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A Regional Approach to Analysis of Food Security Framework and Policies of the Economic Community of West African States (ECOWAS)

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A Regional Approach to Analysis of Food Security Framework and Policies of the Economic Community of West African States (ECOWAS)

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by

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Abstract

Food security is always a concern for consumers, but especially for those in West Africa, where the population of food insecure people has continued to grow over the past decade despite attempts by initiatives such as the World Food Program and the establishment of Millennium Development Goals. The people of West Africa are subject to repetitive natural disasters and are often in political upheaval. Many economic policies have been established to mitigate the impact that production disasters have on the consumers; one of these policies is the utilization of regional food reserves.

In 2010, the Economic Community of West African States began to develop a Regional Food Reserve. To analyze the effect a Regional Food Reserve could have on West African consumers due to a production shock, a spatial partial equilibrium model was utilized to analyze reserve stock management and its impact on price behavior and food security at a regional level.

The model allowed for projected increases in population and gross domestic product (GDP). After creating a deterministic base year for 2013, 2018, and 2023, the impact of a production shock (based on historical and projected data) was simulated. Analysis of these shocks suggests the maximum reserve size needed to address the greatest decrease in consumption is approximately 187 (1000MT).

Key Words: regional food reserve, food security, rice

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Dedication

I dedicate this thesis to my loving family. To my father, Ray Shear, for driving me to my first day of school every year and instilling the importance of education in all of his children. To my mother, Teresa Shear, for her constant love and compassionate ear for all of my struggles. To my older sister, Grace Stewart, for her help in avoiding missed deadlines and last minute reviews. To my younger sister, Lillian Shear, for her sense of humor and for being my confidant. Thank you for having faith in me and supporting me in all that I have done.

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Acronyms

ADB	Asian Development Bank
APTERR	ASEAN +3 Emergency Rice Reserve
ASEAN	Association of Southeast Asian Nations
AU	African Union
CHB	Cadre Harmonisé Bonifié
CILSS	Permanent Interstate Committee for the Fight against Drought in the Sahel
CSA	Commissariat à la Securite Alimentaire, Senegal
ECOWAP	Economic Community of West African States Agriculture Policy
ECOWAS	Economic Community of West African States
EFSRA	Emergency Food Security Reserve Administration - Ethiopia
EU	European Union
EWS	Early Warning System
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GEMPACK	General Equilibrium Modeling Package
IFAD	International Fund for Agriculture Development
IFPRI	International Food Policy Research Institute
MDG	Millennium Development Goals
MENA	Middle East and North Africa
NAFCO	National Food Buffer Stock Company, Ghana
NFRA	National Food Reserve Agency - Nigeria
OECD	Organization for Economic Co-operation and Development
OPAM	Office of Agriculture Products of Mali (Office des Produits Agricoles du Mali)
OPVN	Office of Food Products of Niger (Office des Produits Vivriers du *Niger)*
RECs	Regional Economic Communities
SONAGESS	National Management Company Stocks for Food Security, Burkina Faso (Société Nationale de Gestion du Stock de Sécurité Alimentaire)
UEMOA	West African Economic and Monetary Union (Union Economique et Monétaire Ouest-Africaine)
UN	United Nations
USAID	United States Agency for International Development
US	United States
USD	United States Dollar
USDA	United States Department of Agriculture
WAEMU	West African Economic and Monetary Union
WFP	World Food Program
WFS	World Food Summit
WHO	World Health Organization

Rice Type and Degree of Milling Terminology

LGB, MGB, FRB	Long Grain, Medium Grain, and Fragrant Brown
LGP, MGP, FRP	Long Grain, Medium Grain, and Fragrant Paddy
LGW, MGW, FRW	Long Grain, Medium Grain, and Fragrant White

Chapter 1: Introduction

1.1 Historical Prevalence of Food Insecurity

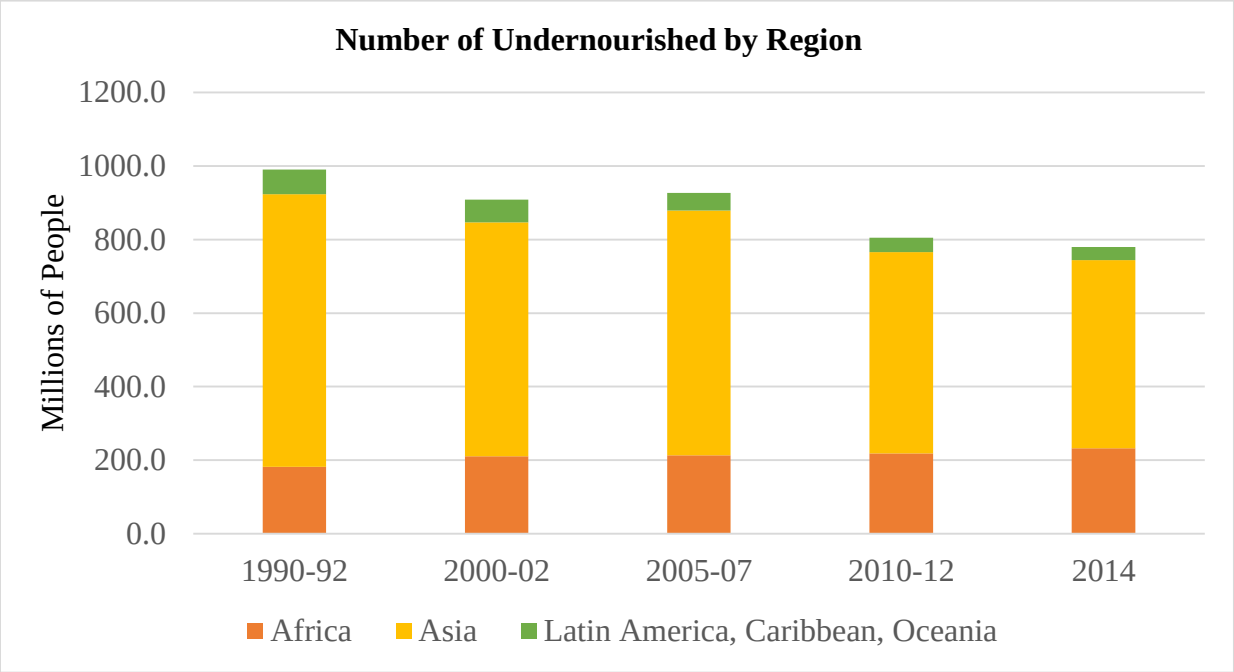
In 1996, the World Food Summit (WFS) defined the parameters of food security to be "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (WHO 2014). The concept of food security must be considered in both the physical form as well as the economic form, since food may be physically available, but not economically accessible by the poorest consumers. The WFS of 1996 resolved to base the understanding of food security on three pillars: availability, access, and use. Availability is focused on assuring that there are sufficient quantities of food available on a consistent basis. Access is focused on assuring that there are sufficient resources to obtain appropriate foods for a nutritious diet. Use, or utilization, is aimed at assuring appropriate allocation of resources based on current knowledge. Although the WFS definition has been internationally accepted, food security can be difficult to measure and the methods used to address food insecurity are many and diverse. Due to this difficulty, food security is often measured through a variety of indicators in an effort to make the term more quantitatively definable to ease interpretation.

There is academic discussion as to which indicators are most useful and accurate in measuring food security. In September of 2011, the Committee on World Food Security Round Table met and developed an initial set of 31 indicators aiming to capture various aspects of food insecurity (FAO 2011). This meeting further illustrated the many indicators used by different countries and spurred the continued development of the EU-US Transatlantic Development Dialogue: Road Map for Cooperation in Food Security. The purpose of this cooperation was to commit the two sides to take action on food security at the global, regional and national levels by

working together to identify food security indicators and infrastructure to fight hunger (EEAS 2011). This continuing debate results in many different sets of indicators being used across the world to measure food insecurity. A lack of agreement on universal food security indicators makes monitoring difficult to do in a timely and accurate manner. FAO noted in their 2015 State of Food Insecurity in the World report that different approaches and different dimensions are required to successfully improve food security; such dimensions include both availability and access (FAO, IFAD, & WFP 2015). While the debate continues as to which indicators to utilize to measure food security, the most common and widely used indicators include: calories consumed per capita, number of people undernourished, chronic hunger, number of people below the poverty line, purchasing power parity, child stunting and mortality rates, and food deficits.

Chronic hunger, defined as regularly not consuming enough food to lead an active life, affected 795 million people across the world in 2014 (FAO, IFAD, & WFP 2015). While this number is extremely high, it is lower than the previous year's report of 827 million people (FAO, IFAD and WFP 2015). This continual decrease in the number of undernourished people is illustrated in Figure 1 (The World Bank 2014). While a drop in absolute value is a positive sign, the most encouraging statistic to those invested in improving food security is the 21.4 percent drop in the total number of undernourished people since 1990 (FAO, IFAD and WFP 2015).

Figure 1. Undernourished People by Region

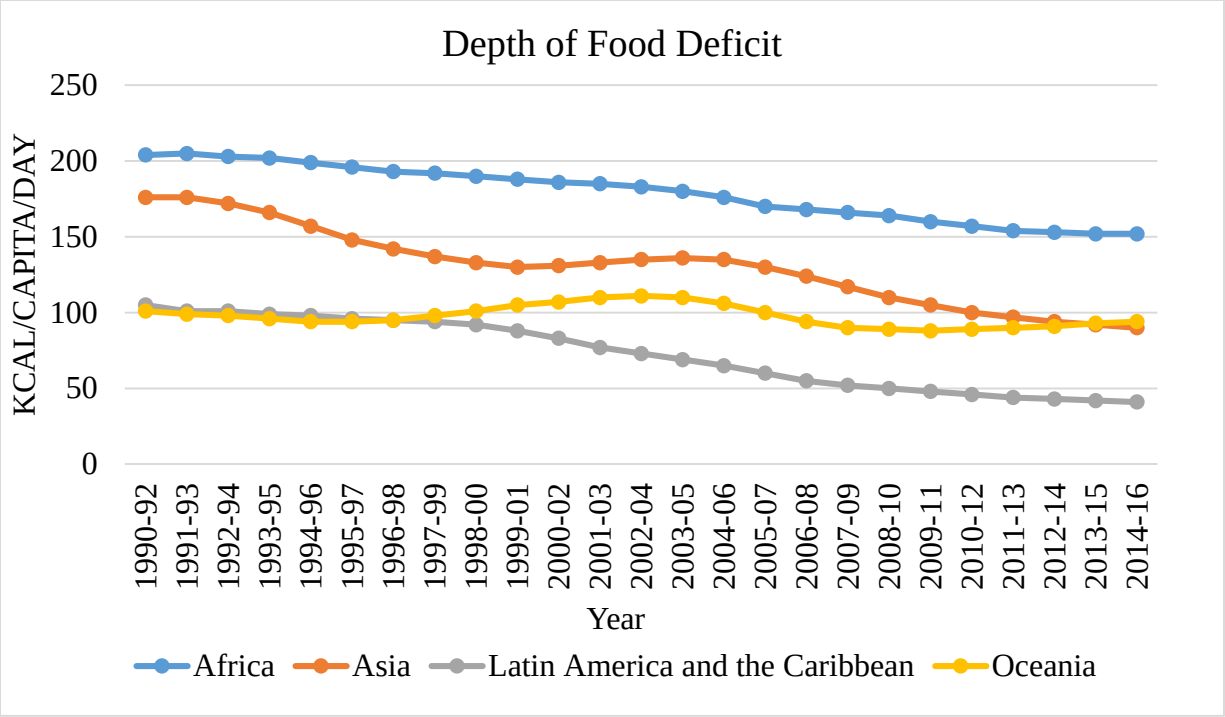


Source: The World Bank 2015: FAO, ILO, ICP 2015

Data collection including the number of people that are considered "undernourished" is valuable; but it is also important to recognize, or measure, the depth to which they are undernourished. In an attempt to determine the "depth" of undernourishment, the Food and Agriculture Organization uses the Food Deficit Indicator[1]. Figure 2 illustrates that the depth of undernourishment is most notable in Africa and Asia.

[1] The depth of the food deficit indicates how many calories would be needed to lift the undernourished from their status, everything else being constant. The average intensity of food deprivation of the undernourished, estimated as the difference between the average dietary energy requirement and the average dietary energy consumption of the undernourished population (food-deprived), is multiplied by the number of undernourished to provide an estimate of the total food deficit in the country, which is then normalized by the total population. It is measured in kcal/caput/day.

Figure 2. Food Deficit by Region

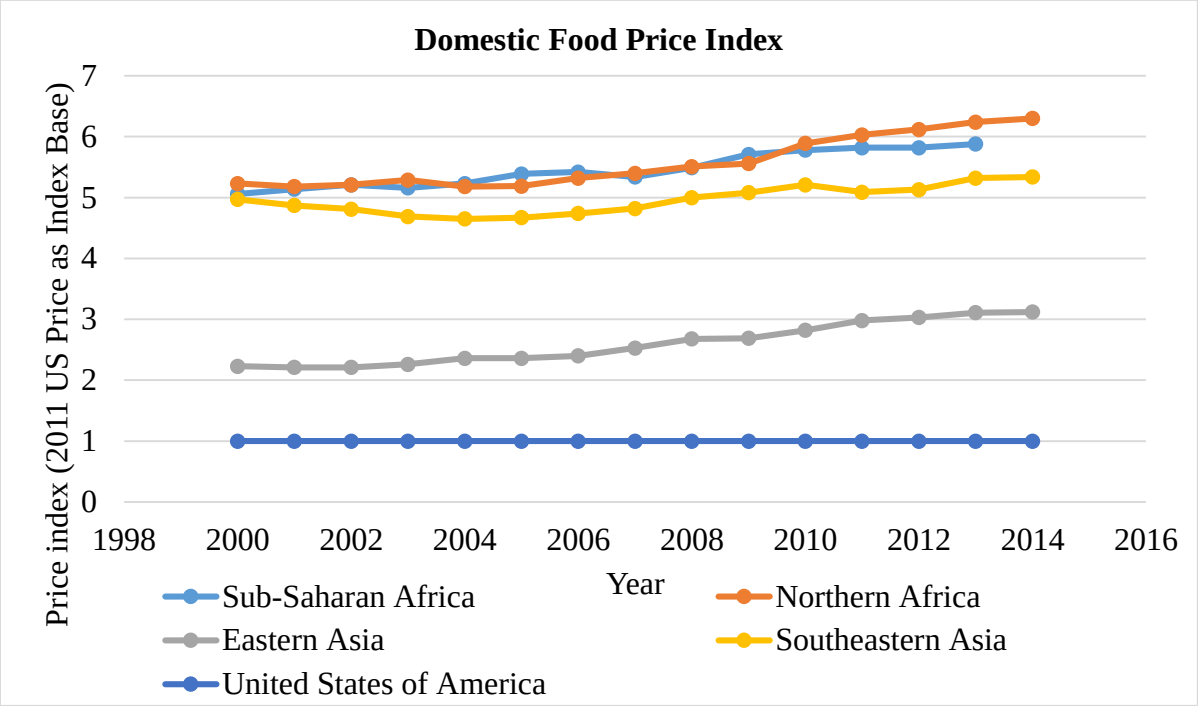


Source: The World Bank 2015: FAO, ILO, ICP 2015

In an effort to address food security, leaders of 189 United Nations (UN) member states adopted the United Nations Millennium Declaration in September of 2000 (FAO, ILO, ICP 2015). The agreement was established to reduce extreme poverty and hunger by setting the Millennium Development Goals (MDGs) (FAO, ILO, and ICP 2015). Millennium Development Goal 1 aims to eradicate extreme poverty and hunger; a goal was set to reduce the number of people who suffer from hunger in half by the year 2015 (FAO, ILO, and ICP 2015). While this goal seems unreasonable by some and not stringent enough by others, progress has been made with 72 countries already having met the goal and some having reduced poverty and hunger by more than half (FAO, ILO, and ICP 2015).

Chronic hunger and food deficits are important food security indicators. Since the 2008 and 2012 food price crises, it has become increasingly important to understand causes and consequences of price spikes and the behavior of international commodity markets that generate price volatility. Price and income swings affect the food security of poor and hungry people more than the steady trend in the prevalence of undernourishment suggests (FAO, ILO, and ICP 2015). The FAO uses the Domestic Food Price Level (Food Purchasing Power Parity divided by the General Purchasing Power Parity) as an important indicator to illustrate the relative price of food across countries or regions over time (FAO, ILO, and ICP 2015). The domestic food price level index is an indicator of the relative price of food in a country and the index is based on a comparison to the prices in the United States in 2011. The overall trend of increasing domestic food prices is shown in Figure 3.

Figure 3. Domestic Food Price Index by Region



Source: The World Bank 2015: FAO, ILO, ICP 2015

Growing economies, increasing population, and dependency on biofuels are factors expected to place increased pressure on the food supply chain and prices. According Fan et al. (2011), elements of the 2007–08 global food crisis are found in the immediate years following the 2008 crisis. Most notably, expanding biofuel production, rising oil prices, US dollar depreciation, export restrictions, and panic purchases affected price trends in the years following the crisis. The Farm Foundation identified five key issues that they believe are important elements to understanding price changes; these key issues are demand for biofuels, increased inelasticity of agricultural markets, poor weather and decreasing stocks, Chinese trade policies, and the macroeconomic issue of the power of the United States Dollar (USD) (Abbott, Hurt, and Tyner 2011). These are some of the many factors that influence agricultural markets and must be considered when addressing food insecurity. These obstacles are compounded by increasingly

scarce natural resources in some regions, increased weather shocks, as well as declining rates of yield growth for some commodities (FAO, IFAD and WFP 2015).

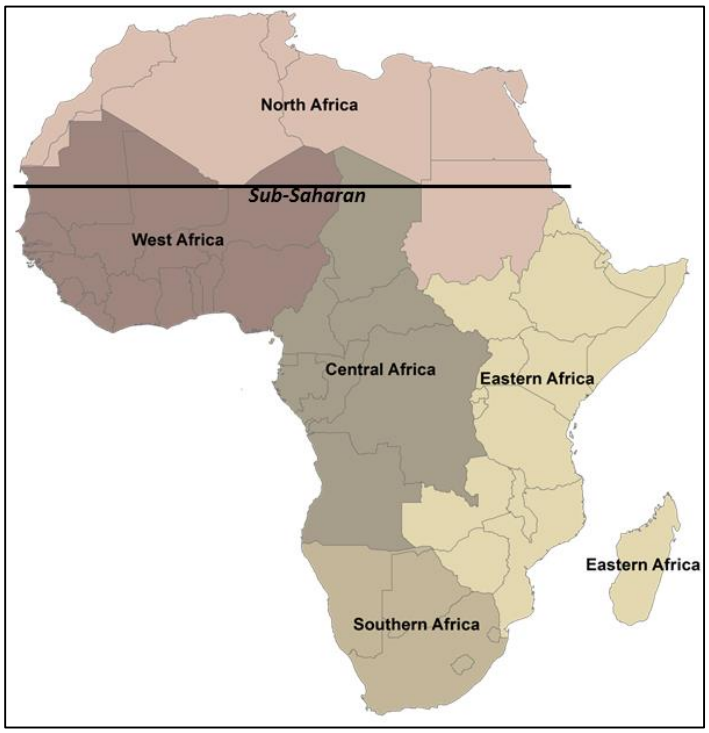
High prices benefit the farmers who have production surpluses but typically high prices are a result of production shortfalls and many farmers who experience the production losses are unable to benefit from the high prices. Benefits do not reach the poorest producers who have little surplus even in a good year (FAO, IFAD and WFP 2015). This, coupled with the fact that the lowest income producers usually buy more food than they sell, results in high food prices exacerbating poverty, food insecurity and malnutrition. However, high prices can also lead to long-term investment in agriculture, which will allow for a reduction in food insecurity in the long-run. In contrast, high food prices have caused an increase in social unrest according to Marc Bellemare (Bellemare 2014).

The achievement of many of the MDGs and the reduction in the number of those plagued by hunger has drastically improved the livelihoods of many, but the progress has been slow. Food insecurity is likely to persist until the underlying factors and causes can be identified and addressed. According to the FAO, the regions of most concern are sub-Saharan Africa, South Asia, and Latin America (FAO, IFAD and WFP 2015).

1.2 Food Insecurity in West Africa

Many data sets, including those composed by the FAO and the World Bank, use the regional identifiers of sub-Saharan, West Africa, South Africa, North Africa, and East Africa. Figure 4 illustrates the corresponding countries that fall within each classification according to the UN, with the line representing the geographical distinction of Sub-Saharan Africa.

Figure 4. African Geographical Region



Source: United Nations 2014

Table 1. United Nations Sub-Region Classification of African Nations

United Nations Classification of African Countries into Sub-Regions				
North Africa	**West Africa**	**Central Africa**	**Eastern Africa**	**Southern Africa**
Algeria	Benin	Angola	Burundi	Botswana
Egypt	Burkina Faso	Cameroon	Comoros	Lesotho
Libya	Cape Verde	Central African Republic	Djibouti	Namibia
Morocco	Ivory Coast	Chad	Eritrea	South Africa
Sudan	Gambia	D.R. of the Congo	Ethiopia	Swaziland
Tunisia	Ghana	Equatorial Guinea	Kenya	
Western Sahara	Guinea	Gabon	Madagascar	
	Guinea-Bissau	Republic of the Congo	Malawi	
	Liberia	São Tomé and Príncipe	Mauritius	
	Mali		Mayotte	
	Mauritania		Mozambique	
	Niger		Reunion	
	Nigeria		Rwanda	
	Saint Helena		Seychelles	
	Senegal		Somalia	
	Sierra Leone		South Sudan	
	Togo		Tanzania	
			Uganda	
			Zambia	
			Zimbabwe	

Source: United Nations 2014

Agriculture has been the main sector in Africa, in terms of labor, output, and export earnings for many years. In 2013, agriculture accounted for approximately 32 percent of the continent's Gross Domestic Product (GDP) (World Bank 2013). While agricultural output has increased at an annual rate of approximately 1.9 percent since 1960, it is trailing the continent’s annual population growth of 2.5 percent (Fuglie and Rada 2013, World Bank 2014). Without significant improvements in the food production and the supply chains of Africa, the food gap is expected to worsen.

