Given that there are spillover effects from agriculture, both manufacturing and services sector were evaluated at a macro level. The effects of productivity in the four EAC economies were modeled using three scenarios- in the first case, where rainfall and temperature change; second scenario- increase in temperature and rainfall variability and the last scenario where both rainfall and temperature change and variability also changes. The percentage changes were applied to the productivity for each of the selected crops. The first scenario examined the changes in rainfall and temperature patterns, the second scenario examined the rainfall and temperature variability while the last scenario examined rainfall and temperature changes and changes in variability. The baseline scenario presents the 'business as usual' scenario, in this scenario; there are no productivity changes associated with temperature and rainfall patterns. The base scenario is then compared to the simulated scenarios on order to establish how the economy will be affected when rainfall and temperature patterns change.

Kenya

A change in rainfall and temperature mean (scenario 1) was found to increase agricultural production by 0.004 percent. Of this overall reduction in agricultural production, maize production increased by 0.001 percent. The production of other grains (beans, millet and sorghum) was adversely affected by rainfall and temperature changes and resulted in approximately 21 percent reduction in production. The changes in manufacture and services sector output due to climatic changes in the agricultural sector is an indicator of sectorial linkage. Manufacture increased by 0.0003 percent while services output increased by 0.001 percent. The service sector recorded a higher increase in output due to output changes from the agricultural sector. This is because increase in agricultural output would affect services such as hotels, trade, restaurants, which use agricultural output as intermediate products. Changes in the variation of temperature and rainfall (Scenario 2), was found to decrease agricultural output by 0.13 percent. This trend was also found in scenario 3 with slightly varying magnitudes.

Table 5-5: (%) Impact of Climate Change on Agricultural Output - (Kenya)

	Base (Million KES)	**Temp. & Rainfall mean** *Scenario 1*	**Temp. & Rainfall Variation** *Scenario 2*	**Temp. & Rainfall mean and Variation** *Scenario 3*
Output				
Agriculture	**290,637**	0.004	-0.13	-0.12
Of which				
Maize	44,453	0.001	-0.04	-0.04
Wheat	510	0.001	-86.15	-86.15
Rice	2,812	0.89	0.00	0.89
Other Grains	88	-20.84	-33.65	-33.65
Manufacture	395,587	0.0003	0.02	0.02
Services	1,107,541	0.001	0.001	0.002

Source: Author's Simulations from Social Accounting Matrix (Kenya 2003)

Tanzania

Changes in temperature and rainfall mean (scenario 1) were found to reduce agricultural output by approximately 3 percent. The most affected commodities were found to be millet, whose production reduced by 37 percent. In scenarios 2, the outputs of crops that were adversely affected by temperature and rainfall variation were pulses (beans), which increased by 77 percent, while production millet decreased by 12 percent and sorghum by 15 percent. This trend was also found in scenario 3 with slightly varying magnitudes. Furthermore, the reduction in services output instigated by climate changes is low in all the scenarios at less than one percent. Compared to the manufacturing sector, the output in this sector is largely affected by changes temperature and rainfall mean, and a combination of changes in temperature and rainfall variation and patterns. This shows that the services sector has weaker backward linkage to agriculture sector as compared to the manufacturing sector.

Table 5-6: (%) Temperature and Rainfall Pattern and Variability Changes (Tanzania)

	Base (Billion TZS)	Temp. & Rainfall patterns *Scenario 1*	Temp. & Rainfall Variation *Scenario 2*	Temp. & Rainfall Pattern and Variation *Scenario 3*
Output				
Agriculture	7,523,774	-3.40	2.64	-2.57
Of which				
Maize	944,392	-3.27	-1.66	-2.93
Sorghum	150,833	-15.29	-15.06	-8.13
Millet	53,335	-36.93	-11.62	48.30
Rice	730,679	-16.43	-0.88	-16.26
Cassava	230,354	-23.89	-6.04	-19.54
Pulses	354,434	-1.22	76.84	-1.20
Manufacture	4,817,098	-3.53	-1.89	-2.55
Services	25,196,473	-0.11	-0.01	-0.04

Source: Author's Simulations from Social Accounting Matrix (Tanzania 2009)