Nearly one in four people are estimated to be undernourished in Africa, with the most startling statistics occurring within sub-Saharan Africa, as the region has the highest prevalence of undernourishment (FAO, IFAD and WFP 2015). Contextually, prevalence of undernourishment is defined as the percentage of the population whose food intake is insufficient to meet dietary energy requirements continuously (World Bank 2014). While sub-Saharan Africa has the highest prevalence of undernourishment, there has been some improvement over the last two decades, with the prevalence of undernourishment declining from 32.2 percent to 23.2 percent between 1990-1992 and 2014-2016 (FAO, IFAD and WFP 2015). Data collection by the FAO indicates that while there has been progress to reduce hunger in West Africa, it has not met the MDG 1 to reduce the number of undernourished by half by the year 2015 (FAO, IFAD and WFP 2015).

The Early Warning System (EWS), developed in 1974 at the World Food Conference, predicted that beginning in 2011 a serious food and nutrition crisis would occur in West Africa due to poor production, price volatility, and political distress (IPC Global Partners 2012). The EWS food crisis prediction was proven to be accurate, and actually was more extreme than predicted due to rebellions in Northern Mali and the rise of the Boko Haram terrorist group in northern Nigeria during 2012 (IPC Global Partners 2012).

While the EWS predicted when a food crisis would occur, it was unable to foresee where or who would be most affected. Looking back through the years building up to the 2011 crisis, the households within the Sahel (a narrow transitional band between the arid Sahara to the north and the humid savannas to the south) are subject to a structural food crisis that occurs nearly every year. These households are characterized by having low purchasing power, limited

production capacity, and a lack of assets and employment opportunities. While food might be available, they are unable to access it due to their impoverished economic position. These households' economic positions are pressured downward with increasing occurrence of shocks, both natural and political. They are unable to rebuild their personal stocks or savings before the next shock occurs. This creates a cyclical system where the poorest of the poor are unable to climb out of poverty and continue to live from one crisis to another.

In West Africa, many of the food crises are based on famines caused by major droughts, which are defined as an extended period of time characterized by a deficiency in a region's water supply that is the result of constantly below average precipitation (EM-DAT 2009). Drought obviously affects agricultural production and since it is a common occurrence in West Africa, it has become the main influence on grain production, which is one of the most important indicators of food crisis. Other factors, in addition to grain production, used to look at household vulnerability include prices, source of income, and access to markets (both financial of physical).

The International Food Policy Research Institute (IFPRI 2013) identified several aspects that they believe to have contributed the most to chronic food insecurity in West Africa:

- low grain production levels
- shortfalls in pasture production and water access for livestock
- high food prices
- political insecurity (return of migrants and terrorist movements)

In 2011, grain production in Sahel countries dropped 26 percent from 2010 which was categorized as a "good year" (World Bank 2013). While the region as a whole recorded a loss, the crises were focused in different areas with the shortfalls being located in Chad, Niger, and Mauritania and surpluses in Mali and Burkina Faso. While 2011 was a poor production year for West Africa, production is estimated to be up to 5 percent compared to the average over the past five years (World Bank 2013). While this is a positive development for food security, it was simultaneously accompanied by a reduction of food availability per person between 2 percent and 4 percent (World Bank 2013).

Agriculture and grain production affect food security through means of availability, but consumer price is quickly becoming a main factor in household food security levels as accessibility becomes more difficult due to rising prices. The 2005 food crisis in West Africa and the 2008 Global Food price hikes have drastically affected the countries and households of West Africa. In 2011, the coastal countries of West Africa, including Senegal, Mauritania, Gambia and Guinea, were subject to a price increase of 25 percent to 33 percent (Inter-reseaux 2012). The markets of these countries are closely tied to the rice and wheat world markets due to their agricultural ports. Inter-reseaux (2012) also reported prices rising up nearly 50% in Burkina Faso, Mali, Togo, Ivory Coast. Uncertainty about production levels, coupled with increased demand from the livestock feed industry in Ghana and the Malian crisis contributed to this drastic price increase. The price increase experienced by Niger, Chad, and Benin can be attributed to the political instability of Nigeria as well as production shocks (Inter-reseaux 2012).

The current food security situation in West Africa remains quite fragile despite the good harvest in 2013 and 2014. The recurrent trends of sporadic rainfall, insect infestations, high and

volatile food prices, and continued political instability have negatively affected food security within the region. The conflict in northern Mali, growing insecurity in northern Nigeria, and migration have only increased the pressure on the region (IFPRI et al 2013). While the countries of West Africa have been working together as a region to address food security issues, a solution has yet to be found.

1.3 Utilizing Regional Communities to Mitigate Food Insecurity

Reducing hunger and achieving food security have been the main challenges for West African governments. Public policies are aimed at assuring the presence of markets as well as the affordability of food within these markets. The 2008 international food crisis illustrated that the public policies in place were not sufficient as the most vulnerable populations clamored for aid. In an international economy, shaped by globalization and regional trade blocks, the issue of a regional approach to ensure food security and political stability is becoming increasingly important.

The 1980 Lagos Plan of Action for the Development of Africa and the 1991 treaty to establish the African Economic Community (also referred to as the Abuja Treaty), proposed the creation of Regional Economic Communities (RECs) as the basis for African integration (United Nations 2014). Currently, there are eight RECs recognized by the African Union (AU). They are:

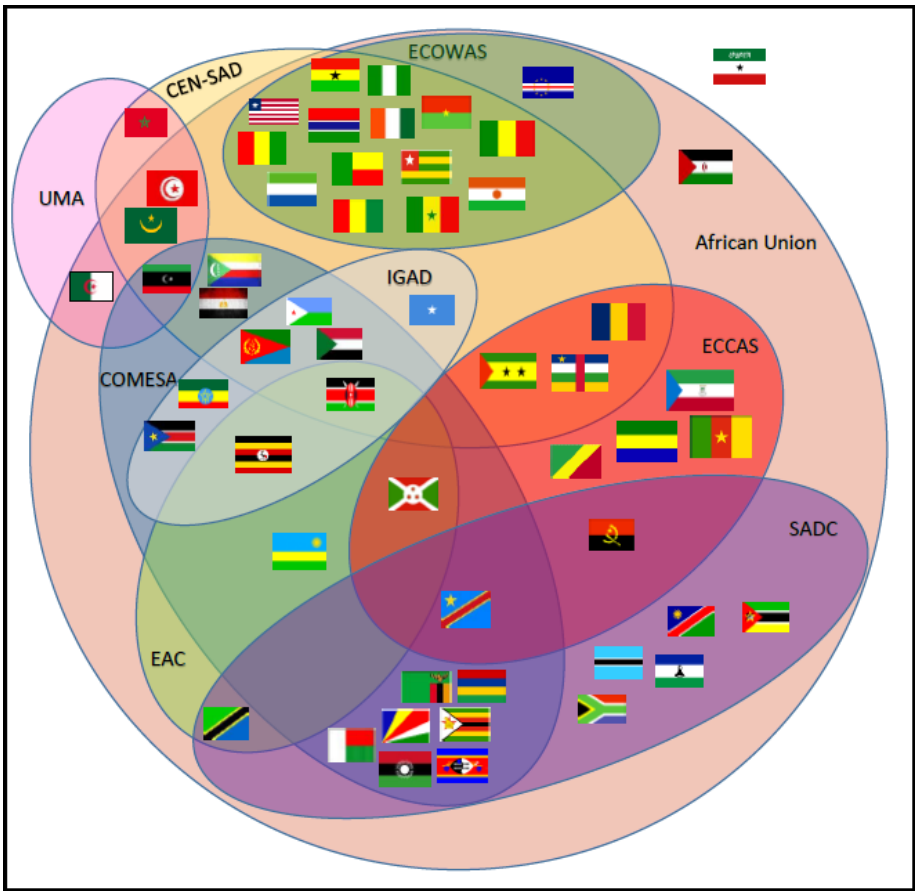
- Arab Maghreb Union (UMA)
- Common Market for Eastern and Southern Africa (COMESA)

- Community of Sahel-Saharan States (CEN-SAD)
- East African Community (EAC)
- Economic Community of Central African States (ECCAS)
- Economic Community of West African States (ECOWAS)
- Intergovernmental Authority on Development (IGAD)
- Southern Africa Development Community (SADC)

The membership of many of the communities overlap, and their rationalization has been under discussion for several years, and was consequently the theme of the 2006 Banjul summit (United Nations 2014). At the July 2007 Accra summit, the Assembly finally decided to adopt a Protocol on Relations between the African Union and the Regional Economic Communities (United Nations 2014). This protocol intended to facilitate the harmonization of policies and ensures compliance with the Abuja Treaty and Lagos Plan of Action.

While there are many different regional and economic agreements between the countries of Africa, as seen in Figure 5, the focus of this research will be on the countries of West Africa. In West Africa, the Economic Community of West African States (ECOWAS) represents a regional economic and political organization where strategies for regulating markets, ensuring self-sufficiency and promoting regional trade are discussed and voted on.

Figure 5. Regional and Economic Integration of African Governments



Source: Image developed by author with data from United Nations 2014

Former Liberian President William Tubman is credited with developing the idea of creating a West African economic community (MSU 2014). Tubman's original idea led to the signing of an agreement between Cote d'Ivoire, Guinea, Liberia, and Sierra Leone in February 1965 (MSU 2014). By 1975, a draft of a new treaty was proposed to other potential states including Togo, Ghana, and Liberia (ECOWAS 2013). On May 28, 1975, fifteen West African countries met in Lagos, Nigeria, to sign the ECOWAS Treaty, also known as the Treaty of Lagos (ECOWAS 2013). These fifteen countries were Benin, Burkina Faso, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal,

Sierra Leone, and Togo (ECOWAS 2013). The ECOWAS Treaty was intended to promote cooperation and integration within West Africa and to eventually establish an economic and monetary union (ECOWAS 2013). Cape Verde became the sixteenth member of ECOWAS in 1977 (ECOWAS 2013).

In 1993, a Summit was held where the treaty was revised to accelerate the integration of economic policy and improving political cooperation (ECOWAS 2013). To achieve the goal of improving political cooperation, the revised treaty established a West African Parliament, an Economic and Social Council, and an ECOWAS Court of Justice (ECOWAS 2013). The revised treaty designated the responsibility of preventing and settling regional conflicts to the member states (ECOWAS 2013). Mauritania withdrew from ECOWAS in 2000 because of conflicting opinions on some of the decisions that were made during this revision process (MSU 2014).

On June 23, 2000, ECOWAS, as a member of the ACP Countries (Africa, Caribean, and Pacific), signed a treaty with the EU in Cotonou, Benin (MSU 2014). This treaty, which is known as the Cotonou Agreement, was a replacement for the Lomé Convention, which was a trade and aid agreement between the European Community and ACP states before the establishment of ECOWAS (MSU 2014). The original version of the agreement allowed the EU to trade with the ACP Countries on a non-reciprocal basis, meaning that the ACP Countries would have tax-free access to EU markets but the EU would have to pay taxes to enter the markets of the ACP Countries (MSU 2014). The EU and ACP Countries implemented the concept of non-reciprocity for the benefit of the developing African countries, but its existence was against the policies of the World Trade Agreement. Therefore, in 2005, with the

introduction of the revised Cotonou Agreement, a provision was added to transform from non-reciprocity to an Economic Partnership Agreement in 2008 (MSU 2014).

ECOWAS and the Economic and Monetary Union of West Africa (UEMOA) signed a Cooperation Agreement for Regional Integration in 2004, at the ECOWAS Secretariat in Abuja, Nigeria. This agreement intended to enhance the coordination and harmonization of ECOWAS and UEMOA programs and to address areas of common interest. While the signing was an attempt to harmonize and to ease the channels to which governments can address issues, one can see the overlapping and confusing partnerships illustrated in Figure 5 are not necessarily in line with the overall goal of achieving stability.

1.4 Methods and Strategies to Address Food Insecurity

There are many ways for governments to address food security and the best method to use is of great discussion within the academic world. Some governments focus on developing and reforming institutions involved in research and development, extension services, or education (IFPRI 2013). Expanding and improving resource endowment is also a method to addressing food security. Other methods include financial credits, insurance schemes, input subsidies and infrastructure support. Multilateral trade and bilateral agreements can also be considered investment policies and are often used to increase food security (IFPRI 2013).

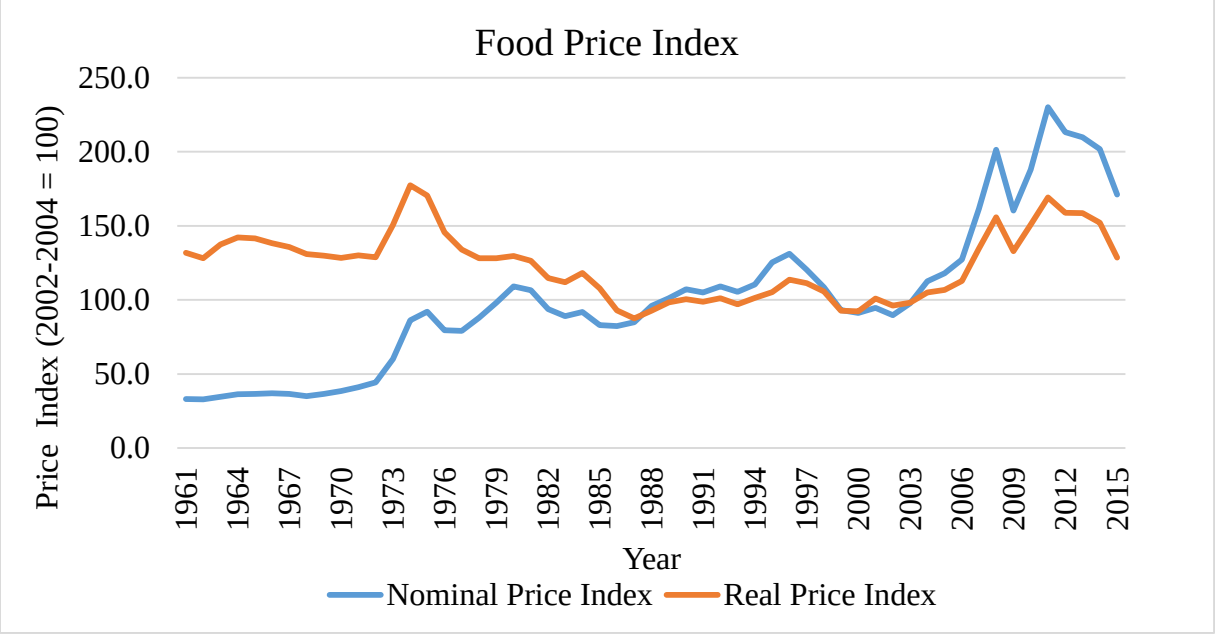
Social policies are also utilized to address food security and often take the form of food price guarantees and food aid. Direct and indirect provision of public food supplies through public stocks, food distribution schemes, and vouchers are often used. The most commonly

utilized methods are trade instruments. These instruments include tariffs, safeguards, quotas, price risk insurance, commodity exchanges, export restrictions, and trade and export promotion.

1.5 Utilizing Food Reserves and Stocks to Address Food Insecurity

After the food price crisis of 2007–2008, food prices started to rise again in June 2010, with international prices of corn and wheat roughly doubling by May 2011. The peak came in February 2011, in a spike that was even more pronounced than that of 2008, according to the food price index of the Food and Agriculture Organization of the United Nations (when adjusted for inflation 2008 price levels are higher) (VV.AA. 2011). These price fluctuations are illustrated in Figure 6.

Figure 6. International Price Index 1961-2015



Source: FAO 2015

In response to high and volatile prices in 2011, the FAO and the World Bank have encouraged countries to establish large food reserves and better-managed grain stocks (VV.AA. 2011). Proposals have been put forth for physical reserves, including emergency reserves, 15 international coordinated grain reserves, 16 regional reserves, and country-level reserves (VV.AA. 2011).

There are two main strategies of food reserve polices; one strategy aims to provide a minimum level of food (consumption) for all consumers while the other strategy aims to reduce price volatility (Wright 2009). Both have the overall effect of keeping food stuffs available for consumers, however there is debate as to which is most effective for addressing food security. In the most basic form, food reserves help to reduce price volatility by accumulating stocks when price is low to prevent steep price slumps and disposing of these stocks when prices are high to smooth price spikes, but only so long as stocks are available (Wright 2009). While stocks can aid in buffering price shocks, they are unable to eliminate all effects of a supply shock on the market.

As stocks decrease, consumers are forced to make decisions regarding their use of the remaining grain stocks. Typically as stocks dwindle, less grain goes to feed animals or produce biofuels, and/or the poorest consumers must reduce their calorie consumption (Wright 2009). In an area with an already low caloric consumption, reducing intake usually leads to hunger or even starvation. However, the demand for stored grains of wealthier consumers is much less responsive to price fluctuations and therefore is more likely to be able to withstand any given shock (Wright 2009).

For countries with a high number of poor and exposure to production shocks, storage policies aimed at ensuring a minimum level of consumption is usually the chosen course of action to address food insecurity. While ideally, a large international grain reserve controlled jointly by national governments would provide the most economical and stable structure to mitigate global food crises, it is unreasonable and unlikely to occur due to the complexity and differing opinions on reserve management (Wright 2009).

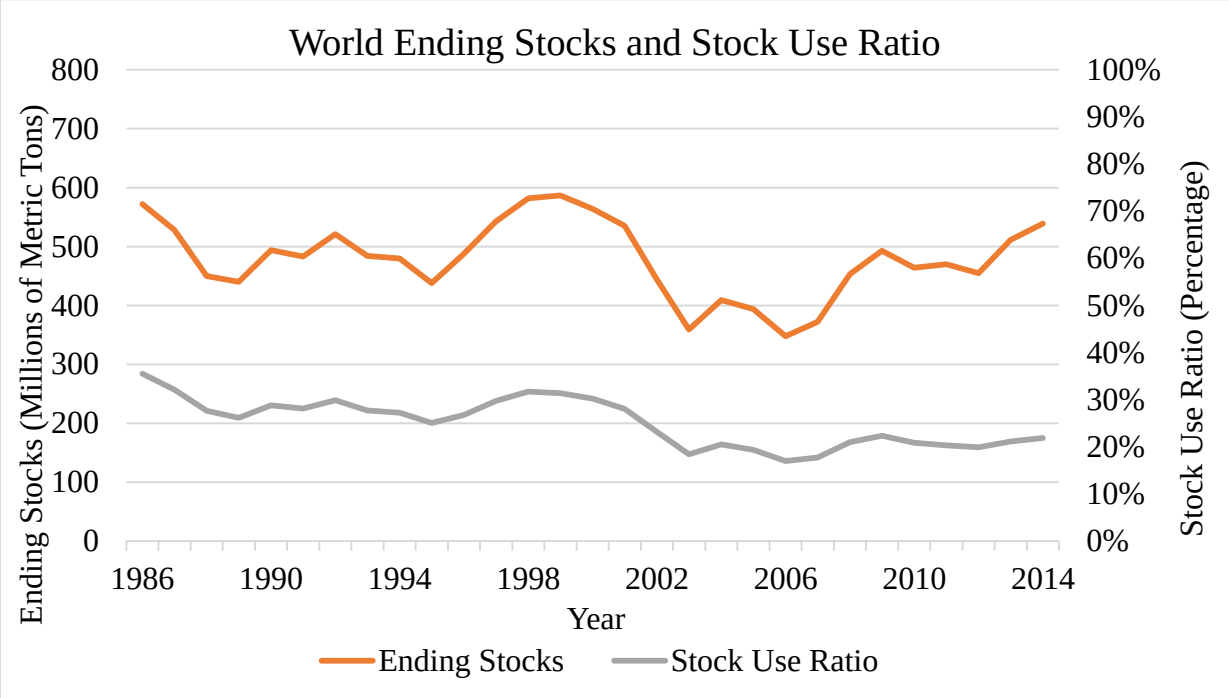
Therefore it is important for the governments of vulnerable populations to consider a national (or regional) strategic reserve as part of their plan to address food security. These governments must determine the optimal size of the reserve; a careful balance between the value of keeping reserves and the cost to store such volumes of grain.

Food reserve policies aimed to limit price volatility are considered less effective in ensuring food security for the vulnerable than focusing on their consumption (Wright 2009). These policies set a "price band" where there is an upper and lower value to which the price of a given commodity may fluctuate (Wright 2009). While this method allows market transparency, there is very little private storage as prices rise towards the ceiling and suppresses the production response to anticipated shortages. This suggests that a food reserve policy aimed at managing price volatility through the use of a price band is not effective for those in the most vulnerable regions (Wright 2009).

The world's stocks of cereals were at historically low levels during 2008 crisis ((FAO, IFAD and WFP 2015). This caused the world market to be more vulnerable to food price spikes and threatened the proper functioning of markets. The world's ending cereals stocks were similarly very low when prices spiked in 1995–1996, 2007–2008, and 2010–2011 (Figure 7).

This indicates that for the market to function effectively, the food system must hold a minimum level of grain stocks to be able to respond to unexpected shocks (such as bad weather) and allow for the transport, marketing, and processing of grains (IFPRI 2011). With such low levels of stocks, using even a small amount of the stocks can lead to longer term problems. In 2007–2008 grain stocks were approximately 60 million tons less than in 2004–2005, representing a decline of 2.7 percent of global production (IFPRI 2011). But when prices rose sharply in 2007–2008, this difference in grain stocks was enough to partially contribute to serious price increases, especially for commodities whose production is concentrated in just a few countries, such as rice (IFPRI 2011). Figure 7 also shows the stock use ratio (ending stocks: domestic consumption) as a percentage.

Figure 7. World Ending Stock 1960-2013



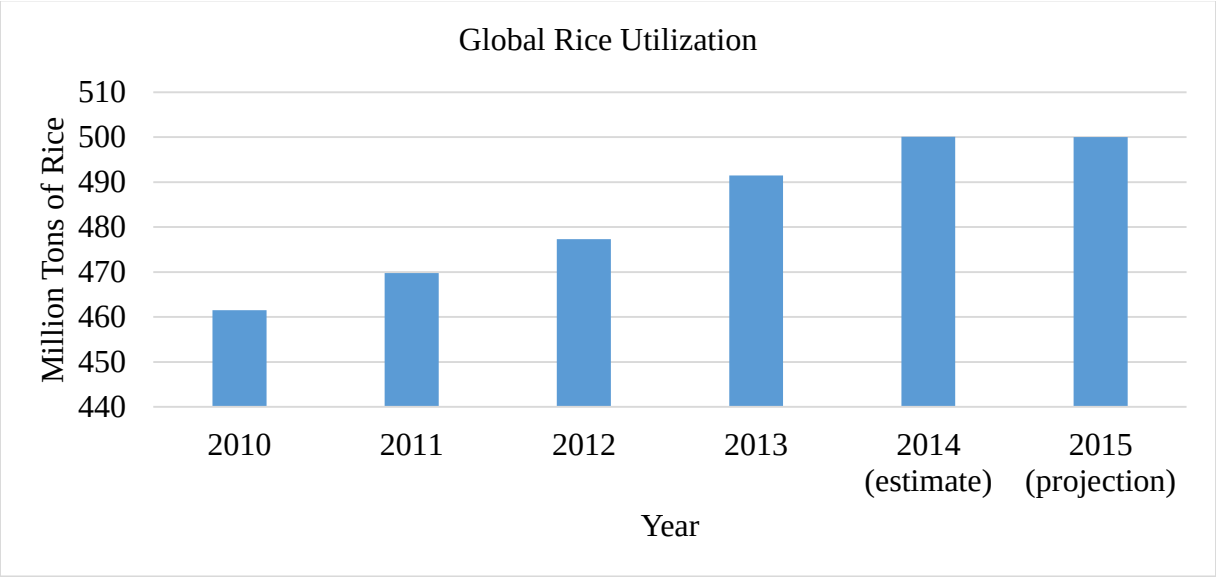
Source: USDA-FAS 2015

While there is a correlation between stock levels and the volatility of prices, reserves can be costly to maintain. However, larger food reserves provide supplies in times of crisis and more importantly, in vulnerable countries, reserves build confidence that trade remains the most efficient mechanism for stabilizing domestic food economies. Once the decision has been made to utilize food reserves to mitigate the impact of production shocks, three main questions must be considered: How large should the reserve be, who will manage the reserve, and where should it be located?

1.6 Rice Production (Supply) and Consumption (Demand) in Africa

Rice is a staple food in many countries of Africa and constitutes a major part of the diet around the world. During the past five years, the crop has seen consistent increases in demand (Figure 8). Rice is playing an important role in the strategic food security policies of many countries, especially in West Africa. In Africa, arable land accounted for 20.3 percent in 2014 (FAOSTAT 2014). Within Africa, West Africa has 29.7 percent arable land, followed by East Africa with 24.6 percent, Central Africa with 19.4 percent, and Southern Africa with the least amount of arable land at 10.5 percent (FAOSTAT 2014). In 2011, the lands under permanent crops represented 2.6 percent of agricultural land in all of Africa, with West Africa having the highest percentage of lands under permanent crops (4.3 percent), while North Africa was 2.8 percent, Central Africa 2.4 percent, East Africa 3.7 percent and Southern Africa with only 0.5 percent (FAOSTAT 2014).

Figure 8. Global Rice Utilization



Source: FAOSTAT 2015

As shown in Oteng and Sant'Anna (1999), rice is produced in Africa in the following five main ecosystems: dryland (rain-fed upland), hydromorphic (rain-fed lowland), mangrove swamp, inland swamp, and irrigated ecology. Dryland (rain-fed uplands) is the most extensive rice ecosystem in Africa, so it has a great influence on the total rice output (FAOSTAT 2014). It occurs in the uppermost part of the topo-sequence and is more important in West Africa than in other African regions. The major producers utilizing this method in West Africa include the following countries: Sierra Leone, Côte d'Ivoire, Liberia, Guinea-Bissau and Nigeria (FAOSTAT 2014). The only source of water is rain, so the crop is highly vulnerable to drought as a result of erratic and poor rains. It is essentially a low-input ecosystem, which results in poor paddy yields.

Lowland (hydromorphic) ecology occurs from the mid-slope to the valley bottom in the topo-sequence. The rice crop here may obtain water from three sources - direct rainfall, high water table and surface water - depending on its location in the topo-sequence. The main

hydraulic characteristic of this ecosystem is the fluctuating water table, caused by cyclical swelling and receding water levels of rivers during the rains. Iron toxicity has been observed in many West African countries, including Benin, Burkina Faso, Côte d'Ivoire, Liberia, Nigeria, Senegal and Sierra Leone; they have experienced loss due to this iron toxicity (FAOSTAT 2014). A major physical constraint in this ecosystem involves uncontrolled floodwaters that sometimes inundate the crop or produce flash floods, which may carry away the harvest.

Mangrove swamps occur mainly along the West African coast and cover a total area of 1.2 million hectares, with approximately only 20% developed for cultivation (FAOSTAT 2014). The mangrove swamps have high salinity levels caused by seawater intrusion brought in by tidal waves from the sea, although nearly all mangrove swamps enjoy a salt-free period during the rainy season as freshwater floods wash the land. This period shortens, from over six months to under four, with increasing proximity to the sea, but is generally long enough to allow a crop of rice to grow. Approximately 80 percent of the potential area is uncultivated, but its development is likely to be very slow due to the high cost of development, inadequate tools for development, long distances between the swamps and villages making access difficult, shortage of labor and its attendant high cost, the control of mangrove clearing for ecological reasons (FAOSTAT 2014). The productivity of this ecosystem is very low, but improved technology and increased applications of inputs could increase yields.

The irrigated ecosystem provides the best conditions for rice cultivation because of the increased control of water compared with other ecologies. However, the utilization of irrigated ecosystems in rice production in West Africa is relatively small when compared to the other systems. An increased use of irrigated production methods would allow for an increased supply

due to the increased yields of rice produced in this environment. A breakdown of each ECOWAS country's rice ecology methods including average yield and percentage of total production per ecology is shown in Table 2.

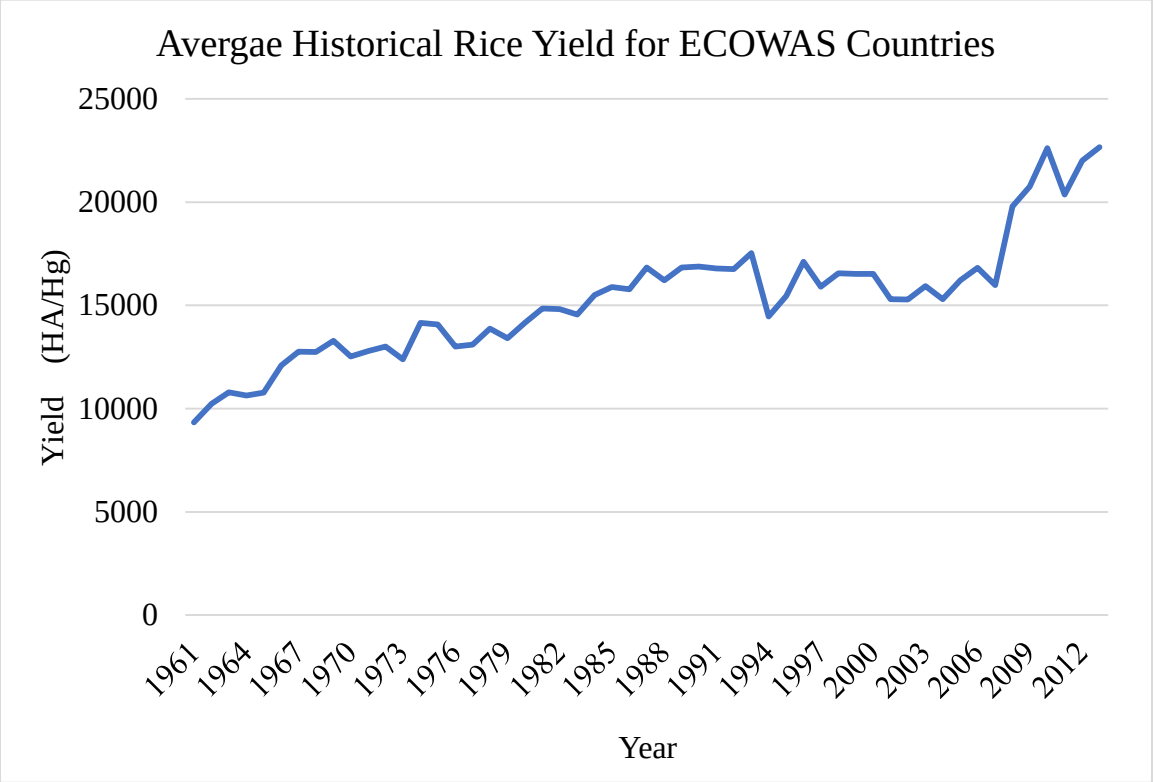
Table 2. Ecology Production and Yield Averages for ECOWAS Countries

	Rainfed		Lowland		Irrigated	
Country	**Yield (t/ha)**	**% Production**	**Yield (t/ha)**	**% Production**	**Yield (t/ha)**	**% Production**
Benin	2.5	30%	4.5	55%	5.5	15%
Burkina Faso	1	5%	1.3-2.5	42%	4.0-7.0	53%
Ivory Coast	0.8	73%	2.5	6%	3.5	21%
Ghana	2.2	15%	3	67%	5	18%
Guinea	1.1	43%	2	19%		
Liberia	1.5	75%	2.5	18%	3.5	7%
Nigeria	1.62	28.30%	1.99	69%	3.5	2.70%
Senegal		30%			6	70%
Sierra Leone	0.96	55%	1.23	45%		
Togo	1.42	10%	2.94	60%	3.11	30%
No data for Niger, Guinea-Bissau, Mali or Gambia *Guinea reports 30% in Mangrove with a yield of 2.5						

Source: Coalition for African Rice Development 2013

Average yield drastically differs from one ecosystem to another. The developing countries of West Africa are continuously increasing their yields through different means such as utilization of fertilizers and pesticides as well as increasing the usage of irrigation. The historical increase in yields for the ECOWAS region is illustrated in Figure 9.

Figure 9. Average Historical Yield - ECOWAS Region

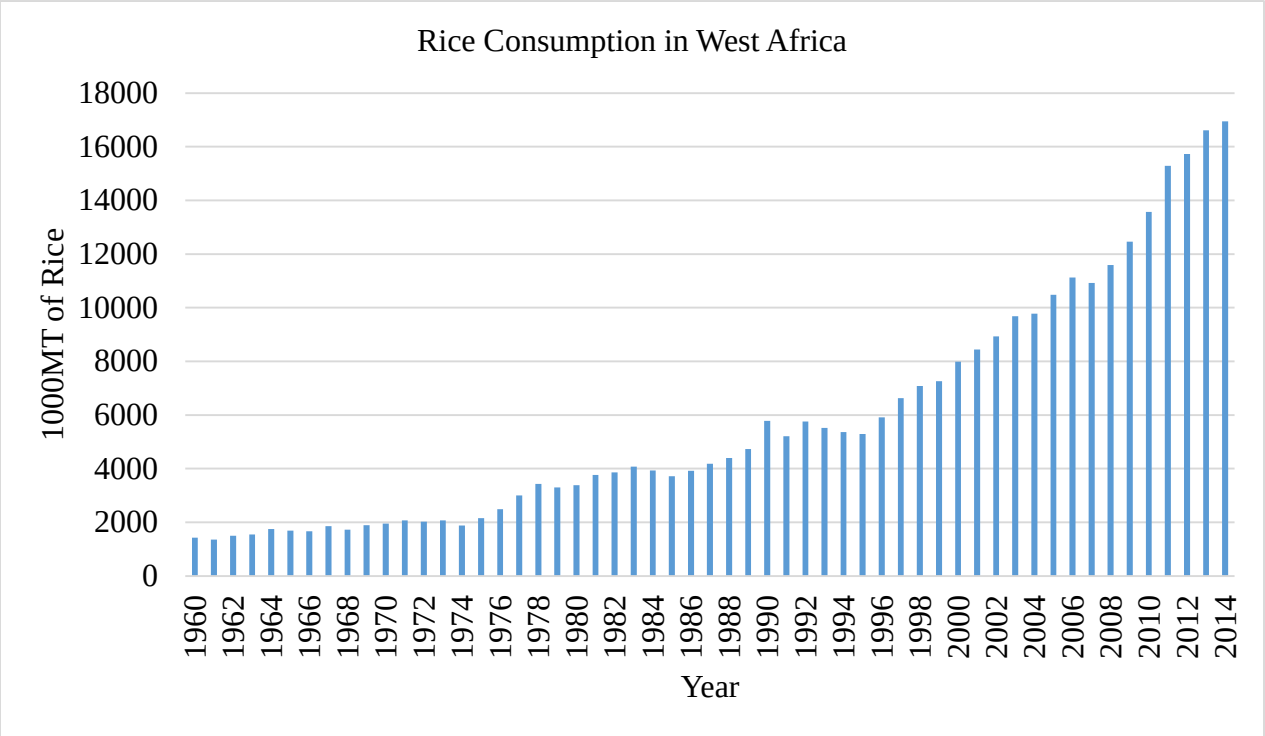


Source: FAOSTAT 2013

While production of rice in West Africa has not reached its full potential, there are positive signs for continued rice development including the fact that there are vast areas of land that are suitable for rice cultivation but are currently underutilized. In addition, there are large bodies of water that could be utilized for rice irrigation, the climate is generally suitable for the cultivation of rice, and a vast potential to cultivate rice for local consumption and export if large investments are made to develop the industry, reduce imports and save scarce foreign exchange.

With the exception of a few countries, rice demand exceeds production and large quantities of rice are imported to meet the demand. Africa consumed a total of 16945 (1000 MT) in 2014, 8945 (1000MT) of which was imported (USDA-FAS 2014). Figure 10 shows the increasing consumption of rice in West Africa.

Figure 10. Rice Consumption in West Africa



Source: USDA Foreign Agricultural Service, Official USDA Estimates

It is also important to consider how much of individual countries' diet is reliant on rice consumption. The food balance sheets from FAO provided the percent of daily caloric intake that is from rice (Table 3).

Table 3. Dietary Intake and Rice Dependency

	(kg/capita/year)	kcal from rice/capita/day	total diet kcal/capita/day	Percent of Daily caloric intake from Rice
Benin	53.2	532	2594	21%
Burkina Faso	20.5	202	2655	8%
Ivory Coast	61.0	553	2781	20%
Gambia	67.9	664	2849	23%
Ghana	34.2	323	3003	11%
Guinea	96.3	977	2553	38%
Guinea Bissau	91.5	916	2304	40%
Liberia	90.5	910	2251	40%
Mali	57.6	571	2833	20%
Niger	10.3	98	2564	4%
Nigeria	30.1	305	2724	11%
Senegal	70.3	695	2426	29%
Sierra Leone	98.1	909	2333	39%
Togo	23.6	235	2366	10%

Source: FAO Food Balance Sheets 2014

Rice is the most important agro-food import, representing around 45% of the supply for the region in 2013 (USDA PS&D). Thailand, and, increasingly, Vietnam, are the region's main rice suppliers. The main importing countries are Benin, Nigeria, Senegal, and Côte d'Ivoire. In 2013, West Africa imported approximately 16971(1000MT) of rice. The impact on the dependency on rice imports is further influenced by countries' import tariffs. Individual country governments implement taxes on rice imports to generate revenue for the country as well as to encourage domestic production. But this also leads to higher prices for consumers. However, due to slow progress in domestic production and the international price increases in 2008, the ECOWAS region recognized the need to address their import tariffs. In October of 2013, the ECOWAS region decided to establish a regional tariff policy (ICTSD 2013). This policy began in January 2015 with a five year implementation window for conformity. Within this period,

member-states are allowed to maintain certain exemptions currently in place but at the end of the conformity window the region will have Common External Tariffs (CET). The ECOWAS CET has 5 tariff bands — 0%, 5%, 10%, 20%, and 35% — for all countries in the sub-region and is based on the 2012 Harmonised Coding System[2] of all member-states (ICTSD 2013).

Africa has great potential for expanding its agricultural production in general and rice in particular. Rice production is most extensive in rain-fed (upland) ecosystems and competes with several other important staple crops, such as maize, sorghum, millet, cassava, yam, coco-yam, plantain and banana, as well as the cash crops of coffee, cocoa, citrus and cola. However, as these crops increase in economic importance, the rice area will diminish because rice is the lowest-yielding crop in that ecology. The wetlands, including irrigated ecologies, will therefore become increasingly important as these ecologies are more suitable for rice production than they are for other upland crops. Increasing rice production is a basic approach to increasing supply that can greatly impact food security. Historically, increasing production has been lagging behind the population growth in Africa, however recent improvements in production have helped increase supply. Paddy rice production has increased from an annual average of 3.2% before the rice price crisis of 2008, to an average of 8.4% (USDA PS&D 2014). While this improvement is significant, the impact has been minimal due to the increased consumption of rice in the region, therefore other methods must be utilized to negate food insecurity.

[2] The 0% tariff category covers essential social commodities such as pharmaceutical products, fertilizers and condoms. The 5% tariff category covers basic raw materials, capital goods and specific inputs such as agro chemicals, machinery and equipment. The 10% tariff category captures intermediate products such as tomato paste concentrate; 20% final consumer goods, such as apparel and clothing accessories, electric domestic appliances. The 35% tariff category covers specific goods that contribute to the promotion of the region's economic development (ICTSD 2013).

This study will attempt to determine the appropriate size of the regional reserve for ECOWAS countries to improve the food security of the region. Location and management decisions are best left to the experts from within the region and therefore are not addressed. This study will utilize historical paddy rice yield data to simulate production shocks that are common in West Africa. These simulated shocks will then be used in a spatial partial equilibrium model to illustrate the impact such a shock will have on consumption and prices. The spatial partial equilibrium model will be run dynamically, over a time period of 10 years, in an effort to more realistically reflect the dynamic effects of production shocks of West Africa. Analysis of such a study will provide insight as to an appropriate level of stocks for the Regional Food Reserve of West Africa in order to mitigate the impact of price increases due to a production shock and therefore improving the regions' food security.

The remainder of this study is organized as follows. Chapter 2 provides a review of the relevant literature and previous studies on regional reserves, Chapter 3 discusses the methods of this study and sources utilized, and Chapter 4 discusses the results and offers reflection on the study with possible improvements.

Chapter 2: Current Research and Models Used to Study Regional Food Stocks

Utilizing regional food stocks for food security is not a new concept, but it is an increasingly popular approach being utilized in multiple areas of the world. Regional government food stocks most notably have been utilized in Asia, where food insecurity affects the highest number of people, as well as in the Middle East and North Africa.

2.1 Regional Food Stocks in Asia

The Association of Southeast Asian Nations[3] (ASEAN) established in August 1967 utilizes regional organizations and governance to accelerate economic growth, social progress, and cultural development throughout the region (Chandra and Lontoh 2010). The ASEAN agreement has many goals, one of which is "to collaborate more effectively for the utilization of their agriculture and industries, the expansion of trade, . . . and the raising of the living standards of their peoples." (ASEAN 2014a).

In response to the multiple natural disasters and other emergency situations, the ASEAN countries decided it was important to improve cooperation with three additional Asian countries, including People's Republic of China, the Republic of Korea, and Japan (ASEAN 2014a). In 1997, the agreement became known as the ASEAN +3 (ASEAN 2014b). It is within the ASEAN +3 that the development of a regional food reserve was initiated.

[3] The present membership of ASEAN includes Indonesia, Malaysia, Philippines, Singapore, Thailand, Brunei Darussalam, Vietnam, Lao People's Democratic Republic, Myanmar, and Cambodia (ASEAN 2014)

With rice being the prominent food stuff consumed in Asia, the ASEAN +3 Emergency Rice Reserve (APTERR) was created to meet food relief requirements resulting from natural disasters and other emergency situations, most notably in 2004/2005 and 2008 (Briones et al 2012). APTERR was established in 2011 and was activated in 2012 (Briones et al 2012). The rice reserves consist of 787,000 tons of rice (earmarked for specific countries) to meet needs in times of food emergencies. Additional donations outside of those designated for specific countries are not tabulated, but are available to be used as humanitarian response to acute emergencies (Briones et al 2012).

The earmarked stocks are typically part of a country's existing national food security reserve (Briones et al 2012). The earmarking country maintains control over these stocks but bears responsibility for storage. Earmarking places these stocks at the disposal of APTERR as a collective scheme and they are delivered under two different conditions, a pre-arranged delivery or an ad hoc emergency (Briones et al 2012). A pre-arranged delivery requires an agreement between the supplying country and the recipient country. The agreement must address the specific quantity and quality of the rice from the earmarked supply to be delivered within 30 days (Briones et al 2012). An emergency situation requires a call letter from the recipient and approval by the APTERR Secretariat and the APTERR Council (Briones et al 2012).

A study supported by the Asian Development Bank (Briones et al 2012) attempts to determine if the APTERR of 787,000 tons is enough to withstand natural calamity, specifically due to climate change. The study utilized the RICEFLOW model, a numerical simulation tool designed for projecting outcomes to market shocks on an annual basis (Briones et al 2012). The study defined a “massive calamity” as a 5% production shock for China and Indonesia (Briones

et al 2012). This translates to a harvest loss of 10 million tons for China and 3 million tons for Indonesia (Briones et al 2012). The model was allowed to respond to this shock through price interactions and trade (Briones et al 2012). This “massive calamity” scenario simulation projects that consumption would decrease by about 3%, coupled with an increase of 30-55% in consumer prices (Briones et al 2012).

To assess the effectiveness of APTERR as a response to this shock, econometric analysis of the impact of monthly trade flows on domestic prices was conducted for the large rice producing and consuming and low to middle income countries in the region: China, Indonesia, the Philippines, Thailand, and Vietnam (Briones et al 2012). The estimated average response was then compared to reserves available from APTERR (787,000 tons and respective earmarks). The study concluded that the estimated impact on domestic prices on a one month basis ranges from 7% to 11% (Briones et al 2012). This contributes to a significant easing of price impacts, but only short term (Briones et al 2012). Quick releases are able to soften the worst spikes in domestic price in the short term but the regional reserves are too small to significantly offset domestic market movements on an annual basis (Briones et al 2012). In summary, the study determined that in order to be effective, the size of the reserve must be increased and the ASEAN countries need to increase their earmarked allowance (Briones et al 2012).

A study by Ranjitsinh Mane also determined that APTERR reserves were most effective in short term and were often limited in their ability to reduce volatile prices in the long term. The stochastic results of Mane’s study show that there is a decrease in the retail price of long grain white rice by 3.11 percent for a 100 percent release of APTERR stocks in the Philippines following a 2 percent production shock (Mane 2014). The deterministic results indicated that

reserves are not adequate to address price volatility at production shortfalls above 4 percent (Mane 2014). The results from the empirical analysis state that APTERR is ideal to address short term emergency situations but is not adequate for addressing extreme price volatility (Mane 2014).

2.2 Food Stocks in the Middle East, North Africa, and East Africa

Wright and Cafiero (2011) studied food insecurity in the countries of the Middle East and North Africa (MENA)[4]. The authors sought to determine how storage could impact international trade and other domestic policies in working toward an acceptable level of food security. Two generalizations were made of MENA countries that affect the utilization of food reserves: 1) extraordinary dependence on grain imports for food supply and 2) continued heavy subsidization of these grains (Wright and Cafiero 2011).