Uganda

The results of simulations for Uganda are presented on table 5.7, it should be noted that only crops of interest are presented in this table. Changes in temperature and rainfall mean (Scenario 1) were found to reduce agricultural output by approximately 20 percent. The most affected commodities associated with this change are maize (4 percent) and other cereals (16 percent), which include millet and sorghum. There is however an increase in beans output by 6.5 percent. In scenario 2, temperature and rainfall variation had an adverse effect on rice production, which reduced by 100 percent resulting in increase for imports by more than 400 percent. In scenario 3, the magnitude of change in output is particularly high for beans, whose output decreased by 46 percent

Table 5-7: (%) Temperature and Rainfall Pattern and Variability Changes - (Uganda)

	Base (Million UGS)	Temp. & Rainfall mean *Scenario 1*	Temp. & Rainfall Variation *Scenario 2*	Temp. & Rainfall meanand Variation *Scenario 3*
Output				
Agriculture	6,129,555	-20.46	-24.46	-12.51
Of which				
Maize	269,738	-4.04	-4.09	-11.33
Rice	67,980	-2.63	-100.00	-100.00
Other Cereals	273,825	-16.53	-1.95	-19.69
Matoke	522,083	-6.45	-20.06	-27.94
Beans	676,342	6.46	-37.39	-45.77
Manufacture	5,765,502	-42.18	-33.21	1.59
Services	21,664,094	-86.52	-74.15	-0.43

Source: Author's Simulations from Social Accounting Matrix (Uganda 2007)

Rwanda

Changes in rainfall and temperature patterns (scenario 1) were found to reduce agricultural output by 3 percent. Change in rainfall and temperature would adversely affect sweet potatoes production, which would reduce by 35 percent. Maize production would reduce by less than 1 percent. Beans production would however increase by around 11 percent. In scenario 2, rainfall and temperature variation increased beans and sweet potato production, but reduced maize production by almost 2 percent. Changes associated with scenario 3, were found to be similar to scenario 2 with varying magnitudes.

Table 5-8: Temperature and Rainfall Pattern and Variability (%) Changes - (Rwanda)

	Base (Million RWF)	**Temp. & Rainfall patterns** *Scenario 1*	**Temp. & Rainfall Variation** *Scenario 2*	**Temp. & Rainfall Pattern and Variation** *Scenario 3*
Output				
Agriculture	639,420	-2.54	72.00	71.42
Of which				
Maize	21,178	0.08	-1.55	-1.50
Sweet Potato	76,560	-35.25	151.63	140.62
Pulses (Beans)	75,459	11.42	525.86	531.16
Manufacture	657,936	0.40	-6.03	-5.83
Services	550,786	-0.40	3.45	3.36
Exports	75,671	0.44	-6.45	-6.20
Imports	-269,596	0.13	-1.81	-1.74
Of which				
Maize	4,745	0.06	-5.02	-4.96
Rice	7,513	0.23	-5.12	-5.01
Private Consumption	1,312,273	-1.52	37.23	36.90
GDP at market price	1,594,321	-1.25	30.64	30.37

Source: Author's Simulations from Social Accounting Matrix (Rwanda 2006)

5.3 Trade

Kenya

Adjustment of output due to climate change focused on scenario 3, which was the more realistic scenario that looked at the combined effect of changes in mean rainfall and temperature and variation. Adjustment of output due to climate change resulted in the alteration of allocation of outputs on demand: how much is exported, sold domestically and whether importation would take place in order to meet consumption needs. In Kenya, the reduction in output associated with climate change resulted in demand for output being altered as follows: There was adjustment between exports and domestic sales so that overall exports increased by 0.06 percent, while domestic sales decreased by 2.43 percent, in order to meet the consumption demand, imports increased by 0.04 percent. A review of specific crops showed that even though domestic sales decreased by 0.02 percent, sales of maize increased by approximately 42 percent, the increase in maize domestic sales is largely triggered by supply price reduction of maize, which resulted in increased demand for maize. Domestic wheat sales reduced by 84 percent, while beans sales, which was included under other grains reduced by approximately 1 percent. The increased domestic sales of maize resulted in reduced maize imports by 0.3 percent, while wheat imports increased by 3.6 percent.

Table 5-9: Demand Response to Output Changes (%)- Kenya.