It was concluded that regional reserves might be beneficial to the region by looking at wheat supplies in all of the countries in the region (Wright and Cafiero 2011). For these MENA countries, sharing the supplies would help smooth the impacts of shortages. Imports are still needed, but the overall impact of food insecurity is dampened with regional food reserves (Wright and Cafiero 2011). This sharing can take place in open trade but food security is a recurrent issue within the region as some governments are unable to keep promises not to ban exports (World Bank 2009).

[4] The countries included within MENA are Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Ethiopia, Sudan, Syria, Tunisia, United Arab Emirates, and Yemen (Wright and Cafiero 2011).

A successful example of food reserves in eastern Africa is that of Ethiopia. Ethiopia's Emergency Food Security Reserve Administration (EFSRA) evolved from the study the FAO conducted at request of the Ethiopian government after a large drought in the early 1970s that resulted in the death of nearly 200,000 people (FAO 2004). The study determined that one of the ways the Ethiopian government could address vulnerability to a production shock was to implement a regional food reserve to supplement their already established local reserves (FAO 2004). The country's reserve was established in the early 1980s and has continued to develop and grow to the present day (FAO 2004). The stock was most recently utilized during the 2008 world food crisis and depleted from 200,000 tons to only 7,600 tons (Rashid and Lemma 2011). This illustrates the importance and necessity of food reserves in these vulnerable areas.

In 1987, the World Food Program completed a study of Ethiopia's food reserve and determined that the EFSRA needed to increase stock levels to 204,600 tons, a number determined by calculating the amount of grain needed for 95% of the food insecure population[5] to be supported for four months with 400 grams per day (FAO 2004). The four month allowance is what is considered the length of time required for international support or monetary support to reach the needy areas. IFPRI conducted another study in 2003 using the same calculation as the WFP to determine size and suggested an increase in the size of the reserve to 407,000 tons due to an increase in the number of food insecure people (Rashid and Lemma 2011).

[5] EFSRA defines the 'food insecure population' as those that fall within the Disaster Risk Management and Food Security Sector (DRMFSS) category of food insecure. DRMFSS was established in 2008. DRMFSS utilizes detailed indicators developed to capture information on all risk components as well as all possible data from secondary sources and primary information is collected from qualitative and quantitative questionnaires at the household level.

The most recent study by IFPRI looked closer at some of the aspects of the EFSRA in order to determine what made it so successful. One of the important aspects of a food reserve that affects the costs of maintaining a food reserve is storage and waste. In Ethiopia, there are seven locations within EFSRA and each of these warehouses has a different storage capacity, but it is the "age" or storage time that influences the efficiency of the reserve (Rashid and Lemma 2011). Unlike the reserves in Kenya and Bangladesh, where a large percentage of the reserves are older than nine months, in Ethiopia over 62% of the reserves are less than 3 months old (Rashid and Lemma 2011). This suggests a high turnover of reserves and reduces the amount of grain wasted due to spoilage or loss.

According to IFPRI, the success of the Ethiopian food reserve is due to organizational structure and management of EFSRA, which reflects a high level of government commitment and clearly defined rules of procurement and distribution. Secondly, unlike similar programs in many other countries, EFSRA does not engage in buying and selling of cereals but only serves as an intermediary focused on lending grain to government and nongovernmental agencies following the well-defined guidelines. The EFSRA serves as the facilitator between those in need and the donors to the reserve, which include the Canadian International Development Agency, USAID, European Union, WFP, and the Catholic Relief Services. Finally, EFSRA has been successful because it has maintained a relatively small stock with very little impact on the market prices (Rashid and Lemma 2011).

2.3 Development of a West African Food Reserve

After many years of price volatility and food insecurity in West Africa, it was after the 2005 food crisis that the ECOWAS Government decided to pursue the development of a Regional Food Reserve (ECOWAS 2011). The G20[6] and World Food Program encouraged ECOWAS to work closely with West African Economic and Monetary Union (WAEMU) and the Inter-State Committee for Drought Control in the Sahel (CILSS) to develop a network of public bodies to be responsible for managing national food security stocks in the Sahel and West Africa, to become known as RESOGEST. The RESOGEST Constitution was adopted in December of 2010 (ECOWAS 2011).

A collective discussion was initiated between many different organizations and governmental institutions to share information and ideas as to the appropriate development of a food reserve. Two separate studies commenced in 2011, one conducted by the WFP and another completed by Rural Hub[7] at the request of the ECOWAS Commission as a part of the RESOGEST (ECOWAS 2011). There are many similarities between the two studies as many of the consultants served on both the WFP's and the Rural Hub's expert panel. Additionally, a pilot program titled Pre-positioning for Predictable Access and Resilience (PREPARE) program was

[6] The G20 is an informal group of 19 countries and the European Union, with representatives of the International Monetary Fund and the World Bank. The members of the G20 are Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States and the European Union.

[7] The Hub's goal is to assist West and Central African stakeholders (States, Inter-governmental Organizations, Civil Society Organizations and Development Partners) to promote coherence in rural development programs worldwide. The Hub provides advisory support, expertise information and promotes consultations on issues concerning rural development and food security. (Rural Hub 2015).

developed after the establishment of RESOGEST and utilizes some aspects of the study in the development of its pilot program.

2.3.1 RESOGEST:

As part of the Regional Agricultural Investment Program (RAIP) adopted in 2010 at the end of a participatory and inclusive process for the implementation of ECOWAP and comprehensive Africa Agriculture Development Program (CAADP), the Member States of ECOWAS paved the way for the establishment of regional instruments designed to regulate agricultural markets (ECOWAS 2012). The RAIP is working to develop modern and sustainable agriculture by focusing on the effectiveness and efficiency of family farms and the promotion of agricultural enterprises (ECOWAS 2012). There are six main components including water and resource management, soil health, market and value chain structure, institutional strengthening and food security measures (ECOWAS 2012). An integral part of the RAIP seeking to address food security is the development of a regional food reserve that should enable the region the full capacity necessary to respond to food crises, whatever their nature or origin (ECOWAS 2012). Other parts of the RAIP include increased efforts to increase production, improve technological adaptation, regional agreement and implementation of trade policies, all of which also improve food security.

ECOWAS intends to achieve two objectives through the regional reserve:

- Limit price shocks and the magnitude of the resulting food crises via market regulation

- Support the establishment of social safety net programs in the country, in line with the provisions of the Charter for Food Crisis Prevention and Management.

The RESOGEST initiative is an approach of co-operation and solidarity between national governments in the region for better management of food crises (ECOWAS 2012). Facilitated by CILSS, the RESOGEST initiative has brought together the countries of West Africa and the Sahel to build a network of bodies responsible for the management of national food security stocks since 2007 (ECOWAS 2012). In 2011, a task force was created to begin the process of establishing a regional food reserve (ECOWAS 2012). The task force included representatives from ECOWAS states with active national reserves, the Rural Hub, the World Food Program, and food reserve experts from Ethiopia (ECOWAS 2012). In 2012, the task force met with the ECOWAS Commission to approve the suggestions and decisions the task force had developed for the regional food reserve (ECOWAS 2012).

To determine the optimal size of the reserve, the task force used the projected population for 2020 and each individual country's most significant shock (either natural, technological, or price related) (ECOWAS 2012). Natural and technological data was collected from the Centre for Research on the Epidemiology of Disasters (CRED) which provides the number and percent of individual countries whose population was affected by different "shocks" (ECOWAS 2012). Price shocks are not recorded by CRED so in order to calculate the impact of price shocks, information was collected from the FAO STAT database. The drop in per capita consumption in 2008 was used as the reference point to estimate need during a price shock (ECOWAS 2012).

The proportion of needs to be met by the regional, national, and international level were also taken into consideration so as to optimally size the reserve. Coastal countries which have

access to international aid in a shorter and less costly time frame will require less immediate support from the regional reserve (ECOWAS 2012). Countries that have their own established national reserve (Burkina Faso, Mali, Niger, and Nigeria) will also require less support from the regional reserve (ECOWAS 2012). By taking this into consideration, the task force determined that no more than 33% of need should come from the regional reserve, the remaining 67% should come from national reserves. The RESOGEST program also includes a scheme to develop national reserves as a priority over the regional reserve. Five scenarios were simulated to determine the size of the shock and to help design the regional reserve.

The five scenarios resulted in a regional reserve size ranging from 200,000 to 550,000 tons (ECOWAS 2012). You can see these scenarios in Table 4. The task force chose to go with scenario 2, moderate duration of need and high proportion met by the regional reserve. This scenario suggests a reserve of 411,000 tons: 140,000 tons of which is physical and 271,000 tons of which is financial (ECOWAS 2012). This division of physical to financial (1/3 physical and 2/3 financial) was decided in effort to provide a more cost-efficient reserve. The five scenarios and the definitions of "Moderate" and "High" proportion as well as the definition of "Moderate" and "High" Duration are shown in Tables 4, 5 and 6.

Table 4. Regional Reserve Scenarios

Scenario	Duration of Annual Need (Country or Region)	Proportion of Needs met by Region	Differentiation by Country	Suggested Reserve Size (tons)
1	Moderate	Moderate	Yes	200,000
2	Moderate	High	Yes	411,000
3	Moderate	High	No	250,000*
4	High	Moderate	Yes	280,000*
5	High	High	Yes	550,000
*Not reported by ECOWAS, calculated utilizing methodology reported by RESOGEST				

Source: ECOWAS 2012

Table 5. Scenario Duration Definitions

Country Classification	"Moderate" Duration	"High" Duration
Coastal Countries (month)	1.5	2
Landlocked Countries (month)	3	4
Annual Needs Met by Country	20%	26%

Source: ECOWAS 2012

Table 6. Scenario Proportion Definition

Country Group	"Moderate" Level of Regional Coverage	"High Level of Regional Coverage
Landlocked LDCs	20%	40%
Coastal LDCs	10%	20%
Landlocked Non-LDCs	10%	20%
Coastal Non-LDCs	5%	10%

Source: ECOWAS 2012

In order to determine the composition of the reserve, the task force first divided West Africa into sub-regions based on their diets, staple food products, and the main crop of production. This allowed the task force to divide the whole of West Africa in to four relatively homogeneous sub-regions:

- Eastern: Nigeria, Niger, and Benin
- Central: Burkina Faso, Mali, Cote d'Ivoire, Ghana, and Togo
- West Atlantic: Senegal, Gambia, Guinea-Bissau, and Cape Verde
- Atlantic Gulf: Guinea, Liberia, and Sierra Leone

These sub-regions were then examined to determine crops they consume and produce in the highest volumes. This led to the development of minimum proportions for the reserves to hold in each sub-region.

Countries with pre-existing national reserves were put in charge of looking after the stocks for each sub-region. This means that Nigeria's National Food Reserve Agency (NFRA) and Niger's Office of Food Products of Niger (OPVN) will manage the Eastern Sub region. Burkina Faso's National Management Company Stocks for Food Security (SONAGESS), Mali's Office of Agriculture Products (OPAM), and Ghana's National Food Buffer Stock Company (NAFCO) will manage the stocks of the Central Region. Senegal's Commissariat a la Securite Alimentaire (CSA) will manage the stocks for the West Atlantic sub-region. However, no public body has been selected to manage the stocks for the Atlantic Gulf sub-region as no pre-existing national reserve or institution has experience managing stocks.

The trigger mechanism chosen by the RESOGEST task force is the Cadre Harmonise Bonifie (CHB). This food insecurity classification is widely accepted in Sahelian countries and is expected to be fully implemented in ECOWAS countries upon the establishment of the regional reserve. The CHB uses 12 food security and nutrition indicators to categorize countries into 5 phases of food insecurity seen in Table 7.

Table 7. Cadre Harmonisé Bonifié Phase Classification

Food Insecurity Phase	Description
Generally Food Secure	Generally adequate and stable access to food supplies
Moderate Food Insecurity	Limited access to adequate food supplies and accumulation of risks of worsening food situation
Critical Food Insecurity	Acute lack of assets of access to adequate food supplies and rapid exhaustion of livelihood assets, risking precipitation of phase 4 or 5
Extreme Food Insecurity	Chronic lack of access to food supplies accompanied by increased mortality, very high levels of malnutrition and loss of livelihood assets
Famine	Total lack of access to food supplies, serious social upheaval, massive population displacement and exhaustion of livelihood assets

Source: ECOWAS 2012

The 12 indicators used to classify countries within the CHB scale are availability, accessibility, food diversity, migration, malnutrition, chronic malnutrition, exceptional phenomena, civil unrest, insurance mechanisms, water access, mortality, and morbidity. Each indicator has subsequent ranges for all five classifications of food insecurity. Food is released to countries when they meet the phase 3 category of "Critical" within the CHB classification and the amount released is contingent upon the limit predetermined by the RESOGEST task force as well as a country's classification (landlocked, coastal, and lesser developed country). This is overseen by the Management Committee, a group of representatives from all National Reserve groups as well as members of CILSS, WAEMU, and a representative from every member state of ECOWAS (ECOWAS 2012).

To calculate the expected cost of setting up and maintaining the regional reserve, the task force considered the cost of purchasing grain, transportation of the product to the warehouses, as well as the warehouse rental costs, management, and stock rotation/losses (ECOWAS 2012). Additionally, the costs to set up the financial or "virtual" portion of the stock was taken into consideration. The task force determined that the establishment of the regional reserve should be spread out over an eight year period. This budgeting tactic led to a plan costing 263 million over 8 years beginning in 2013 and being fully operational in 2020 (ECOWAS 2012).

2.3.2 World Food Program PREPARE:

The WFP investigated the feasibility of a pilot program to serve the people of the Sahel and West Africa, called Pre-positioning for Predictable Access and Resilience (PREPARE) system (ECOWAS 2011). The PREPARE system was developed to meet the needs of the ECOWAS member states and was created with the understanding that it would work in conjunction with the RESOGEST (ECOWAS 2011). The PREPARE pilot program was to be initiated in 2011 with the first steps of food procurement to begin in 2013 and to be fully operational by the first quarter of 2014 (ECOWAS 2011).

The WFP used historical food balance supply and demand (with special focus on 2008 crisis) to determine the size of the reserve (ECOWAS 2011). The volume of the stock is to be determined by considering the number of people likely to be vulnerable in a price-related shock and the amount of food they would need for 90 days (30 days of which is to be a physical reserve and 60 of which is to be financial) (ECOWAS 2011).

Grain demand and supply per capita was calculated for each country over the period 2001-2010 based on FAO's national food balance sheets (ECOWAS 2011). National amounts were then added together to get a combined total for the eligible countries. A 10-year average of per-capita demand and supply was then calculated for the countries and the region as a whole; this was considered the "baseline" level of per-capita demand and consumption in a typical period. On the demand side, three components of grain demand (food use, feed use and seed use) were considered to constitute the total food demand for each country (ECOWAS 2011). The continuity of all three uses during a crisis is critical to ensuring that vulnerable populations do not engage in survival mechanisms that would damage their longer-term development prospects. Individual years were compared to the average to calculate the percentage movement away from the average in any given year (ECOWAS 2011). Movements below the average were considered as "shocks." (ECOWAS 2011). All years were analyzed, but the movement observed in 2007-2008 was used as the primary case, as these years represented precisely the kind of scenario that PREPARE seeks to address (ECOWAS 2011).

By using this method, the PREPARE pilot program suggests a physical reserve of 67,000 metric tons to be optimal to meeting the needs and costs (ECOWAS 2011). A reserve of 67,000 metric tons would provide 15 kilograms/person for 30 days for 20% of the vulnerable population. This is significantly different from the Ethiopian reserve, as the PREPARE reserve is meant only to serve as short-term food aid, and the remaining 2/3 of the reserve is financial, suggesting more physical reserves can be purchased if needed.

Once the size of the reserve was determined for PREPARE, the composition of the reserve had to be determined. The WFP utilized the food balance sheets once again to consider

what grains were most consumed in each country. The grains most highly consumed in the region are maize, millet/sorghum, and rice (ECOWAS 2011). The location of such reserves was also determined using the national food balance sheets and known populations of the countries. Consideration was also made as to countries with already existing national reserves (Mali and Burkina Faso) and coastal countries for international shipments (Senegal and Ghana) (ECOWAS 2011). Quantity to be stored in these locations was determined by considering surrounding populations and need estimates from the food balance sheets (ECOWAS 2011).

The trigger for PREPARE was designed to be two-stepped, meaning there is a trigger at both the global level as well as the country level (ECOWAS 2011). The global trigger level is in reference to global price volatility to be measured by the Nonparametric Extreme Quantile[8] Model (NEXQ), developed by IFPRI. The country level trigger is based on the countries classification within the Famine Early Warning Systems Network[9] (FEWSNET) (ECOWAS 2011).

The financial burden of the reserve was determined using present grain prices as well as current fuel costs and other setup costs. Recurring costs to maintain the reserve include the cost

[8] This tool measures excessive food price variability and is the only mechanism currently available to identify time spans of increased price variability. NEXQ provides daily price variability ratings for four major crops—hard wheat, soft wheat, corn, and soybeans. Data for the model are obtained from closing prices of futures contracts traded on the Chicago Board of Trade and, in the case of hard wheat, the Kansas Board of Trade.

[9] Created in 1985 by the US Agency for International Development (USAID), and the US Department of State, after devastating famines in East and West Africa. Using an integrated approach that considers climate, agriculture production, prices, trade, nutrition, and other factors, together with an understanding of local livelihoods, FEWS NET forecasts most likely outcomes and anticipates change six to twelve months in advance. FEWSNET uses the Integrated Food Security Phase Classification Version 2.0 a five step classification they created to quantify food insecurity.

of storage, stock rotation, as well as governance and administration. In total, 60.9 million USD (United States Dollar) for the first year; 44.3 million USD initial costs and 16.6 million USD in recurring costs (ECOWAS 2011). While this information is valuable, there was no benefit-cost calculation for the scenarios presented which would aid in selecting the economically efficient reserve size.

2.3.3 Research Contribution:

The growing number of food insecure people in West Africa is a global concern. Many institutions and governments are focused on improving food security for these people. The regional reserves in Ethiopia and Asia indicate that this is an effective method to improve food security. Previous studies have been conducted for other regions of the world, but the establishment and study of reserves in West Africa is fairly new. Studies conducted by ECOWAS and partners have provided a base upon which to build, but these studies have lacked any sort of dynamic modeling or statistical simulation. This study will utilize historical rice yield data for 14 of the ECOWAS countries and 15 top rice exporters to simulate production shocks. A partial spatial equilibrium model will be utilized to measure the impact such shocks will have on prices, consumption, and ultimately on food security. Additionally, this study will consider a multiple year time frame (10 years) in an effort to more realistically model the impact a production shock has on supply and demand. These improvements will allow for a deeper and more robust understanding of the risk environment and the impact that a regional food reserve will have on the food insecure people of West Africa.

It is very important to analyze the benefit of a regional food reserve policy and its effectiveness in stabilizing prices in West Africa as well as improving household food security. Such a study will be very valuable to the ECOWAS community as it will provide information on the effective size of the regional stocks and provide a more measured understanding of the risk environment and socio-economic impact, as well as the impact on market regulation and food security.

Chapter 3: RICEFLOW Model Utilization and Methodology

3.1 Methods

The continued growth in the number of food insecure people in West Africa has led to the development of a regional food reserve. This regional food reserve provides emergency food relief and monetary support for countries in time of food crisis. When developing a regional food reserve there are many aspects that must be considered. The size of the reserve, the location of the reserve, the trigger mechanism for release, accumulation methods, management options, and most importantly the cost to maintain must all be considered. The purpose of this research is to provide a suggested reserve size and identify countries that are the most vulnerable to a food deficit. This study will provide ECOWAS with a dynamic spatial partial equilibrium analysis of their regional food reserve system, which is important in the continued efforts to increase food security in West Africa.

There are many methods for market and policy analysis, such as price and consumption, and how it affects food security. The studies mentioned previously do not provide a full picture of the market, as they do not include trade, price changes, production changes, and many other aspects that affect the international and regional market. This study utilizes the RICEFLOW model, specifically built to simulate the global rice market. Consequently, this study does not analyze other grain markets that are a part of the regional reserve. This is not ideal, but will provide a better understanding of the impact a food crisis will have on the region and the changes it will undergo due to a "shock" of one of the most important foodstuffs for the region.

3.2 RICEFLOW Explanation

The RICEFLOW model (Durand-Morat and Wailes 2010) is a spatial partial equilibrium framework of the global rice economy. It allows for non-linearity of behavioral equations, which in turn allows for a more realistic specification of supply and demand functions. The model is written in linear form, so variables in the model are shown by their percentage change rather than in absolute values (excluding stocks). One drawback to the model is that since it is not a pure optimization model, new bilateral trade flows and production cannot occur. This means that the model only allows trade, production, and consumption to change on the basis of existing trade flows and outputs in the baseline. While this is a disadvantage of the model, it could be said that its impact to this study is minimal due to the fact that rice cultivation will typically increase only in countries where it is already established and the simulated shock will not allow for an expansion of production in effort to model stock deficits.

Bilateral trade in RICEFLOW is specified according to the Armington model (Armington 1969). This assumption allows for the heterogeneity of product origin differentiation between countries allowing for price differentiation between local production and imports. This is especially important for this study as regional food reserves and food security will rely on imports in times of need, and the value of imports in contrast to domestic production is important to consider when determining the optimal size of a regional food reserve.

Production is modeled as a two-level, separable, constant-return-to-scale, CES technology. At the highest level, the derived demand for two composites, namely value-added and intermediate input composites, is determined, while at the lowest level, the derived demand for factors of production (land, labor, and capital) and intermediate inputs (seeds, fertilizer,

pesticides, water, and energy) is defined. The model incorporates several technological variables related to productivity of factors and inputs. Therefore, the demand for intermediate and value added composites is a function of activity level, technological characteristics of production, producer prices, and the relative prices of each composite.

Based on the value of the elasticity of substitution, ESUB, the production technology at each level can be specified as Leontief (ESUB = 0), Cobb-Douglas (ESUB = 1), or a Constant Elasticity of Substitution (any other value of ESUB). A list of key model specifications is included in the Appendix Table 1.

System constraints in RICEFLOW include market clearing conditions and zero profit conditions. The market clearing condition requires that all markets are cleared; this means that in each case supply is equal to demand and market equilibrium can be obtained. The markets included in the model are markets for input factors, domestic commodities, and composite commodities. For the factor market, elasticities were specified in the model, making supply of labor and capital elastic and supply of land inelastic. Commodity markets include both domestic production and imports.

A zero profit condition requires that activities by wholesalers or producers cannot receive extra profits. This condition allows for producer prices to be directly correlated to the costs of factors of production and input costs and that no additional value is created during the production process.

The latest version of the RICFLOW database depicts the market situation in calendar year 2013, and disaggregates the global rice market into nine commodities and 73 regions

covering all global production, consumption, and trade. The 9 commodities result from the combination of 3 types of rice (long grain, medium grain, and fragrant rice) and 3 milling degrees (paddy, brown, and white rice).

3.3 RICEFLOW Data Sources

The RICEFLOW model is a data intensive model, as it requires a baseline database in order to calibrate and to allow for the assumed scenarios. The different scenarios will provide a comparison of the results with regard to food security and the previously determined stock levels by ECOWAS and WFP.

The database includes 67 individual countries with remaining countries aggregated into regional groups. Table 8 contains the full list of countries and regions included in the database.

Table 8. RICEFLOW Database: Countries

ARGENTINA	EU27	MEXICO	TAIWAN
AUSTRALIA	GAMBIA	MYANMAR	TANZANIA
BANGLADESH	GHANA	NICARAGUA	THAILAND
BENIN	GUATEMALA	NIGER	TOGO
BOLIVIA	GUINEA	NIGERIA	TURKEY
BRAZIL	GUINEA BISSAU	PAKISTAN	UAE
BURKINA FASO	GUYANA	PANAMA	URUGUAY
CANADA	HAITI	PARAGUAY	USA
CAMBODIA	HONDURAS	PERU	VENEZUELA
CAMEROON	HONGKONG	PHILIPPINES	VIETNAM
CHILE	INDIA	RUSSIA	OAFRICA
CHINA	INDONESIA	SAUDI ARABIA	OASIA
COLOMBIA	IRAN	SENEGAL	OCARIBBEAN
COSTARICA	IRAQ	SINGAPORE	OEUROPE
COTE D'IVOIRE	JAPAN	SIERRA LEONE	OMIDDLEEAST
CUBA	LAOS	SKOREA	OOCEANIA
ECUADOR	LIBERIA	SOUTH AFRICA	
EGYPT	MALAYSIA	SRI LANKA	
EL SALVADOR	MALI	SURINAME	

*The table above includes country names as they appear in the Riceflow GEMPAK software
*For regions labeled O-region this suggests the rest of the unlisted individual countries are aggregated

The database is disaggregated into nine different activities, these activities include primary production of long grain, medium and short grain, and fragrant rice at three different milling stages including paddy, brown, and white. Each commodity is created by the activity based on factors of production and intermediate inputs. These intermediate inputs are represented as exogenous commodities in the data base and include: fertilizers, pesticides, energy, water, and seeds.

Primary production data were obtained from the Food and Agriculture Organization of the United Nations' database (FAOSTAT). This production data are disaggregated according to rice type based on information from the Ministries of Agriculture. Bilateral trade data were

collected from the United Nations Commodity Trade Statistics Database (UN Comtrade). Rice inventory data were provided by the United States Department of Agriculture Production, Supply & Distribution (USDA PS&D) database. Changes in the stock are deducted from the previous year's inventory, if no value is reported then no change in stock is assumed. Consumption data are provided by FAOSTAT and USDA PS&D. Market prices were gathered from FAOSTAT and additional sources such as OECD and National Agriculture Investment Program reports from all relevant countries.

3.4 Establishing 2013 Base Year

Using the RICEFLOW model and dataset compiled from the numerous sources described previously, the impact of a production shock was modeled to aid in an analysis of price, production, and consumption changes in West Africa. In order to do this, first a base year for 2013 was created. This was done by utilizing historical yield data for the 14 ECOWAS countries and 15 of the world's top rice exporting countries[10] over a period of time from 1985-2013. This data are reported in Appendix Table 2. Yield data were collected from the FAO. Using Simetar©, the historical data were de-trended across time and then were used to generate an empirical probability distribution including the correlation among countries. Table 9 shows the correlation of yields between ECOWAS countries. The historical yield distribution was then used in Simetar© to generate 100 draws of correlated rice yields for the 29 selected countries. These 100 random draws are in Appendix Table 6.

[10] Argentina, Australia, Bangladesh, Brazil, Burma, Cambodia, China, India, Indonesia, Pakistan, Philippines, Thailand, United States of America, Uruguay, and Vietnam

Table 9. Yield Correlation for ECOWAS Countries

	Benin	**Burkina**	**Ivory Coast**	**Gambia**	**Ghana**	**Guinea**	**Guinea Bissau**	**Liberia**	**Mali**	**Niger**	**Nigeria**	**Senegal**	**Sierra Leone**	**Togo**
Benin	1.00	0.31	0.77	-0.19	0.69	0.81	0.43	0.17	0.88	0.76	-0.07	0.72	0.37	0.84
Burkina		1.00	0.37	0.13	0.34	0.38	0.19	0.25	0.37	0.32	-0.23	0.20	0.02	0.43
Ivory Coast			1.00	-0.07	0.59	0.71	0.28	0.27	0.77	0.60	-0.28	0.60	0.13	0.86
Gambia				1.00	-0.10	-0.25	-0.13	-0.30	-0.23	-0.27	-0.13	-0.25	-0.35	-0.18
Ghana					1.00	0.85	0.65	-0.03	0.79	0.56	0.06	0.61	0.22	0.69
Guinea						1.00	0.70	0.10	0.93	0.68	-0.09	0.69	0.35	0.80
Guinea-Bissau							1.00	-0.12	0.61	0.36	0.18	0.45	0.41	0.36
Liberia								1.00	0.11	0.05	-0.11	-0.04	0.06	0.23
Mali									1.00	0.75	-0.02	0.81	0.45	0.87
Niger										1.00	0.08	0.81	0.67	0.73
Nigeria											1.00	0.17	0.57	-0.16
Senegal												1.00	0.63	0.71
Sierra Leone													1.00	0.25
Togo														1.00

Source: Correlation table based on historical yield data from FAOSTAT 2013

This correlation table provides a glimpse of how important a regional food reserve can be in mitigating food insecurity. The correlations imply that when one area is experiencing a production shock, nearly all other countries are also experiencing and responding similarly to the shock. There are high correlations between countries that are geographically close. A correlation greater than 0.60 was considered highly correlated and occurred in 31 of the 91 correlations. Gambia had negative correlations with all other countries, but at no level greater than .35. This suggests that Gambian yields are not likely to suffer in the same way as countries both geographically close and distant when a production shock occurs. There were only 21 negative correlations, and none of these correlations were significant. This suggests that when one area of

the region is affected, it is more than likely a widespread occurrence in more than one country, therefore a regional reserve might be able to more effectively respond to production shocks. A statistical summary of the yield shocks in 2013 for each of the ECOWAS countries is presented in Table 10. These statistics provide a basic understanding of the yield variability within specific countries and how this translated into supply shocks in the model.

Table 10. Historical Yield Simulation Data

Country	Mean Yield Paddy Ton/ha	StDev	CV	Probability of Yield Below Observed	Predominant Ecology
Benin	3.35	0.47	14.01	42%	Lowland
Burkina-Faso	2.33	0.37	15.91	50%	Irrigated
Ivory Coast	1.88	0.21	10.96	48%	Rainfed
Gambia	1.31	0.26	20.18	45%	Lowland
Ghana	2.54	0.38	14.92	52%	Lowland
Guinea	1.93	0.18	9.10	48%	Rainfed
Guinea Bissau	1.84	0.32	17.42	54%	Lowland
Liberia	1.19	0.13	11.32	40%	Rainfed
Mali	3.11	0.33	10.48	57%	Lowland
Niger	5.98	1.39	23.24	62%	Rainfed
Nigeria	1.87	0.30	15.79	57%	Lowland
Senegal	3.99	0.54	13.51	53%	Irrigated
Sierra Leone	1.84	0.27	14.74	52%	Rainfed
Togo	2.53	0.51	20.05	54%	Lowland

Source: based on historical yield data from FAOSTAT 2013

The standard deviation and covariance were calculated by Simetar© based on the deviations from the trend line within the historical data. These deviations translated into the 100 simulations and impacted the probability of yields occurring below the actual observed yield of 2013. These probabilities are reported in Table 10.

Each of the correlated 100 yield draws was used to "shock" the RICEFLOW model for year 2013, 2018 and 2023 to create probabilities of each ECOWAS country's ability to respond to a production shock through yields. While there is not a specific variable defined as yield, the variable that is shocked is a technological variable that affects land productivity. There are multiple variables that affect land productivity, but this study will shock the variable representing the technological variable impacting land yield (as opposed to impacting yield from fertilizer use or milling technology, etc). Analysis will include consumption changes as well as looking at dependency on imports. Reducing dependency on imports can reduce the impact of high international prices on the poorest consumer, but imports can also alleviate the pressure on domestic production.

In order to measure the probability and level of food deficit in the stochastic baseline year of 2013, change in stocks were held exogenous (fixed), and the impact of the simulated yield "shocks" were analyzed by looking at changes in prices, consumption, and imports. Table 11 provides a summary of key measurements for the 2013 base year, to which later shock impacts will be compared. It is important to recognize that some data sources may report prices for varying packages of rice (some might include aromatic) as well as have varying percentages of broken grain. This can account for some of the large disparity between retail prices reported in Table 11.

Table 11. Base Year 2013 Key Measurements

Country	Average Yield (Hg/Ha)	Observed Retail Price LGW (USD per MT)	Observed Consumption (1000MT)	Observed Production (1000MT)	Observed Imports (1000MT)
Benin	3.35	$1,048.61	506.3	140.2	366.6
Burkina-Faso	2.33	$794.54	298.0	195.0	105.5
Ivory Coast	1.88	$708.34	2205.6	499.9	1688.3
Gambia	1.31	$314.71	162.0	24.7	127.4
Ghana	2.54	$2,899.61	1000.5	289.2	694.9
Guinea	1.93	$571.12	1819.9	1267.2	565.2
Guinea Bissau	1.84	$627.77	168.9	118.8	54.3
Liberia	1.19	$1,199.99	365.7	182.1	184.3
Mali	3.11	$1,275.02	1335.6	1309.8	16.5
Niger	5.98	$1,100.00	127.1	55.3	71.8
Nigeria	1.87	$1,899.99	4838.0	2370.1	2420.9
Senegal	3.99	$869.63	1735.6	442.7	1308.9
Sierra Leone	1.84	$397.50	1088.6	819.0	279.3
Togo	2.53	$969.52	299.7	80.0	221.0

Sources: FAOSTAT, USDA-PS&D, OECD, RAIP

3.5 Deterministic Base and Impact Scenarios for Year 5 and Year 10

In addition to yield "shock" scenarios, Year 5 (2018) and Year 10 (2023) simulations will allow for exogenous assumptions in population and consumer expenditure. The estimates for population growth and growth in domestic production (GDP) are modeled after the Global Insight projections, these projections are found in Appendix Tables 4 and 5. Incorporating the projected changes in population and GDP created a new deterministic base year for 2018 and 2023.

Once the deterministic base year was established, the model had to once again be "shocked." Yield shocks were determined by utilizing the projected yield estimates from the Arkansas Global Rice Model (AGRM) and are included in Appendix Table 3 (Wailes and Chavez 2015) and the distribution determined by the historical data. Similar to the procedure

applied in the baseline year 2013, the stochastic distributions of projected yields were estimated using Simetar© to create 100 iterations for year 2018 and 2023. The base years (with population and GDP changes incorporated) were then "shocked" to generate the 100 iterations of simulated yields, and are reported in Appendix Tables 7 and 8. Analysis of price, consumption, and import change probabilities and magnitude compared to the deterministic base year means will be utilized to determine the need for a regional food reserve based on the probability of production shortfalls and consumption decreases.

Table 12. Year 5 (2018) Deterministic Year Key Measurements

Country	Average Yield (Hg/Ha)	Observed Retail Price LGW (USD per MT)	Average Consumption (1000MT)	Average Production (1000MT)	Average Imports (1000MT)
Benin	3.68	$1,049.86	586.6	159.2	428.7
Burkina-Faso	2.54	$800.04	354.6	227.1	131.4
Ivory Coast	2.06	$708.98	2461.2	557.6	1886.6
Gambia	1.43	$315.03	191.8	31.6	150.2
Ghana	2.80	$2,905.08	1135.7	329.4	790.6
Guinea	2.11	$572.30	2081.8	1434.7	663.7
Guinea Bissau	2.00	$631.06	188.1	132.1	59.6
Liberia	1.60	$1,201.75	417.0	213.9	206.3
Mali	3.07	$1,310.47	1513.3	1465.4	46.9
Niger	6.59	$1,100.33	157.1	67.7	89.3
Nigeria	2.07	$1,904.78	5823.8	2794.3	2975.5
Senegal	4.31	$870.56	2001.0	488.5	1529.3
Sierra Leone	2.04	$400.21	1227.3	927.6	310.2
Togo	2.78	$971.41	346.9	91.1	257.5

Table 13. Year 10 (2023) Deterministic Year Key Measurements

Country	Average Yield (Hg/Ha)	Observed Retail Price LGW (USD per MT)	Average Consumption (1000MT)	Average Production (1000MT)	Average Imports (1000MT)
Benin	3.88	$1,049.58	665.4	172.8	492.9
Burkina-Faso	2.70	$799.00	412.6	253.6	162.8
Ivory Coast	2.26	$708.83	2672.6	606.9	2053.0
Gambia	1.52	$314.95	225.3	38.0	177.6
Ghana	3.05	$2,904.51	1274.9	366.9	895.9
Guinea	2.34	$571.94	2345.0	1609.4	756.3
Guinea Bissau	2.14	$631.97	209.2	144.4	68.5
Liberia	1.69	$1,201.33	472.4	235.2	241.9
Mali	3.39	$1,298.64	1727.9	1672.2	55.2
Niger	6.94	$1,100.23	190.7	80.4	110.5
Nigeria	2.26	$1,905.19	6871.1	3200.3	3636.4
Senegal	4.79	$870.28	2278.6	555.2	1743.3
Sierra Leone	2.28	$400.18	1374.0	1041.1	340.2
Togo	2.93	$971.18	394.2	99.5	297.4

Chapter 4: Analysis and Results

4.1 Base Year 2013 Results and Analysis

Table 14 provides the observed retail prices for white long grain rice in 2013, and estimates of their distribution conditional on the stochastic yield simulations (e.g. the standard deviation, an average of the ten highest price changes and their associated average change in consumption as well as the probability that the simulated shock would have caused the price to be above the actual price observed in 2013).

Table 14. Simulated Change in Price Statistics for ECOWAS Countries, 2013

Country	Observed Retail Price LGW (USD per MT)	StDev	Average Change of 10 Highest Price Changes	Average Change in Consumption Associated with 10 Highest Price Changes	Probability of Price Higher than Observed
Benin	$1,048.61	0.94	1.70%	-0.20%	46%
Burkina-Faso	$794.54	3.31	7.13%	-1.02%	51%
Ivory Coast	$708.34	0.80	1.48%	-0.58%	50%
Gambia	$314.71	0.62	1.01%	-0.15%	55%
Ghana	$2,899.61	0.86	2.20%	-0.20%	44%
Guinea	$571.12	2.73	5.40%	-0.77%	46%
Guinea Bissau	$627.77	2.38	6.21%	-0.82%	58%
Liberia	$1,199.99	1.12	2.34%	-0.31%	48%
Mali	$1,275.02	11.91	27.61%	-3.55%	59%
Niger	$1,100.00	0.35	0.66%	-0.05%	40%
Nigeria	$1,899.99	1.34	2.86%	-0.27%	51%
Senegal	$869.63	1.57	3.29%	-0.45%	43%
Sierra Leone	$397.50	3.19	7.28%	-1.05%	52%
Togo	$969.52	0.91	1.86%	-0.24%	50%

In general, the impact of an increase in prices caused a slight decrease in consumption with an increase in imports, because of the inelasticity of demand with respect to own price. This follows since for the consumers of West Africa, rice is a staple food. While an increase in prices may have deterred consumption in small amounts, the true impact of a yield shocks resulting in higher prices is a loss in consumer surplus and an increased dependency on imports. It is also important to note that without the increase in imports, it is likely that the domestic retail price for rice would have been even higher. Table 14 also provides evidence that the largest price increases occur in countries with a low dependency on trade (ex. Mali and Burkina Faso).

To further understand the impact and probability of varying yields on food security, the changes in production, imports, and consumption must be taken into account. Changes in production and consumption are the basic variables used to determine food security. Availability of rice can be calculated by [(production – Δ stocks + imports – exports. The RICEFLOW model does not have data on exports from ECOWAS countries. While trade may actually occur within the region, it is marginal relative to extra-ECOWAS imports. The simulated values must be compared to what was actually observed for 2013 in order to understand the probability that a given country would have needed to import more rice (or to rely on food reserves) to maintain the observed level (or deterministic level) of consumption. The probability of a consumption decrease and a production decrease and the average magnitude in comparison to the observed 2013 values is included in Table 15. The import dependency was also included to illustrate a country's dependency on rice imports in the face of domestic production deficits (Table 15).

Table 15. Simulated Food Deficit Occurrence Statistics for ECOWAS Countries in 2013

Country	Probability of increased Imports	Average Magnitude	Probability of decreased Consumption	Average Magnitude	Probability of decreased Production	Average Magnitude	Import Dependency
Benin	42%	3.33%	47%	-0.11%	41%	-9.2%	72%
Burkina Faso	48%	12.67%	52%	-0.45%	48%	-7.4%	35%
Ivory Coast	50%	1.98%	50%	-0.27%	52%	-6.5%	77%
Gambia	45%	0.75%	55%	-0.07%	45%	-3.4%	79%
Ghana	51%	2.71%	47%	-0.07%	52%	-6.5%	69%
Guinea	50%	9.89%	46%	-0.34%	50%	-4.8%	31%
Guinea Bissau	59%	8.41%	56%	-0.28%	59%	-4.1%	32%
Liberia	60%	3.45%	48%	-0.14%	56%	-4.1%	50%
Mali	57%	72.14%	59%	-1.39%	58%	-2.2%	2%
Niger	59%	0.94%	44%	-0.02%	60%	-1.2%	57%
Nigeria	57%	5.40%	56%	-0.15%	57%	-5.7%	50%
Senegal	53%	3.52%	48%	-0.17%	53%	-10.9%	75%
Sierra Leone	50%	15.38%	54%	-0.41%	50%	-5.7%	26%
Togo	48%	3.19%	52%	-0.10%	48%	-9.0%	74%

Table 16. Price Shock Probabilities for 2013 Simulation

2013	Probability of 2.5% Price Increase	Probability of 5% Price Increase	Probability of 8% Price Increase	Probability of 10% Price Increase
Benin	0%	0%	0%	0%
Burkina Faso	24%	11%	4%	1%
Ivory Coast	0%	0%	0%	0%
Gambia	0%	0%	0%	0%
Ghana	2%	0%	0%	0%
Guinea	18%	5%	0%	0%
Guinea Bissau	16%	6%	1%	0%
Liberia	3%	0%	0%	0%
Mali	44%	37%	32%	20%
Niger	0%	0%	0%	0%
Nigeria	6%	0%	0%	0%
Senegal	10%	0%	0%	0%
Sierra Leone	21%	12%	2%	0%
Togo	1%	0%	0%	0%

When considering the probabilities of increased prices or decreased consumption determined by a production shock, the model provides several insights to the rice market in West Africa. The impact scenarios for 2013 suggest that percentage of consumption from imports is significantly higher in countries with coastal ports. Senegal is not a large rice producing country, but most of the rice production (70%) utilizes irrigation systems that provide higher yields, and on average 75% of their consumption comes from imports. However, many other countries also experienced high probabilities in increased imports. Guinea Bissau-, Liberia, and Niger all experienced increased imports nearly 60% of the time.

Benin responded very little to the simulated production shocks, which is expected given the low variability of yields. Simulated prices were higher than the observed level only 46% of the time and consumption decreased 47% of the time with an average magnitude of -.11%. The low response to a production shock in Benin results from its high reliance on trade and the stability of production, since a large percentage of rice grown in the country (70%) is grown utilizing irrigation and lowland production methods, decreasing the probability of a drastic production shock.

Burkina Faso, with a standard deviation of yields estimated at -.45%, responded more to the production shocks. Prices in Burkina Faso increased 51% of the time, and these price increases were significant (greater than 5%) more than 10% of the time. However, this did not translate into a very high decrease in consumption, as Burkina Faso only decreased consumption 52% of the time with an average magnitude of -.45%. This can be explained due to the low level of rice consumption in Burkina Faso; only 8% of their diet comes from rice. Additionally, Burkina Faso produces their rice utilizing irrigation, therefore minimizing the probability of a

production shock, with a decrease in production only occurring 48% of the time with an average magnitude of -7.4%.

The historical yield data for the Ivory Coast determined a low standard deviation of .80. This translated into very little response to changes in prices for the country. Prices were higher than observed only 50% of the time, but of these price changes, no increases were greater than 2.5%. Gambia responded much like Benin, and with a similarly low standard deviation (.62) and percentage daily intake of rice (23%), such reaction was expected. Gambian prices increased 55% of the time, but never by more than 2.5%.

Based on historical data, rice yields in Ghana have a standard deviation of only .86. This translated to into price increases 44% of the time and only 2% of the price increases greater than 2.5% and none greater than 5%. Ghana reduced consumption 47% of the time with an average magnitude of -.07%. Guinea responded to production shocks by increasing imports 50% of the time and only decreasing consumption 46% of the time with an average magnitude of -.34%.

Guinea Bissau relies heavily on rice for their diet with 40% of daily caloric intake coming from rice. Prices greater than the observed 2013 price occurred 58% of the time, and the probability of decreased consumption was also high, recording a decrease 56% of the time with an average magnitude of -.28%. Meanwhile, Liberia recorded price increases 48% of the time, and of these price increases, 3% were greater than 2.5%. However, Liberia only decreased consumption 8% of the time with an average magnitude of -.14%. This could be due to the high probability of increased imports, at 60% of the time. Additionally, 75% of production in Liberia is rainfed, which makes the country more susceptible to production shocks, with decreased

production occurring 56% of the time. However, approximately 40% of the consumers' diet in Liberia is from rice, which further stresses the importance of rice imports for the country.