	Base (Million KES)	**Temp. & Rainfall mean** *Scenario 1*	**Temp. & Rainfall Variation** *Scenario 2*	**Temp. & Rainfall mean and Variation** *Scenario 3*
Exports	**281,116**	0.004	0.07	0.06
Of which				
Maize	*286.07*	0.01	0.24	0.24
Wheat	*74.28*	0.002	-97.76	-97.76
Other Grains	*37*	-51.66	-92.65	-92.65
Domestic Sales	**1,530,330**	**-0.33**	**2.44**	**2.43**
Of which				
Maize	44,167	-5.18	41.82	41.55
Wheat	436	-0.39	-84.03	-84.04
Rice	2,812	0.90	-0.31	0.56
Other Grains	51	-0.66	-1.05	-1.05
Imports	**-416,892**	0.00	0.04	0.04
Of which				
Maize	*920*	-0.01	-0.30	-0.30
Wheat	*11,803*	0.00	3.62	3.62
Rice	*4,605*	-0.18	-0.07	-0.25
Private Consumption	848,484	0.00	-0.05	-0.04

Source: Author's Simulations from Social Accounting Matrix (Kenya 2003)

Tanzania

This output is allocated between exports and domestic sales, the overall reduction in aggregate output reduced imports, exports and domestic sales. In Tanzania, the decrease in output (scenario 3) led to reduction in both exports and domestic sales by 0.42 and 0.99 percent respectively, imports further decreased by 0.27 percent. A review of crops of interest showed that maize, rice, wheat beans and sorghum reduced, while domestic sales of millet went up by approximately 23 percent. This resulted in millet imports reducing by approximately 83 percent. Even though Tanzania recorded major changes in demand, especially for exports, imports and domestic sales, this not translate to major reduction in private consumption, which reduced by 2 percent. Even though crops like maize and rice output was found to reduce, this did not translate to private consumption since these products constitute less than 25 percent of total agricultural commodities consumed by households.

Table 5-10: Demand Response to Output Changes (%)- Tanzania.

	Base (Billion TZS)	Temp. & Rainfall mean *Scenario 1*	Temp. & Rainfall mean *Scenario 2*	Temp. & Rainfall mean and Variation *Scenario 3*
Exports	**6,179,379**	-0.96	1.14	-0.42
Of which				
Maize	6,745	-4.91	-3.14	-4.69
Sorghum	730	-25.27	-100.00	-7.33
Millet	550	-73.12	57.46	1113.11
Rice	199	-88.57	3.29	-88.73
Pulses	92,966	-2.77	187.87	-3.06
Domestic Sales	31,604,887	-1.27	0.06	-0.99
Of which				
Maize	937,647	-3.26	-1.65	-2.92
Sorghum	150,103	-15.25	-14.76	-8.14
Millet	52,785	-36.62	-12.47	23.14
Rice	730,480	-16.42	-0.88	-16.24
Cassava	230,354	-23.89	-6.04	-19.54
Pulses	261,468	-0.68	28.83	-0.55
Imports	**-9,543,170**	-0.62	0.74	-0.27
Of which				
Maize	28,041	-1.49	-0.38	-1.12
Sorghum	32	-4.30	344.63	-8.73
Millet	2,701	42.59	-51.25	-83.16
Pulses	4,780	1.64	-40.82	2.04
Private Consumption	17,427,110	-2.50	2.02	-2.05

Source: Author's Simulations from Social Accounting Matrix (Tanzania 2009)

Uganda

Out of the six food security crops under study, Uganda was found to export only maize and beans, hence the decrease in maize output would reduce maize exports by 10 percent, while exports for bean would increase by 21 percent (Scenario 1). As can be seen, the decrease in outputs for maize, rice and other cereals would result in an increase in their import. In scenario 3, reduction in output resulted in the reduction of exports by 2.3 percent, domestic sales reduced by 2.28 percent, while imports reduced by 1.15 percent. Maize and beans exports for Uganda reduced by 24 and 94 percent respectively. The reduction in output resulted in the further reduction of domestic sales for maize, beans, rice and other cereals. Consequently, Uganda would record a very large increase in the imports of rice as compared to maize and other cereals. The adjustment of output demand between exports; domestic sales and imports would result in private consumption reducing by 4.26 percent.

Table 5-11: Demand Response to Output Changes (%)- Uganda.