Mali recorded the greatest standard deviation of rice yields at 11.91, which translated into prices being higher than observed nearly 60% of the time. Of these price increases, 37% of them were greater than 5%. Consumption decreases nearly 60% of the time, with an average magnitude of -1.39%, and the need for increased imports occurred 57% of the time with a magnitude of 72.14%. In contrast, Niger experienced very few changes due to their low standard deviation of .35. Prices only increased 40% of the time and never by more than 2%. Niger only decreases consumption 44% of the time with an average magnitude of -.02%.

Nigeria responded to production shocks in a similar fashion to Liberia, but with Nigerian diets being composed of only 11% rice, consumption decreased more significantly with observations greater than the observed occurring 56% of the time with an average magnitude of -.15%. Simulated prices were higher than observed 51% of the time, but only 6% of them being greater than 2.5%, and none greater than 5%. Senegal recorded a standard deviation of 1.57 which translated into prices being higher than observed levels only 43% of the time, but of these price increases, 10% of them were greater than 2.5%. The probability of increased imports for Senegal was 53%. Despite having 70% of rice production under irrigation, a decrease in production occurred 53% of the time.

Sierra Leone experienced increased prices 52% of the time, and 12% of these price increases were greater than a 5%. Price increases translated into decreased consumption 54% of the time with an average magnitude of .41%. Togo responded very little to production shocks, with prices only increasing 50% of the time, and only 1 % of these changes greater than 2.5%.

Production decreased only 48% of the time and consumption only decreased 52% of the time with an average magnitude of -.10%.

4.2 Year 5 and Year 10 Impact Scenario Results and Analysis

Yield projections for the large rice producing countries[11], as well as the ECOWAS countries, were taken from the AGRM model to simulate possible yield shocks for years 2018 and 2023. The results from the stochastic iterations are included in Appendix Tables 7 and 8. As expected, these yield shocks impacted prices and therefore consumption and imports. Table 17 provides the statistical analysis of price changes in year 2018.

Table 17. Simulated Change in Price for ECOWAS Countries, 2018

Country	2018 Deterministic Price (USD per MT)	StDev	Average of 10 Highest Price Changes	Average Change in Consumption Associated with 10 Highest Price Changes	Probability of Price Higher than Observed
Benin	$1,049.86	1.01	1.87%	-0.24%	53%
Burkina-Faso	$800.04	3.71	8.40%	-1.20%	51%
Ivory Coast	$708.98	0.92	1.25%	-0.72%	53%
Gambia	$315.03	0.80	1.42%	-0.21%	55%
Ghana	$2,905.08	1.07	1.74%	-0.22%	49%
Guinea	$572.30	3.35	7.82%	-1.09%	42%
Guinea Bissau	$631.06	2.02	4.90%	-0.64%	57%
Liberia	$1,201.75	1.12	2.21%	-0.30%	51%
Mali	$1,310.47	16.01	33.58%	-4.23%	56%
Niger	$1,100.33	0.43	0.78%	-0.05%	49%
Nigeria	$1,904.78	1.51	3.08%	-0.30%	52%
Senegal	$870.56	1.75	3.37%	-0.46%	46%
Sierra Leone	$400.21	3.24	7.25%	-1.02%	48%
Togo	$971.41	1.02	2.25%	-0.29%	55%

[11] Argentina, Australia, Bangladesh, Brazil, Burma, Cambodia, China, India, Indonesia, Pakistan, Philippines, Thailand, United States of America, Uruguay, and Vietnam

Table 18. Simulated Food Deficit Occurrence Statistics for ECOWAS Countries, 2018

Country	Probability of increased Imports	Average Magnitude	Probability of decreased Consumption	Average Magnitude	Probability of decreased Production	Average Magnitude	Import Dependency
Benin	55%	3.05%	49%	-0.12%	55%	-8.44%	73%
Burkina Faso	46%	16.18%	50%	-0.52%	47%	-9.67%	37%
Ivory Coast	53%	2.05%	49%	-0.35%	54%	-6.74%	77%
Gambia	45%	0.97%	55%	-0.11%	45%	-4.02%	78%
Ghana	41%	3.54%	46%	-0.09%	40%	-8.96%	70%
Guinea	45%	11.60%	43%	-0.42%	45%	-5.81%	32%
Guinea Bissau	60%	6.18%	57%	-0.22%	59%	-3.02%	32%
Liberia	55%	3.88%	50%	-0.13%	55%	-4.02%	49%
Mali	56%	102.81%	56%	-1.82%	56%	-4.28%	3%
Niger	50%	1.26%	51%	-0.03%	50%	-1.61%	57%
Nigeria	49%	5.85%	52%	-0.16%	48%	-6.66%	51%
Senegal	49%	3.76%	45%	-0.23%	48%	-12.56%	76%
Sierra Leone	52%	14.17%	48%	-0.49%	52%	-5.19%	25%
Togo	48%	3.41%	56%	-0.11%	48%	-9.84%	74%

Moving from year 2013 into 2018 the general theme was an increase in dependency on imports which also led to higher probabilities of decreased consumption. While an increased dependency on imports was evident, the probability of deceased production was significantly lower in nearly every country. The same approach was used for 2023 (Tables 19 and 20).

Table 19. Simulated Change in Price for ECOWAS Countries, 2023

Country	2023 Deterministic Price (USD per MT)	StDev	Average of 10 Highest Price Changes	Average Change in Consumption Associated with 10 Highest Price Changes	Probability of Price Higher than Observed
Benin	$1,049.58	0.91	1.74%	-0.20%	53%
Burkina -Faso	$799.00	3.46	7.16%	-1.03%	53%
Ivory Coast	$708.83	0.77	0.97%	-0.57%	53%
Gambia	$314.95	0.59	1.02%	-0.15%	55%
Ghana	$2,904.51	0.89	1.39%	-0.20%	49%
Guinea	$571.94	2.65	5.42%	-0.77%	47%
Guinea Bissau	$631.97	2.40	6.20%	-0.82%	58%
Liberia	$1,201.33	0.96	2.00%	-0.26%	47%
Mali	$1,298.64	13.21	27.22%	-3.52%	57%
Niger	$1,100.23	0.33	0.65%	-0.04%	44%
Nigeria	$1,905.19	1.45	3.01%	-0.28%	56%
Senegal	$870.28	1.52	3.25%	-0.43%	44%
Sierra Leone	$400.18	3.08	7.17%	-1.03%	55%
Togo	$971.18	0.88	1.83%	-0.23%	54%

Table 20. Simulated Food Deficit Occurrence Statistics for ECOWAS Countries, 2023

Country	Probability of increased Imports	Average Magnitude	Probability of decreased Consumption	Average Magnitude	Probability of decreased Production	Average Magnitude	Import Dependency
Benin	46%	3.29%	51%	-0.10%	44%	-9.45%	74%
Burkina Faso	48%	13.91%	52%	-0.47%	50%	-8.65%	39%
Ivory Coast	53%	2.19%	51%	-0.26%	51%	-6.40%	77%
Gambia	51%	0.93%	55%	-0.08%	45%	-2.71%	79%
Ghana	51%	3.13%	49%	-0.07%	50%	-6.74%	70%
Guinea	47%	12.34%	48%	-0.34%	51%	-5.03%	32%
Guinea Bissau	55%	7.07%	56%	-0.27%	53%	-4.45%	33%
Liberia	62%	3.64%	52%	-0.11%	59%	-3.36%	51%
Mali	55%	95.24%	57%	-1.47%	57%	-3.39%	3%
Niger	60%	1.01%	47%	-0.02%	56%	-1.08%	58%
Nigeria	52%	5.84%	57%	-0.16%	57%	-6.38%	53%
Senegal	55%	3.38%	48%	-0.17%	53%	-11.08%	77%
Sierra Leone	45%	13.90%	55%	-0.40%	50%	-5.37%	25%
Togo	48%	3.98%	54%	-0.10%	50%	-9.79%	75%

Simulation of 2023 followed the changes between 2013 and 2018, with an increased dependency on imports. However 2023 suggests that countries had a higher probability of lower production and decreased consumption.

According to OXFAM a price increase of more than 5% for consumers in West Africa can cause significant food insecurity for the most vulnerable populations (OXFAM 2012). Using the RICEFLOW simulation, Tables 21 and 22 provide the price shock probabilities of a production shock causing prices to be higher than the deterministic base year in the ECOWAS countries for 2018 and 2023.

Table 21. Price Shock Probability for 2018 Simulation

2018	Probability of 2.5% Price Increase	Probability of 5% Price Increase	Probability of 8% Price Increase	Probability of 10% Price Increase
Benin	1%	0%	0%	0%
Burkina Faso	25%	15%	8%	1%
Ivory Coast	0%	0%	0%	0%
Gambia	0%	0%	0%	0%
Ghana	4%	0%	0%	0%
Guinea	18%	13%	5%	1%
Guinea Bissau	10%	4%	0%	0%
Liberia	3%	0%	0%	0%
Mali	45%	36%	33%	29%
Niger	0%	0%	0%	0%
Nigeria	7%	0%	0%	0%
Senegal	14%	0%	0%	0%
Sierra Leone	21%	14%	3%	0%
Togo	2%	0%	0%	0%

Table 22. Price Shock Probability for 2023 Simulation

2023	Probability of 2.5% Price Increase	Probability of 5% Price Increase	Probability of 8% Price Increase	Probability of 10% Price Increase
Benin	0%	0%	0%	0%
Burkina Faso	24%	14%	5%	1%
Ivory Coast	0%	0%	0%	0%
Gambia	0%	0%	0%	0%
Ghana	2%	0%	0%	0%
Guinea	18%	5%	0%	0%
Guinea Bissau	15%	6%	0%	0%
Liberia	0%	0%	0%	0%
Mali	42%	37%	33%	26%
Niger	0%	0%	0%	0%
Nigeria	8%	0%	0%	0%
Senegal	9%	0%	0%	0%
Sierra Leone	20%	12%	2%	0%
Togo	0%	0%	0%	0%

4.3 Determining the Appropriate Size of the Reserve

To determine the appropriate size of the reserve, this study will utilize the deterministic base year levels of consumption in comparison to the shock scenarios that resulted in decreased consumption. Both the change in consumption or depth of the decline (volume) and the probability of a negative consumption change will be considered to effectively determine the regional reserve size.

Table 23 provides the greatest decrease in consumption for each ECOWAS country in 2018. The 'worst case scenario' approach (the largest consumption shortfall of the 100 iterations) was utilized to determine the maximum size of the reserve needed. The probability distribution of the consumption shocks are shown in Figures 11 and 12. These figures show the probability distribution for all 100 iterations of each country in ECOWAS. The same approach was used for 2023 scenarios (Table 23).

Table 23. Greatest Deviation from Deterministic Mean Consumption

Country	2013 Maximum Consumption Decrease (1000MT)	2018 Maximum Consumption Decrease (1000MT)	2023 Maximum Consumption Decrease (1000MT)
Benin	1.2	1.8	1.5
Burkina Faso	4.2	5.2	5.9
Ivory Coast	19.5	22.8	22.5
Gambia	.31	0.570	0.4
Ghana	2.4	3.9	3.1
Guinea	19.0	29.6	24.2
Guinea Bissau	1.8	1.9	2.2
Liberia	1.9	2.1	2.1
Mali	58.5	69.8	72.9
Niger	0.08	0.1	0.1
Nigeria	15.2	20.7	22.2
Senegal	10.2	12.1	12.6
Sierra Leone	1.1	1.2	1.4
Togo	14.1	15.8	17.7
Regional Need:	149.5	187.6	188.8

Figure 11. Probability Distribution of Decreased Consumption in ECOWAS 2018

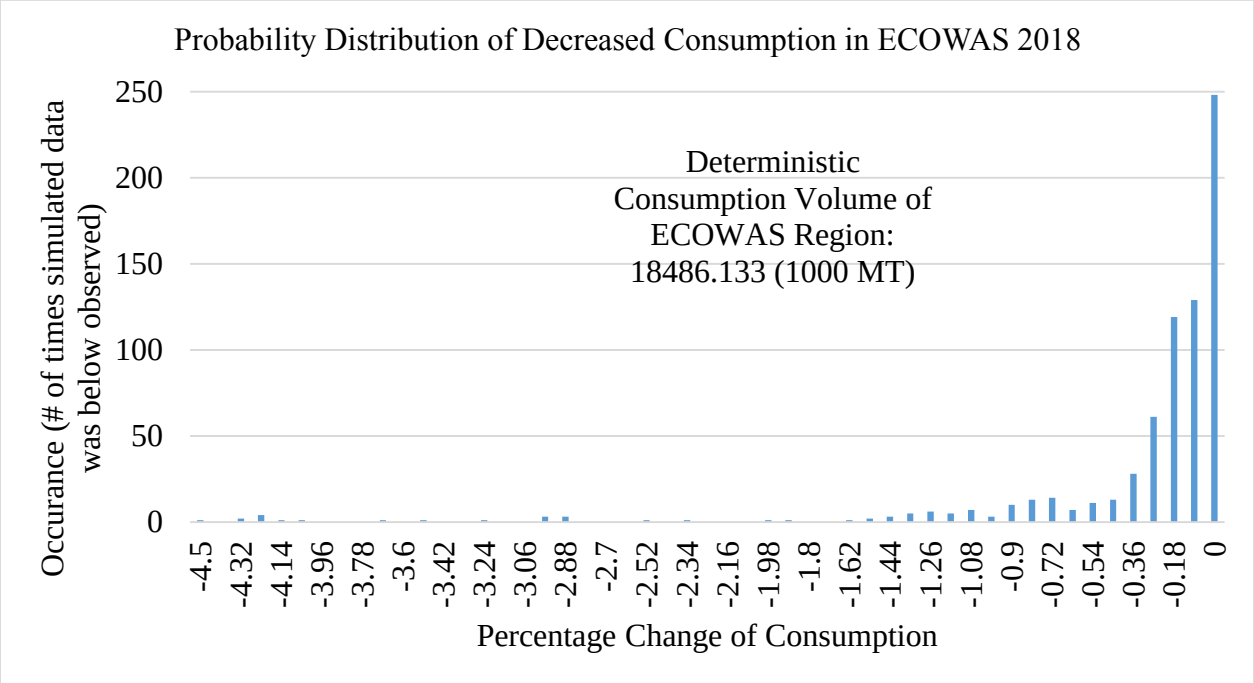
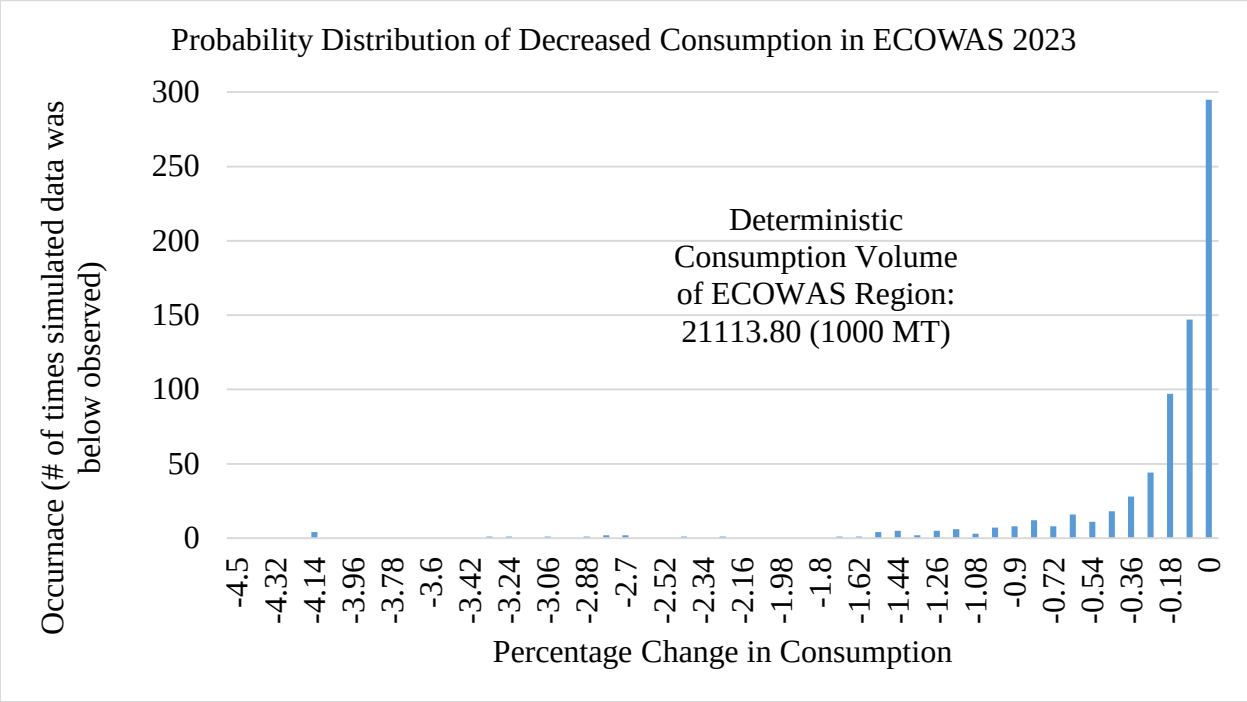


Figure 12. Probability Distribution Function of Decreased Consumption 2023



Both the RESOGEST and PREPARE models utilize a 1/3 physical and 2/3 financial division. Using this same approach, for comparison, the total reserve will be divided by 3 to represent the 1/3 physical portion of the reserve. This suggests that the physical reserve need only to be 62,000 tons. However, when considering the probability distribution of decreased consumption, seen in Figures 11 and 12, and recognizing that a worst case scenario approach was utilized, it can be argued that the reserve size could be less than 62,000 tons. Figure 11 and 12 graph the occurrence of the simulated data for the ECOWAS region recording a decrease in consumption at the magnitude provided on the x-axis.

4.4 Comparison to Other Regional Reserve Approaches

Using the method utilized by the ASEAN +3 reserve, where a massive calamity occurs with a 5% production shock, (translated to a consumption decrease by about 3%) (Briones et al 2012) the West African Reserve size in 2018 would be 554,580 tons and 633,414 tons in 2023.

In review, the Ethiopian reserve identified the vulnerable population according to standards set by IFPRI and then calculated the volume to support 95% of them with 400 grams per day for four months. Using the method utilized to determine the size of the Ethiopia food reserve, the West African Food Reserve should have approximately 528,354 tons for 2013. While this is a widely accepted method to sizing a reserve, it could be over estimating need, as the fertility rates of the region have continual decreased and therefore population projections for the area may be high.

The RESOGEST task force used the projected population for 2020 and each individual country's most significant shock (either natural or technological from CRED) or price related (drop in consumption in 2008 in comparison to the average over 2000-2009). This scenario suggests a reserve of 411,000 tons: 140,000 tons of which is physical and 271,000 tons of which is financial.

The PREPARE pilot program set up by the WFP determined the volume of the stock by comparing the drop in supply and demand in 2008 to the 10 year average (4% consumption decrease). This method calculated a physical reserve of 67,000 tons. The remaining portion of the reserve is financial and should be able to purchase 134,000 tons of rice. (ECOWAS 2011). A

reserve of 67,000 metric tons would provide 15 kilograms/person for 30 days for 20% of the vulnerable population of the entire ECOWAS region.

Table 24. Suggested Reserve Size for ECOWAS

Method	Suggested ECOWAS Reserve Size (tons)	Percent of Consumption (2018 Deterministic Level)
ASEAN +3	554,580 (2018) and 633,414 (2023)	3%
Ethiopian	528,354 (2013)	2.85%
RESOGEST	140,000 + financial reserves	2.27%
PREPARE	67,000 + financial reserves	1.09%
RICEFLOW	62,000 + financial reserves	1.01%

Source: Calculations based on methods presented in ASEAN 2014, FAO 2004, ECOWAS 2012, and ECOWAS 2011

Upon comparison of the methods utilized to determine regional reserve size, there is a drastic difference in approach and therefore the final volume. While different methods aim to address different durations of need as well as the depth of hunger, there remains a drastic difference in suggested reserve size. The high volumes determined by the other approaches for the reserve can be understood when recognizing that the methods used to reach this conclusion were fairly static. The methods utilized by these other studies were not stochastic and did not allow for a whole market simulation, including the regions ability to respond to production shocks with imports. By utilizing the RICEFLOW model, a more accurate simulation of market response, including endogenous changes in production and trade, can be simulated. While increasing production through improved yields and land use expansion will aid in improving the food security of the region, it is more realistic to recognize that trade, and most significantly imports, can play a larger role in reducing hunger.

4.5 General Observations and Future Studies

Additional consideration should be made to balance the appropriate volume with the cost to develop such a volume and to maintain the reserve. Future studies should compare alternative approaches to price stabilization by examining productivity growth, land and irrigation development and income payments to enable poor households to avoid food shortages. For instance, the National Rice Development Strategy (NRDS) developed for many of the ECOWAS countries stresses the importance of dramatic increases in acreage and yield to achieve food security. An assessment of these strategies and their impact on ECOWAS rice security situation is needed.

There may be many different approaches to calculate the appropriate size of a food reserve for a region. But it is clear that a precise system must be in place to manage and maintain the program. As mentioned in section 1.3, there are many governmental organizations and agreements aiming to solve food insecurity. However, these efforts may be convoluting the decision-making process of food security programs in West Africa. Additional complications surface when considering individual nation's reserves.

National reserves, while ideally will remove some pressure on the regional reserve, it simultaneously creates a 'conflict of interest.' Countries with their own national reserve might be less likely to support the regional reserve scheme. The fear comes with the idea that the national reserves will be utilized for regional shortages but the cost of maintaining the nation's reserve will remain with the nation. This is where a clear and precise management scheme must be developed. Additionally, the development of a regional reserve removes the incentive for nations to develop their own national food reserve. While the RESOGEST approach includes the

development of national reserves, countries may no longer see the benefit in a regional reserve or have the resources to develop a national reserve.

Future studies can add value to the study of food security and regional food reserves in West Africa by incorporating more data into the RICEFLOW database. This study would benefit from updated and more consistent data sources. The RICEFLOW model is data dependent, and for many of the countries of West Africa there are large data gaps. Such additional information could include the ecological breakdown of production, more regional specific elasticities of land and labor, and most importantly by including updated stock level and intra-regional rice trade information. This study focuses only on one of the main foodstuffs for West African consumers, it would also be useful to model a reserve composed of multiple grains to more accurately describe the market changes during times of crisis. Other research could utilize optimization or linear models to determine efficient transportation and transaction costs, but is beyond the scope of this study.