	Base (Million UGS)	Temp. & Rainfall mean *Scenario 1*	Temp. & Rainfall Variation *Scenario 2*	Temp. & Rainfall mean and Variation *Scenario 3*
Exports	**3,632,979**	**0.03**	**-1.13**	**-2.30**
Of which				
Maize	53,814	-10.04	-7.96	-25.09
Beans	117,722	20.50	-85.66	-93.81
Domestic Sales	**30,224,587**	**-0.36**	**-1.48**	**-2.28**
Of which				
Maize	215,924	-2.56	-3.13	-8.01
Beans	558,621	3.44	-28.94	-37.72
Rice	67,980	-2.63	-100.00	-100.00
Other Cereals	273,825	-16.53	-1.95	-19.69
Imports	**-7,259,720**	**0.01**	**-0.56**	**-1.15**
Of which				
Maize	59,553	4.78	5.02	15.78
Rice	25,072	3.28	413.83	409.42
Other Cereals	150,891	17.91	1.06	21.27
Private Consumption	**18,742,540**	**-0.59**	**-2.84**	**-4.26**

Source: Author's Simulations from Social Accounting Matrix (Uganda 2007)

Rwanda

In scenario 1, even though there is substantive reduction in production for the sweet potatoes, there was increase in exports by 0.44 percent. The crops under study, do not form part of the exports, this is a major drawback of CGE, if from the initial data presented, a crop was not exported, even with an increase in production that necessitates export due to surplus, the crop will not be exported, as can be seen with beans. The imports of maize and rice also increased due to reduction in maize production as well as sweet potatoes.

In scenario 3, the reduction in output associated with climate change altered demand for output. The 71.42 percent increase in output resulted in an increase in a reduction in exports by 6.2 percent; however, the food crops of interest (maize, beans and sweet potatoes) did not form part of the exports. Domestic sales further increased by approximately 74 percent in adjustment to increase in output. The increase in domestic sales was largely driven by the increase in domestic sales of sweet potatoes and beans (pulses). The increase in domestic sales resulted in a reduction of overall imports by 1.74 percent, particularly maize and rice, which both reduced by 5 percent. The increase in domestic sales increased private consumption by approximately 37 percent.

Table 5-12: Demand Response to Output Changes (%)- Rwanda.

	Base (Million RWF)	Temp. & Rainfall mean *Scenario 1*	Temp. & Rainfall Variation *Scenario 2*	Temp. & Rainfall mean and Variation

				Scenario 3
Exports	75,671	0.44	-6.45	-6.20
Imports	-269,596	0.13	-1.81	-1.74
Of which				
Maize	4,745	0.06	-5.02	-4.96
Rice	7,513	0.23	-5.12	-5.01
Private Consumption	1,312,273	-1.52	37.23	36.90
GDP at market price	1,594,321	-1.25	30.64	30.37

Source: Author's Simulations from Social Accounting Matrix (Rwanda 2006)

Intra- EAC Trade in Maize

Further to the analysis presented in tables 5.5 to 5.12, intra EAC trade on maize was simulated for the three scenarios following the changes in maize exports. Several assumptions were made, first, the percentage change in maize exports applied to all maize exports irrespective of destination, and second, exports were assumed to mirror the imports of the country of destination. Overall exports of maize within the EAC would reduce due to climate change. Even though Rwanda did not export maize from the 2006 SAM, there were minimal maize exports from the trade map data in 2015, exports for Rwanda also decreased.

Table 5-13: Intra-EAC Exports of Maize ('000 USD).

From…	**To…**	**Base Scenario**	**Temp. & Rainfall mean** *Scenario 1*	**Temp. & Rainfall Variation** *Scenario 2*	**Temp. & Rainfall mean and Variation** *Scenario 3*
Uganda	Kenya	44,835.00	40,333.57	41,266.13	33,585.90
	Tanzania	880.00	791.65	809.95	659.21
	Rwanda	10,632.00	9,564.55	9,785.69	7,964.43
Kenya	Uganda	757.00	756.92	755.18	755.18
	Tanzania	827.00	826.92	825.02	825.02
	Rwanda	2,530.00	2,529.75	2,523.93	2,523.93
Tanzania	Uganda	1,520.00	1,456.31	1,472.27	1,448.71
	Kenya	94,090.00	90,147.63	91,135.57	89,677.18
	Rwanda	220.00	210.78	213.09	209.68
Rwanda	Uganda	12.00	12.05	11.23	11.26
	Kenya	2.00	2.01	1.87	1.88
	Tanzania	185.00	185.81	173.07	173.53

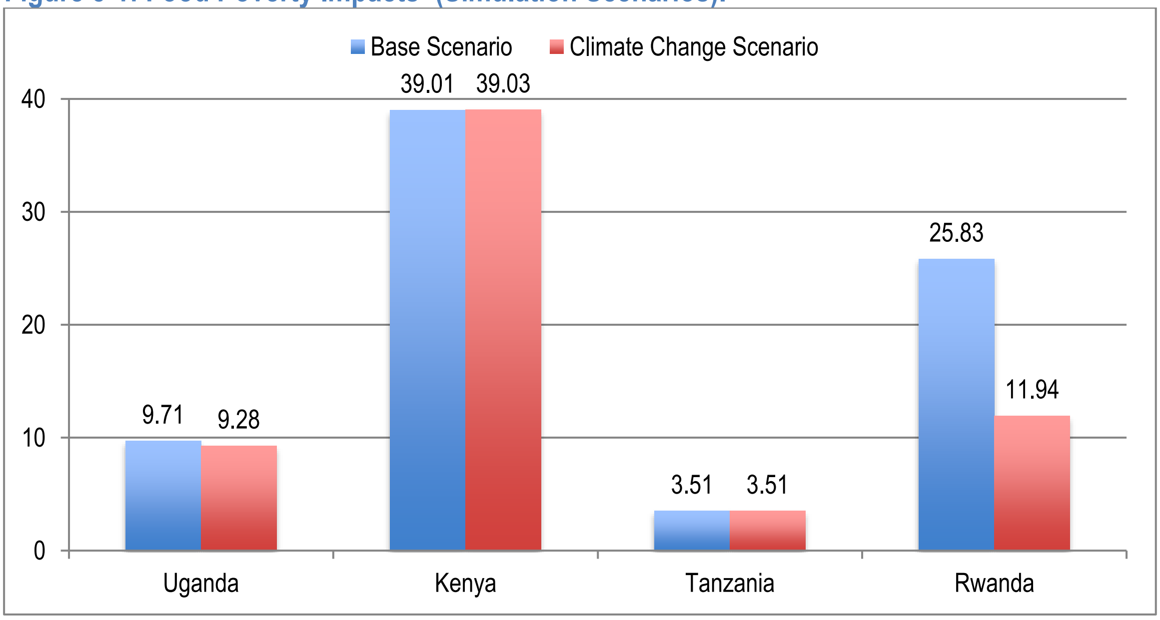
Source: Author's Simulations from ITC Database and Simulation results.

5.4 Consumption and Food Poverty Impacts

Food security is largely affected by how much food is available for consumption. The increase or decrease in private consumption, was further disaggregated in order to establish how each household category was affected in terms of change in consumption. Figure 5.1 presents the results of food poverty incidence due to climate change. Comparison was made for the base scenario and scenario 3, given that scenario 1 and 2 were intermediate steps for achieving scenario 3

The increase or decrease in private consumption, was further disaggregated by household quintiles in order to establish how each household category was affected in terms of change in consumption. Figure 3.1 presents the results of food poverty incidence due to climate change. In Kenya, the base scenario food poverty incidence was at 39.01 in the climate change scenario, with a 0.04 percent decrease in private consumption, food poverty incidence increased to 39.03 percent. The reduction in private consumption has resulted increase in food poverty. This can largely be attributed to the country's consumption basket, which is largely made up of maize approximately 58 percent of households consume maize, so any negative change in consumption will result in less of the food being available to the households, this makes a household food insecure. Even though the percentage changes in food poverty incidences were found to be generally low, when this is translated to number of households, the number would show a different picture. At the Base scenario, there were 3,316,314 poor households, with climate change, an additional 1,700 households become food poor.

Figure 5-1: Food Poverty Impacts (Simulation Scenarios).



Source: Author's calculations from Various Household Survey Data

In Tanzania, food poverty incidence was at 3.51 percent in the base scenario, however, when private consumption decreased to 2.05 percent in climate change scenario, food poverty incidence remained at 3.51 percent. This is because the most commonly consumed products by Tanzanian households: cereals, vegetables, forestry and poultry were not affected by climate change, the effect associated by reduction in the production of maize, was not felt in the households even though 15 percent of households consumed maize, due to substitution effects. At the base scenario, there were 326,430 poor households, with climate change, the number of poor households remain the same.