While this study defined imports as exogenous, and allowed the market to respond with trade, it would be beneficial to continue this research by defining imports as endogenous. This would allow the RICEFLOW model to simulate the impact of production shocks on consumption and price in the region when imports are not able to respond to the changes in the market. This would allow for a true understanding of the ability of imports to improve food security.

There are many methods used to improve global food security, and the development of food reserves is just one approach. However, when developing a regional food reserve without looking at the whole market and the subsequent responses to production shocks, the reserve size

will be overestimated. This study suggests that in the process of developing a food reserve the impact of trade must be takin into account.

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Appendix

Appendix Table 1. Key Model Specifications

Price Elasticity of Demand	LGW	MGW	FGW
Benin	.250	.250	.250
Burkina Faso	.250	0	.250
Ivory Coast	.140	.140	.140
Gambia	.140	0	0
Ghana	.140	.140	.140
Guinea	.140	0	.140
Guinea Bissau	.140	0	.140
Liberia	.140	.140	.140
Mali	.140	0	.140
Niger	.250	0	.250
Nigeria	.250	0	.250
Senegal	.140	.140	.140
Sierra Leone	.140	0	.140
Togo	.250	0	.250
Elasticity of Supply – Land (all ECOWAS)	.250 (inelastic)		
Elasticity of Supply – Labor & Capital (all ECOWAS)	1000 (Perfectly elastic)		
Elasticity of Supply – Fertilizer, Pesticide, Water, Energy, Seed (all ECOWAS)	1000 (Perfectly elastic)		

Appendix Table 2. Historical Yield Data

	Benin	Burkina Faso	Côte d'Ivoire	Gambia	Ghana	Guinea	Guinea Bissau	Liberia	Mali	Niger	Nigeria	Senegal	Sierra Leone	Togo
1985	1.20	1.95	1.25	2.57	0.94	1.71	1.05	1.29	0.66	2.52	2.00	2.06	1.58	0.84
1986	1.28	1.81	1.20	1.91	1.18	1.71	1.75	1.25	1.16	2.75	2.13	1.88	1.27	0.70
1987	1.21	1.68	1.10	1.61	0.91	1.71	2.00	1.24	1.18	2.73	2.02	2.00	1.54	1.15
1988	1.17	1.15	1.13	1.28	1.12	1.71	2.10	1.26	1.45	2.45	2.39	1.83	1.30	1.50
1989	1.36	1.79	1.20	1.54	1.83	1.71	2.01	1.28	1.24	3.01	2.00	1.86	1.27	1.14
1990	1.38	2.05	1.20	1.51	1.03	1.71	2.02	1.17	1.46	3.41	2.00	2.12	1.28	1.39
1991	1.40	2.08	1.20	1.47	1.65	1.71	2.05	1.03	1.44	3.14	2.07	2.48	1.28	1.31
1992	1.34	2.14	1.05	1.53	1.59	1.71	2.01	0.91	1.73	3.56	1.95	2.35	1.35	1.57
1993	1.33	1.88	1.02	1.73	1.65	1.71	1.90	0.92	1.76	2.50	1.96	2.41	1.35	1.85
1994	1.32	2.16	1.34	1.46	2.04	1.71	1.97	1.08	1.74	2.62	1.96	2.48	1.27	1.20
1995	1.57	1.96	1.09	1.54	2.01	1.71	2.01	1.11	1.65	2.21	1.42	2.09	1.23	0.95
1996	1.67	1.92	1.06	1.23	2.02	1.71	1.91	1.12	1.55	2.43	1.63	2.25	1.30	1.22
1997	1.85	2.39	1.46	1.07	2.05	1.71	1.84	1.25	1.91	2.51	1.75	2.02	1.35	1.33
1998	1.88	1.58	1.21	1.02	1.67	1.71	1.67	1.25	1.76	3.64	1.60	2.33	1.30	2.70
1999	2.08	1.94	1.56	1.34	1.48	1.71	1.50	1.29	2.20	2.95	1.60	2.72	1.15	2.04
2000	1.94	2.48	1.78	2.17	1.99	1.71	1.18	1.28	2.24	4.11	1.50	2.50	1.16	2.13
2001	2.11	2.57	1.82	2.21	2.16	1.71	1.42	1.28	2.11	2.75	1.50	2.35	1.09	1.92
2002	2.07	1.88	1.86	2.33	2.02	1.72	1.23	1.12	2.01	2.76	1.30	2.37	1.00	1.93
2003	2.22	1.90	1.90	2.05	2.28	1.73	1.29	0.92	1.97	3.35	1.34	2.27	1.00	2.16
2004	2.31	2.00	1.94	1.74	2.04	1.74	1.36	0.83	2.30	3.05	1.41	2.64	1.01	2.17
2005	2.61	1.50	2.00	2.04	2.03	1.75	1.37	0.92	1.59	3.34	1.42	2.48	1.00	2.12
2006	2.71	1.78	1.99	1.00	2.39	1.76	1.51	1.29	2.28	3.96	1.43	2.85	1.14	2.21
2007	2.64	2.57	1.93	1.69	2.00	1.77	1.63	1.26	2.55	3.71	1.48	2.24	1.43	2.48
2008	2.74	1.70	1.70	0.69	1.70	1.78	1.82	1.45	2.76	3.12	1.30	2.41	1.36	2.28
2009	3.17	2.44	1.85	1.13	2.27	1.93	1.81	1.55	3.37	1.83	1.75	3.26	1.43	2.34
2010	2.76	2.32	1.82	1.08	2.41	1.90	2.04	1.18	2.31	1.43	1.93	3.60	1.78	2.65
2011	2.66	2.02	1.83	1.16	2.71	1.85	2.08	1.18	3.36	1.49	1.84	4.10	1.87	2.32
2012	3.94	1.77	1.85	1.22	2.35	1.90	1.65	1.18	2.10	1.53	1.77	3.72	1.79	2.51
2013	3.33	2.33	1.88	0.85	2.54	1.92	1.86	1.16	3.10	4.33	1.80	4.67	1.89	2.55

Appendix *Table 2. Historical Yield Data (Continued)*

	Argen-tina	Aust-alia	Bangla-desh	Brazil	Burma	Camb-odia	China	India	Indo-nesia	Pakistan	Philipp-ines	Thai-land	US	Uruguay	Vietnam
1985	3.42	6.86	2.16	1.82	2.46	1.29	5.37	2.13	3.94	2.49	2.55	2.07	5.55	5.06	2.8
1986	3.35	6.42	2.17	1.76	2.47	1.25	5.26	2.33	4.01	2.35	2.67	2.06	6.07	4.72	2.74
1987	3.91	5.73	2.18	1.77	2.53	1.38	5.34	2.22	3.91	2.53	2.64	1.95	6.33	4.15	2.62
1988	3.8	7.06	2.24	1.98	2.54	1.32	5.41	2.2	4.25	2.48	2.65	2.01	6.22	4.7	3.04
1989	4.15	8.22	2.28	2.07	2.76	1.37	5.3	2.53	4.25	2.35	2.65	2.15	6.18	5.3	3.05
1990	3.31	8.06	2.56	1.91	2.85	1.43	5.51	2.62	4.3	2.29	2.58	2.09	6.45	4.39	3.2
1991	4.18	8.84	2.57	2.36	2.85	1.35	5.73	2.61	4.35	2.32	2.88	1.96	6.2	4.74	2.99
1992	4.67	8.87	2.67	2.19	2.83	1.39	5.64	2.63	4.34	2.32	2.78	2.25	6.42	4.87	3.42
1993	4.34	7.64	2.71	2.26	2.76	1.32	5.8	2.62	4.38	2.37	2.94	2.17	6.43	5.22	3.35
1994	4.31	8.2	2.71	2.4	2.77	1.31	5.85	2.87	4.34	2.74	2.88	2.21	6.18	4.67	3.66
1995	5.03	8.88	2.55	2.65	2.9	1.49	5.83	2.89	4.35	2.43	2.86	2.33	6.68	5.51	3.62
1996	5.11	7.05	2.67	2.6	3	1.79	6.02	2.73	4.42	2.75	2.85	2.41	6.3	6.62	3.76
1997	5.38	8.22	2.72	2.67	2.77	1.81	6.21	2.83	4.43	2.87	2.86	2.23	6.86	6.66	3.87
1998	4.88	9.01	2.76	2.76	2.74	1.77	6.32	2.85	4.2	2.81	2.85	2.36	6.61	5.08	3.92
1999	5.74	9.2	3.07	3.02	2.86	1.79	6.37	2.9	4.25	2.89	2.83	2.39	6.35	6.39	4.02
2000	4.79	8.28	3.23	3.13	2.83	1.94	6.34	2.98	4.4	3.08	2.99	2.51	6.58	6.4	4.14
2001	5.77	9.28	3.46	3.25	3.1	2.12	6.27	2.87	4.44	3.03	3.11	2.61	7.04	6.69	4.14
2002	5.74	8.45	3.42	3.3	2.9	2.07	6.16	3.14	4.41	2.75	3.19	2.62	7.28	5.87	4.27
2003	5.4	9.52	3.51	3.25	3	1.92	6.19	2.67	4.5	3.02	3.17	2.57	7.37	5.92	4.37
2004	6.56	8.36	3.6	3.43	2.94	2.1	6.06	3.13	4.56	2.96	3.46	2.65	7.48	6.75	4.48
2005	6.37	6.67	3.49	3.37	2.43	1.98	6.31	2.95	4.64	2.99	3.54	2.63	7.83	6.6	4.62
2006	6.95	9.81	3.89	3.86	2.57	2.05	6.26	3.17	4.59	3.18	3.63	2.7	7.43	7.29	4.72
2007	6.56	8.2	3.88	3.81	2.61	2.08	6.28	3.18	4.6	3.18	3.7	2.69	7.73	7.9	4.82
2008	6.81	9	3.89	4.2	2.61	2.01	6.43	3.31	4.82	3.35	3.83	2.77	8.09	7.92	4.98
2009	6.88	8.71	4.12	4.33	2.61	2.39	6.56	3.28	4.88	3.55	3.77	2.78	7.68	7.99	5.3
2010	5.05	10.37	4.01	4.22	2.6	2.37	6.59	3.19	4.73	3.64	3.52	2.81	7.94	7.09	5.39
2011	6.69	9.53	4.06	4.83	2.45	2.38	6.55	3.36	4.67	3.57	3.69	2.88	7.54	8.38	5.55
2012	6.6	8.92	4.31	4.78	2.55	2.41	6.69	3.58	4.73	3.38	3.71	2.82	7.92	7.87	5.61
2013	6.7	10.18	4.35	4.95	2.6	2.45	6.78	3.72	4.72	3.63	3.86	2.82	8.37	7.86	5.6

Appendix Table 3. Arkansas Global Rice Model Projected Yields 2018 and 2023

AGRM Projected Yields 2018 & 2023 (t/ha (milled)						
Country	**2018**	**2023**		**Country**	**2018**	**2023**
Argentina	4.45	4.71		Japan	4.88	4.93
Australia	7.57	8.08		Laos	1.87	2.02
Bangladesh	3.05	3.28		Liberia	0.88	0.93
Benin	3.64	3.85		Malaysia	2.64	2.79
Brazil	3.55	3.79		Mali	2.35	2.6
Burkina	2.55	2.69		Mexico	3.86	4
Burma	1.85	1.97		Niger	6.50	6.87
Cambodia	1.75	2		Nigeria	1.22	1.34
Cameroon	1.02	1.12		Pakistan	2.51	2.65
China	4.84	4.97		Philippines	2.56	2.65
Columbia	3.37	3.57		Senegal	2.91	3.25
Cote d'Ivoire	1.27	1.39		Sierra Leone	1.35	1.51
Egypt	6.43	6.8		South Korea	5.17	5.24
Gambia, The	1.43	1.51		Taiwan	4.16	4.23
Ghana	1.76	1.92		Tanzania	1.55	1.69
Guinea	1.35	1.49		Thailand	1.95	2.06
Guinea-Bissau	2.03	2.15		Togo	2.74	2.90
India	2.55	2.71		Turkey	5.25	5.54
Indonesia	3.14	3.32		United States	6.23	6.52
Iran	2.91	3.03		Uruguay	5.91	6.17
Iraq	2.25	2.31		Vietnam	3.7	3.79

Appendix Table 4. Global Insight Population Projections

Global Insight World Population Projections (millions of people)						
Regions	**2018**	**2023**		**Regions**	**2018**	**2023**
Argentina	0.782	0.716		Mali	2.607	2.360
Australia	1.246	1.138		Mexico	1.043	0.932
Bangladesh	1.118	0.963		Myanmar	1.000	0.537
Benin	2.300	1.986		Nicaragua	1.270	1.087
Bolivia	1.562	1.450		Niger	3.737	3.598
Brazil	0.719	0.601		Nigeria	2.745	2.679
Burkina Faso	2.692	2.526		Pakistan	1.571	1.415
Cambodia	1.562	1.352		Panama	1.500	1.364
Cameroon	1.325	1.180		Paraguay	1.584	1.426
Canada	1.099	1.045		Peru	1.203	1.064
Chile	0.793	0.678		Philippines	1.631	1.554
China	0.445	0.219		Russia	-0.286	-0.446
Colombia	1.117	0.942		Saudi Arabia	1.600	1.117
Costa Rica	1.145	0.939		Senegal	2.479	2.252
Cote d'Ivoire	1.304	1.211		Sierra Leone	1.834	1.758
Cuba	-0.155	-0.262		Singapore	1.534	0.849
Ecuador	1.424	1.284		South Africa	0.579	0.563
Egypt	1.456	1.267		South Korea	0.401	0.328
El Salvador	0.581	0.425		Sri Lanka	0.665	0.476
EU 27	0.002	0.001		Suriname	0.755	0.649
Gambia	3.081	2.952		Taiwan	0.154	0.143
Ghana	1.973	1.791		Tanzania	2.888	2.782
Guatemala	2.374	2.212		Thailand	0.127	0.012
Guinea	2.203	1.921		Togo	2.345	2.127
Guinea-Bissau	2.042	1.970		Turkey	0.901	0.839
Guyana	0.428	0.383		UAE	2.222	1.581
Haiti	1.256	1.119		USA	0.769	0.739
Honduras	1.854	1.676		Uruguay	0.290	0.318
Hong Kong	0.630	0.508		Venezuela	1.359	1.168
India	1.078	0.951		Vietnam	0.774	0.557
Indonesia	1.047	0.917		Africa	0.024	0.022
Iran	1.151	0.909		Asia	0.013	0.011
Iraq	2.589	2.448		Caribbean	0.007	0.006
Japan	-0.341	-0.433		Europe	-0.003	-0.004
Laos	1.742	1.529		Middle East	0.020	0.016
Liberia	2.261	1.942		Oceania	0.015	0.015
Malaysia	1.392	1.250				

Appendix Table 5. Global Insight Gross Domestic Product Growth Projections 2018 & 2023

Global Insight Real GDP Percentage Change Projections (2013 Base Year)						
Regions	**2018**	**2023**		**Regions**	**2018**	**2023**
Argentina	4.16	3.72		Mali	4.62	3.97
Australia	2.75	2.70		Mexico	3.60	3.24
Bangladesh	6.24	5.70		Myanmar	6.80	5.70
Benin	4.11	3.53		Nicaragua	3.32	4.17
Bolivia	5.27	4.80		Niger	5.49	4.39
Brazil	3.64	3.79		Nigeria	5.96	4.61
Burkina Faso	4.91	4.31		Pakistan	4.84	5.03
Cambodia	7.90	7.43		Panama	4.58	3.48
Cameroon	4.70	3.83		Paraguay	3.84	2.87
Canada	2.06	2.02		Peru	4.70	4.06
Chile	4.77	4.70		Philippines	4.74	4.70
China	7.76	6.32		Russia	2.60	2.47
Colombia	4.60	4.35		Saudi Arabia	4.48	4.35
Costa Rica	3.98	4.07		Senegal	4.41	4.05
Cote d'Ivoire	5.07	2.85		Sierra Leone	6.28	4.54
Cuba	4.77	5.11		Singapore	3.98	3.70
Ecuador	3.21	3.25		South Africa	4.34	4.51
Egypt	4.81	4.54		South Korea	3.22	2.58
El Salvador	3.23	3.45		Sri Lanka	6.18	5.81
EU 27	1.83	1.74		Suriname	3.73	3.86
Gambia	5.01	4.65		Taiwan	3.47	2.89
Ghana	5.50	5.00		Tanzania	7.41	7.06
Guatemala	3.54	3.61		Thailand	3.98	3.91
Guinea	7.00	3.30		Togo	3.86	3.38
Guinea-Bissau	3.10	2.89		Turkey	3.99	3.46
Guyana	3.01	2.75		UAE	4.50	3.46
Haiti	4.00	3.00		USA	1.56	1.71
Honduras	3.75	3.67		Uruguay	3.83	3.04
Hong Kong	3.58	3.34		Venezuela	3.28	3.99
India	7.65	6.71		Vietnam	5.95	6.44
Indonesia	5.22	5.02		Africa	5.16	4.56
Iran	3.01	3.42		Asia	4.65	3.49
Iraq	6.55	5.73		Caribbean	2.81	2.80
Japan	0.96	0.86		Europe	2.12	1.92
Laos	7.41	6.66		Middle East	4.46	3.86
Liberia	5.65	4.85		Oceania	3.15	2.66
Malaysia	4.54	4.31				

Appendix Table 6. 2013 Yield Simulation Iterations

	1	2	3	4	5	6	7	8	9	10	11	12	13
Argentina	6.959	6.913	7.288	6.546	7.304	7.283	5.380	5.558	6.554	6.951	7.091	6.180	6.342
Australia	11.118	9.827	10.551	11.146	9.704	8.230	8.542	10.639	9.392	9.253	9.914	11.808	9.600
Bangladesh	4.649	4.238	4.433	4.479	4.576	4.399	4.408	4.360	4.429	4.467	4.650	4.471	4.333
Benin	3.640	4.338	2.901	3.581	4.423	3.753	3.724	3.450	3.522	3.451	3.798	2.529	2.953
Brazil	5.882	5.252	4.758	4.656	5.114	5.296	4.630	4.860	5.073	5.112	5.818	4.687	4.968
Burkina	2.222	2.960	2.472	1.803	2.232	2.032	2.265	2.951	1.988	2.947	2.465	2.709	1.933
Burma	2.416	2.455	2.727	2.713	2.381	2.361	2.500	2.500	2.343	2.507	2.507	2.963	2.649
Cambodia	2.554	2.659	2.616	2.120	2.521	2.486	2.490	2.455	2.616	2.658	2.643	2.201	2.486
China	6.560	7.148	6.804	6.671	6.709	6.667	6.840	6.928	6.869	6.670	6.537	6.784	6.669
Cote d'Ivoire	1.948	1.929	1.468	1.619	2.112	1.662	1.905	2.096	2.260	2.355	1.895	1.592	1.654
Gambia	1.320	1.062	1.294	1.211	0.924	1.298	1.408	1.330	1.249	1.383	0.942	1.294	1.454
Ghana	2.428	2.454	2.178	2.768	1.725	2.434	2.084	2.550	1.704	2.493	2.283	2.766	2.536
Guinea	1.783	2.077	2.115	1.543	1.874	2.126	1.874	1.989	1.528	1.520	1.975	1.935	1.878
Guinea-Bissau	1.163	1.644	1.864	1.900	1.346	1.746	1.894	1.759	1.780	1.625	1.639	2.524	1.822
India	3.677	3.523	3.872	3.740	3.734	3.749	3.674	3.758	3.699	3.672	3.760	3.797	3.671
Indonesia	4.503	4.679	4.538	4.899	4.642	4.510	4.721	4.765	4.599	4.678	4.906	4.853	4.568
Liberia	1.217	1.461	1.198	0.897	1.446	1.101	1.095	1.308	1.298	1.308	1.280	0.629	0.897
Mali	3.242	3.008	3.394	3.008	3.065	3.583	3.057	3.023	2.743	2.871	4.341	2.897	3.286
Niger	8.906	6.776	5.813	5.458	6.079	7.578	6.546	4.839	8.298	6.409	5.898	4.307	7.224
Nigeria	1.674	1.729	1.654	2.512	1.590	1.601	1.981	1.827	1.870	1.577	2.210	1.868	1.701
Pakistan	3.990	3.984	3.582	3.300	3.850	3.779	3.555	3.745	3.777	3.773	3.909	3.280	3.671
Philippines	3.993	3.755	3.718	3.997	4.042	4.002	3.760	3.687	4.001	3.842	4.108	3.681	3.710
Senegal	4.657	3.255	4.750	4.530	3.683	4.536	3.893	3.710	4.940	3.884	3.565	4.238	4.597
Sierra Leone	1.969	1.843	1.955	2.048	1.558	2.014	1.769	1.748	2.013	1.607	2.193	1.843	1.837
Thailand	2.871	2.854	2.758	2.830	2.800	2.854	2.762	2.817	2.741	2.872	2.890	2.831	2.878
Togo	4.092	2.898	2.842	2.301	3.104	2.875	1.941	2.333	2.945	2.830	3.060	1.678	2.448
United States	8.267	7.958	8.079	8.510	8.395	8.236	8.514	7.894	8.519	8.514	8.635	8.263	8.269
Uruguay	7.306	8.647	7.128	8.518	8.178	7.933	7.414	7.664	7.895	8.476	9.115	7.391	6.816
Vietnam	5.769	5.657	5.442	5.766	5.547	5.647	5.647	5.772	5.529	5.527	6.089	5.488	5.712