In Uganda, food poverty incidence was at 9.71 percent, however, when private consumption decreased by 4.3 percent in the climate change scenario 1, this resulted in food poverty incidence of 9.28 percent. Conventionally, it is expected when private consumption decreases, food security incidence goes up. However, in the case of Uganda, decrease in private consumption resulted in the decrease in food poverty incidence, for several reasons, first, the decrease in private consumption largely affected non-poor households, secondly, commodities like sweet potatoes and forestry, which is largely, consumed by households recorded increases in production this improved the welfare of most households even though private consumption decreased in general. Lastly, information could have been lost between the social accounting matrix and the household survey data, the households are classified by rural, urban and farm and capital, while the households survey data classifies these households by quintiles. Matching these households could have resulted in some lost information. With climate change, the numbers of poor households reduce by 26,600 from the base number of 602,020 households.

Rwanda, unlike most of the other EAC countries, has very positive results on food poverty incidence due to climate change. In the climate change scenario, food poverty incidence reduced to 11.94 percent following a 37 percent increase in private consumption. One major challenge encountered with the Rwanda data is that the Social accounting matrix had all households lumped together as one, however, in the household survey data, the household were divided into quintiles, this meant that all households were assumed to bear the same impact of changes in private consumption, however, in reality different households, classified by quintiles or location rarely have unitary impacts associated with changes in private consumption. With an original number of 626,351 households being food poor, more than half the households, 336,818 households move out of food poverty.

6 CONCLUSION AND POLICY RECOMMENDATIONS

The objective of the study was to establish the effect of climate change on agricultural production (supply), and how the four EAC countries meet their needs through trade (imports and exports) and the overall impact on food security. The study used several models to answer these questions. First the study used a log-linear regression model to model the effects of climate change on crop yield, the productivity changes from the model were then used to shock the CGE model in order to determine how trade and private consumption change due to changes in productivity triggered by climate change. The consumption changes derived from the CGE model were then simulated in a micro model in order to establish the changes incidence of food security in the selected EAC countries.

The study found that climate change would overall reduce private consumption in three EAC countries (Kenya, Uganda, and Tanzania), which would in turn result in increasing food poverty incidence. There were cases particularly in Uganda where food poverty incidence did not increase even though private consumption decreased. This was largely attributed to the particular commodities where consumption decreased and the household’s quintiles, which consumed these commodities.

In providing policy recommendations, the changes in rainfall and temperature affect crops that are important for food security in Kenya, Uganda and Tanzania as compared to rainfall and temperature variability, these changes affect the planning activities by farmers, hence adequate planning by farmers to circumvent changes in rainfall and temperature patterns is paramount. The respective governments also improve their meteorological facilities so that weather patterns can be predicted and reported more accurately. This will also enable farmers' plan well. There should be more investments in irrigation schemes that help in mitigating rainfall variations, by ensuring steady water supply for the crops. In order to address the challenge of temperature change, the respective governments could invest in seeds that can withstand varied temperatures.

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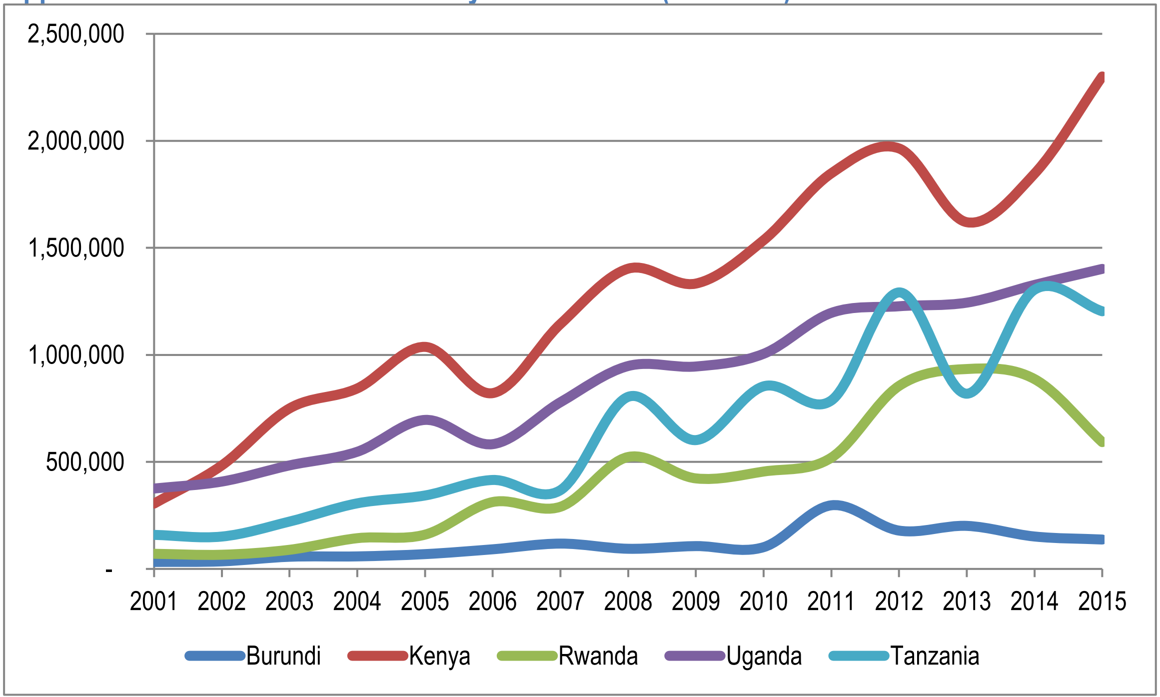
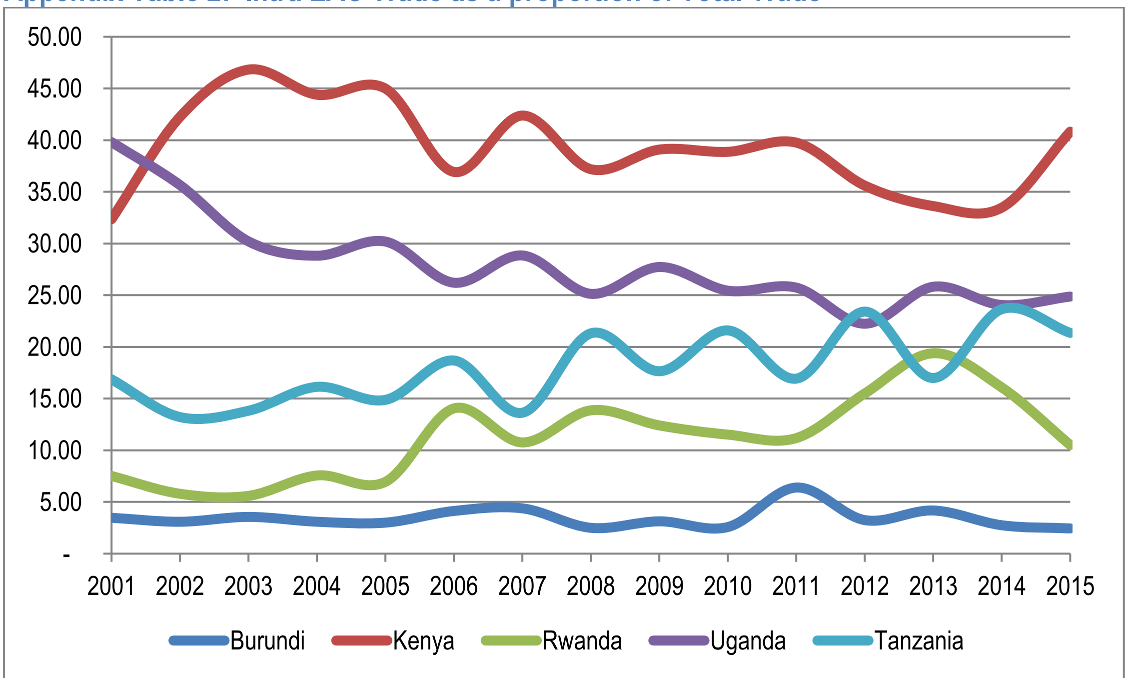
APPENDIX

Appendix Table 1: Total EAC Trade By Partner State (000' USD).



Source: ITC Database

Appendix Table 2: Intra EAC Trade as a proportion of Total Trade



Source: ITC Database

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