Appendix Table 6. 2013 Yield Simulation Iterations **(Continued)**

	14	15	16	17	18	19	20	21	22	23	24	25	26
Argentina	7.096	7.002	7.018	7.125	6.071	7.131	7.055	7.037	7.100	7.021	6.410	6.178	5.975
Australia	9.481	11.186	11.384	11.163	11.202	11.220	11.111	10.039	9.533	8.483	9.914	11.050	11.164
Bangladesh	4.336	4.317	4.384	4.357	4.295	3.944	4.238	3.985	4.290	4.351	4.588	4.486	4.345
Benin	3.253	3.452	2.678	2.902	3.718	3.458	2.747	3.502	2.914	2.909	3.649	4.005	3.391
Brazil	4.646	4.689	4.877	4.864	5.227	4.635	4.602	4.993	4.680	4.991	5.886	5.233	4.712
Burkina	1.935	2.733	2.055	1.539	2.348	2.669	2.700	1.941	2.029	2.171	1.931	1.900	1.934
Burma	2.700	2.906	2.812	2.451	2.727	2.889	2.865	2.497	2.629	2.475	2.348	2.451	2.461
Cambodia	2.347	2.668	2.231	2.025	2.632	2.489	2.245	2.449	2.532	2.416	2.312	2.477	2.365
China	6.787	6.694	6.901	6.751	7.081	6.923	6.765	6.855	6.670	6.605	6.761	6.731	6.853
Cote d'Ivoire	2.107	1.929	1.716	1.632	1.670	1.410	1.790	1.658	1.812	1.912	2.169	2.195	1.959
Gambia	1.343	1.413	1.778	0.959	1.347	1.018	1.460	1.447	1.547	0.948	0.946	1.320	1.448
Ghana	2.462	2.358	3.113	3.164	2.510	2.922	2.796	3.079	2.894	1.993	1.875	2.195	2.476
Guinea	1.795	1.484	2.052	2.090	1.843	1.987	1.887	2.106	2.061	1.987	1.866	1.816	1.687
Guinea-Bissau	1.795	1.862	1.666	2.284	2.171	2.083	2.373	1.899	1.861	1.836	1.759	1.180	1.880
India	3.505	3.781	3.853	3.997	3.759	3.893	3.917	3.864	3.537	3.687	3.880	3.670	3.686
Indonesia	4.706	4.858	4.629	4.906	4.653	4.829	4.876	4.773	4.680	4.718	4.784	4.590	4.759
Liberia	1.095	1.270	0.898	1.133	1.217	1.254	1.140	1.274	1.253	1.053	1.284	1.282	1.230
Mali	2.479	2.687	2.981	3.357	3.306	3.068	2.892	3.062	3.288	3.063	3.595	3.171	2.926
Niger	4.688	4.754	4.689	4.607	8.771	4.652	3.788	5.461	4.928	4.990	7.575	8.597	7.625
Nigeria	1.550	1.836	1.607	2.530	2.213	2.063	1.789	2.227	2.032	1.462	2.161	1.588	2.189
Pakistan	3.515	3.284	3.526	3.440	3.568	3.295	3.281	3.598	3.614	3.723	3.831	3.734	3.525
Philippines	4.001	3.844	3.847	4.044	3.635	3.636	3.883	3.843	3.692	4.071	4.047	3.749	3.730
Senegal	3.263	3.441	3.904	4.873	4.770	3.727	3.226	3.703	3.578	3.335	4.971	4.587	4.297
Sierra Leone	1.424	1.735	1.449	1.985	2.351	1.792	1.393	2.243	1.722	1.439	2.289	1.848	2.135
Thailand	2.859	2.752	2.825	2.772	2.707	2.741	2.762	2.740	2.855	2.921	2.769	2.954	2.741
Togo	2.475	1.751	2.487	2.310	1.996	1.721	1.902	2.132	2.784	2.660	3.122	3.062	2.522
United States	8.520	8.964	8.116	7.921	8.668	8.331	8.504	8.268	8.341	8.526	8.492	8.492	8.792
Uruguay	8.426	7.674	6.748	7.347	7.390	7.671	7.665	7.937	7.659	7.802	8.368	6.804	7.782
Vietnam	5.251	5.191	5.524	5.821	5.466	5.442	5.435	5.644	5.630	5.677	6.031	5.810	5.596

Appendix Table 6. 2013 Yield Simulation Iterations **(Continued)**

	27	28	29	30	31	32	33	34	35	36	37	38	39
Argentina	7.099	6.079	6.031	7.076	6.651	7.002	7.578	7.089	7.255	7.290	5.859	6.303	7.001
Australia	9.068	9.470	11.317	10.013	9.704	9.183	8.947	11.376	10.852	9.181	11.134	11.121	8.938
Bangladesh	4.427	4.438	4.314	4.069	4.319	4.177	4.251	4.433	4.292	3.945	4.087	4.399	4.299
Benin	4.010	2.932	2.918	3.135	4.737	3.420	3.086	3.359	2.790	2.692	3.525	3.603	2.926
Brazil	5.332	5.279	4.717	4.923	5.418	5.278	5.273	5.155	4.792	4.645	4.860	4.822	4.711
Burkina	2.766	2.536	2.210	2.570	2.268	1.930	2.769	2.297	2.237	2.484	1.878	2.041	2.304
Burma	2.387	2.494	2.641	2.643	2.354	2.360	2.655	2.722	2.637	2.739	2.489	2.711	2.488
Cambodia	2.722	2.529	2.228	2.560	2.574	2.466	2.546	2.442	2.356	2.486	2.177	2.369	2.487
China	7.077	6.500	6.977	6.854	6.773	6.670	6.855	6.520	6.823	6.762	6.670	6.645	6.690
Cote d'Ivoire	1.941	2.271	1.595	1.613	1.609	2.098	1.782	1.799	1.886	1.596	1.831	1.794	2.097
Gambia	1.270	1.341	1.060	0.956	0.573	1.034	1.347	0.946	1.294	1.286	1.331	1.327	1.800
Ghana	2.334	2.344	2.564	2.788	2.405	2.545	3.090	2.831	2.801	2.913	3.047	2.515	2.510
Guinea	2.126	1.874	1.791	2.231	2.087	2.074	2.294	1.935	2.139	2.272	1.770	1.958	1.881
Guinea-Bissau	1.855	1.648	2.571	2.054	1.870	2.086	1.860	1.852	2.004	1.823	2.520	2.057	2.544
India	3.675	3.736	3.756	3.456	3.759	3.760	3.679	3.760	3.904	3.542	3.673	3.762	3.854
Indonesia	4.577	4.644	4.832	4.645	4.776	4.805	4.542	4.820	4.864	4.685	4.876	4.903	4.861
Liberia	1.277	1.136	1.095	1.202	1.362	1.274	1.255	1.137	1.274	1.248	1.185	1.139	1.254
Mali	3.056	3.544	2.675	3.057	3.664	3.421	2.916	3.384	3.495	3.475	2.477	3.257	3.517
Niger	8.788	8.149	5.562	5.523	8.366	6.564	4.689	7.619	4.255	4.335	7.568	5.835	4.655
Nigeria	1.594	1.522	2.218	1.587	2.214	1.880	1.462	2.208	1.661	1.538	2.363	2.219	2.198
Pakistan	4.011	3.741	3.295	3.718	4.056	3.744	3.778	3.445	3.446	3.724	3.638	3.405	3.555
Philippines	3.965	3.847	3.756	3.720	3.925	4.044	3.851	3.991	3.940	3.758	3.882	3.923	3.989
Senegal	4.368	3.715	4.673	3.268	4.673	3.855	3.254	3.688	3.445	3.153	3.701	3.941	4.394
Sierra Leone	2.257	1.856	2.039	1.722	2.359	2.216	1.538	2.115	1.705	1.390	2.260	2.264	2.244
Thailand	2.759	2.973	2.632	2.827	2.764	2.905	2.829	2.884	2.829	2.861	2.746	2.883	2.879
Togo	2.819	2.907	1.708	2.025	2.663	2.625	2.163	2.663	2.308	2.659	1.717	1.818	2.641
United States	8.321	8.495	8.508	8.266	8.267	8.519	7.699	8.745	8.274	7.887	8.802	8.641	8.718
Uruguay	9.274	8.000	7.292	8.158	8.597	8.574	8.694	8.475	8.426	7.665	7.774	8.305	8.488
Vietnam	5.493	5.833	5.542	5.613	5.907	5.768	5.442	5.544	5.564	5.485	5.776	5.800	5.653

Appendix Table 6. 2013 Yield Simulation Iterations **(Continued)**

	40	41	42	43	44	45	46	47	48	49	50	51	52
Argentina	6.137	6.553	6.232	6.319	6.430	5.366	6.945	6.522	7.186	5.344	6.937	7.018	6.292
Australia	11.080	9.214	11.376	11.330	11.814	11.035	11.081	11.039	8.047	11.054	11.089	8.192	11.036
Bangladesh	4.395	4.292	4.456	4.445	4.302	4.433	4.278	4.324	4.448	4.543	4.468	4.433	4.045
Benin	3.839	2.283	3.407	3.329	2.940	4.008	3.408	3.083	4.142	2.829	3.268	2.661	2.871
Brazil	5.422	4.548	5.147	4.965	4.779	4.778	4.864	4.636	5.233	4.683	4.677	4.865	5.279
Burkina	2.456	2.504	2.697	2.269	2.210	2.702	2.206	2.887	2.346	2.547	2.547	2.637	2.308
Burma	2.354	2.731	2.501	2.500	2.727	2.653	2.638	2.712	2.343	2.727	2.815	2.655	2.635
Cambodia	2.458	2.530	2.236	2.448	2.471	2.489	2.295	2.606	2.531	2.321	2.615	2.537	2.470
China	6.585	6.824	6.669	6.879	6.698	6.717	7.149	7.084	6.720	6.699	6.855	6.694	6.878
Cote d'Ivoire	1.970	2.096	1.806	2.056	1.663	2.111	1.792	1.930	1.946	2.067	2.094	2.046	1.659
Gambia	0.941	1.813	1.125	1.366	1.340	1.843	1.344	1.344	0.918	1.416	1.071	1.623	1.294
Ghana	2.513	2.510	2.590	2.529	3.137	1.814	2.798	2.358	2.305	2.519	2.753	2.773	3.165
Guinea	1.863	2.049	1.757	1.874	1.989	1.457	2.051	1.969	2.051	1.792	1.983	2.087	2.263
Guinea-Bissau	1.660	2.544	1.912	1.668	1.863	1.534	2.328	1.869	1.767	1.372	1.312	1.760	1.892
India	3.671	3.827	4.015	3.520	3.760	3.758	3.757	3.674	3.678	3.753	3.416	3.446	3.504
Indonesia	4.680	4.783	4.887	4.684	4.722	4.672	4.791	4.642	4.662	4.771	4.672	4.829	4.623
Liberia	1.263	1.146	1.250	1.222	1.204	1.095	1.190	1.276	1.360	1.148	1.295	1.137	1.168
Mali	3.052	3.211	2.922	2.602	3.406	2.481	2.921	2.899	3.212	3.005	2.975	3.594	3.331
Niger	8.924	4.451	5.454	7.627	6.011	7.913	4.737	5.243	7.209	5.710	4.994	4.537	7.959
Nigeria	2.187	1.678	2.411	2.189	2.604	1.701	2.215	1.675	1.700	2.186	1.584	1.531	2.170
Pakistan	3.698	3.552	3.346	3.631	3.547	3.312	3.588	3.534	3.985	3.696	3.854	3.745	4.034
Philippines	4.002	3.752	4.041	3.960	3.686	3.702	3.926	3.678	4.053	3.763	3.688	3.928	3.686
Senegal	4.671	3.722	4.661	4.536	4.204	3.921	3.743	4.421	4.330	4.215	3.009	3.420	3.847
Sierra Leone	2.300	1.526	2.238	2.036	2.174	1.929	1.957	1.775	1.963	1.736	1.321	1.327	1.970
Thailand	2.912	2.875	2.739	2.772	2.826	2.859	2.562	2.880	2.756	2.831	2.968	2.951	2.817
Togo	2.870	2.139	1.832	2.728	2.478	2.475	2.109	2.600	2.761	2.866	3.474	3.537	2.475
United States	8.493	8.495	8.505	8.737	8.256	8.503	8.526	8.386	8.498	8.167	7.915	7.960	7.897
Uruguay	7.963	7.686	7.365	7.335	7.258	8.132	8.012	7.951	8.523	6.906	8.043	7.846	7.334
Vietnam	5.793	5.490	5.744	5.521	5.603	5.540	5.426	5.442	5.581	5.550	5.650	5.788	5.734

Appendix Table 6. 2013 Yield Simulation Iterations **(Continued)**

	53	54	55	56	57	58	59	60	61	62	63	64	65
Argentina	7.086	6.522	7.581	6.399	7.100	6.361	6.409	7.275	7.017	7.532	6.529	6.926	6.762
Australia	9.914	10.159	8.168	8.144	10.043	9.748	11.208	9.914	10.020	11.081	11.160	10.044	10.366
Bangladesh	4.416	4.282	4.516	4.659	4.359	4.658	4.395	4.321	4.648	4.484	4.516	4.449	3.967
Benin	3.415	3.448	3.667	3.769	2.662	3.460	3.450	3.529	3.478	2.918	3.410	3.451	2.879
Brazil	5.375	4.818	5.232	5.328	4.598	5.324	5.293	4.702	5.297	5.148	4.813	5.184	4.593
Burkina	2.479	1.811	1.737	2.343	1.987	2.709	2.733	1.929	2.350	2.704	2.731	2.721	2.343
Burma	2.507	2.479	2.354	2.357	2.743	2.458	2.727	2.496	2.480	2.795	2.740	2.714	2.669
Cambodia	2.614	2.447	2.530	2.531	2.240	2.481	2.458	2.425	2.658	2.479	2.465	2.600	2.483
China	6.703	6.928	6.582	6.505	6.504	6.755	6.856	6.904	6.576	6.838	6.812	6.761	6.712
Cote d'Ivoire	1.810	1.792	1.913	2.312	1.910	2.388	1.934	1.957	2.139	1.681	2.156	1.973	1.806
Gambia	1.292	0.966	0.971	1.344	1.421	1.227	1.187	1.294	1.071	1.067	1.744	1.354	1.490
Ghana	2.689	2.510	2.269	1.677	2.237	2.454	2.997	2.700	2.607	2.757	2.830	2.529	2.606
Guinea	2.144	1.988	1.933	1.774	1.874	1.860	1.934	2.014	1.791	2.336	1.991	1.866	1.935
Guinea-Bissau	1.928	1.857	1.534	1.193	1.746	1.431	1.754	1.981	1.337	1.797	1.866	1.656	2.458
India	3.880	3.741	3.588	3.675	3.860	3.651	3.828	3.863	3.290	3.760	3.892	3.498	3.860
Indonesia	4.688	4.738	4.761	4.514	4.679	4.856	4.643	4.722	4.525	4.652	4.845	4.771	4.746
Liberia	1.248	1.255	1.277	1.100	0.898	1.304	1.223	1.278	1.137	1.252	1.136	1.255	1.252
Mali	3.672	3.098	3.225	3.292	3.115	2.912	2.874	3.183	2.986	3.602	2.863	2.699	3.037
Niger	6.491	4.927	5.042	8.959	4.634	5.843	6.716	4.647	8.881	4.980	4.680	6.017	4.638
Nigeria	1.596	2.052	1.630	1.519	1.506	1.812	1.805	2.034	1.607	1.569	1.804	1.877	1.814
Pakistan	3.873	3.695	3.636	3.924	3.445	3.906	3.697	3.743	3.892	3.695	3.541	3.778	3.302
Philippines	3.977	3.723	4.142	4.096	4.038	4.035	3.721	4.002	3.963	3.997	3.897	4.008	3.690
Senegal	4.619	4.157	4.682	4.672	3.346	3.883	3.897	3.608	4.738	3.420	3.724	3.222	3.718
Sierra Leone	1.859	1.937	1.868	1.769	1.510	1.856	1.722	1.788	1.855	1.814	1.683	1.779	1.855
Thailand	2.966	2.741	2.871	2.968	2.867	2.878	2.885	2.771	2.965	2.854	2.869	2.744	2.804
Togo	2.793	2.147	2.834	4.510	2.477	2.784	2.474	2.299	3.064	2.477	2.041	2.407	1.712
United States	7.917	8.508	8.516	8.504	8.864	8.508	7.817	8.504	8.429	8.107	8.322	8.774	8.559
Uruguay	8.178	7.148	8.431	7.332	6.688	9.020	8.427	8.597	8.167	8.430	8.177	8.171	7.117
Vietnam	6.021	5.655	5.600	5.769	5.220	5.769	5.729	5.462	5.767	5.441	5.702	5.442	5.443

Appendix Table 6. 2013 Yield Simulation Iterations **(Continued)**

	66	67	68	69	70	71	72	73	74	75	76	77	78
Argentina	6.927	6.482	7.059	6.407	6.504	6.435	6.861	6.516	5.685	6.423	5.560	7.001	6.422
Australia	11.080	10.640	8.456	11.210	11.027	11.053	9.710	9.138	10.997	11.067	11.204	11.186	9.956
Bangladesh	4.383	4.444	4.156	4.306	4.395	4.320	4.429	4.105	4.495	4.397	4.453	4.545	4.325
Benin	2.940	3.504	3.552	3.406	2.689	2.934	2.698	3.165	4.372	4.577	2.834	3.462	2.916
Brazil	4.863	5.377	4.871	4.606	4.710	4.976	4.565	4.816	5.390	5.282	4.639	4.822	4.634
Burkina	2.196	2.956	1.931	2.877	2.203	1.927	2.367	2.727	2.527	2.472	2.259	2.748	2.194
Burma	2.641	2.500	2.425	2.887	2.645	2.432	2.859	2.361	2.361	2.644	2.897	2.800	2.711
Cambodia	2.470	2.635	2.367	2.393	2.261	2.237	2.615	2.330	2.486	2.507	2.340	2.589	2.477
China	6.798	6.886	6.854	6.687	6.669	6.739	6.577	6.767	6.761	6.928	6.910	6.927	6.889
Cote d'Ivoire	1.592	1.851	1.901	1.786	1.711	1.913	1.799	1.934	1.812	1.793	1.800	1.592	2.108
Gambia	0.941	0.880	1.651	1.510	1.375	1.211	1.816	1.741	1.069	1.335	1.839	1.454	1.354
Ghana	2.768	2.706	3.099	2.362	2.491	2.506	2.378	2.223	2.368	2.869	2.825	2.321	1.699
Guinea	2.145	2.137	1.878	1.647	1.976	1.936	1.986	1.935	1.777	1.870	1.866	2.074	1.978
Guinea-Bissau	1.757	1.768	1.785	2.083	2.011	2.100	1.779	1.787	1.776	1.429	1.823	1.439	2.569
India	3.748	3.506	3.785	3.929	3.802	3.860	3.745	3.861	3.525	3.748	3.751	3.687	3.830
Indonesia	4.617	4.601	4.722	4.877	4.752	4.691	4.680	4.591	4.877	4.597	4.873	4.513	4.877
Liberia	1.248	1.295	1.148	1.234	1.095	1.248	0.897	1.304	1.235	1.187	0.898	1.254	1.271
Mali	3.662	3.225	2.653	2.844	3.070	3.119	3.435	2.890	3.076	2.701	3.073	3.141	3.384
Niger	6.133	6.763	5.201	4.568	5.420	5.789	4.845	5.684	8.673	8.416	4.655	6.636	5.536
Nigeria	2.191	1.588	2.110	1.675	2.187	1.898	1.624	1.681	2.604	1.883	2.191	1.972	2.027
Pakistan	3.718	4.136	3.635	3.293	3.510	3.563	3.306	3.729	3.636	3.739	3.283	3.745	3.352
Philippines	3.634	3.842	3.998	3.747	4.002	3.927	3.722	4.004	4.002	3.619	3.638	3.683	4.001
Senegal	4.649	3.368	3.477	3.635	4.146	4.413	4.147	3.314	4.661	3.302	4.689	3.636	4.147
Sierra Leone	2.096	1.572	1.685	1.722	1.968	1.999	1.797	1.681	2.370	1.787	1.841	1.869	1.987
Thailand	2.855	2.885	2.732	2.740	2.740	2.771	2.897	2.745	2.739	2.829	2.757	2.743	2.745
Togo	2.774	3.395	2.232	1.704	2.137	2.383	1.947	3.059	2.297	2.721	1.781	2.839	2.380
United States	7.687	7.922	8.339	8.814	8.517	8.495	8.763	8.508	8.512	7.978	8.351	7.902	8.983
Uruguay	7.657	8.369	8.170	6.984	6.942	7.371	6.942	6.968	9.081	8.603	6.870	7.306	7.704
Vietnam	5.724	6.057	5.542	5.418	5.448	5.516	5.475	5.489	5.770	5.826	5.599	5.509	5.323

Appendix Table 6. 2013 Yield Simulation Iterations **(Continued)**

	79	80	81	82	83	84	85	86	87	88	89	90	91
Argentina	6.339	6.268	7.093	7.197	6.543	7.533	7.292	6.377	6.438	6.377	7.073	6.440	6.937
Australia	11.017	11.140	11.029	9.046	10.640	7.656	9.589	11.401	9.701	9.615	9.951	11.278	9.940
Bangladesh	4.296	4.319	4.405	4.600	4.439	4.371	4.361	4.416	4.491	3.941	4.305	4.323	4.484
Benin	3.631	3.064	3.418	3.465	3.720	4.052	3.191	3.201	3.455	2.928	3.422	3.372	3.836
Brazil	4.701	4.641	4.882	4.968	5.198	5.289	4.877	4.678	5.002	4.861	5.176	4.694	4.845
Burkina	2.724	2.920	2.907	2.532	2.950	2.435	1.973	1.633	1.933	2.239	1.898	2.247	1.599
Burma	2.838	2.727	2.777	2.727	2.710	2.361	2.713	2.727	2.465	2.508	2.655	2.654	2.460
Cambodia	2.730	2.459	2.608	2.569	2.661	2.303	2.616	2.459	2.350	2.347	2.452	2.364	2.472
China	6.716	6.868	6.897	6.767	6.883	6.527	6.738	6.915	6.670	6.771	6.901	7.026	6.736
Cote d'Ivoire	1.745	1.911	1.906	1.902	1.913	2.145	1.960	1.637	2.200	1.716	1.785	1.829	1.777
Gambia	1.775	1.554	1.355	1.630	1.450	1.025	1.646	1.278	1.298	1.344	1.001	1.433	0.871
Ghana	2.768	2.722	2.783	1.648	1.714	1.695	3.078	2.801	2.365	3.122	2.339	2.594	1.695
Guinea	1.776	1.555	1.891	1.649	1.878	1.973	2.019	1.755	1.807	2.129	2.109	1.800	1.884
Guinea-Bissau	1.758	1.638	1.527	1.346	1.754	1.780	1.580	1.872	1.795	2.086	2.505	1.861	1.896
India	3.795	3.955	3.666	3.987	3.827	3.785	3.522	3.482	3.509	3.679	3.805	3.856	3.789
Indonesia	4.591	4.669	4.534	4.653	4.514	4.782	4.661	4.686	4.870	4.607	4.680	4.645	4.834
Liberia	1.141	1.193	1.222	1.186	1.276	1.242	1.235	1.067	1.140	0.773	1.104	1.122	1.246
Mali	3.236	2.482	2.625	3.287	2.912	2.772	3.546	2.689	2.880	3.297	3.224	2.879	3.420
Niger	7.317	4.863	5.364	4.720	7.797	4.687	4.869	5.800	5.786	6.263	5.700	5.746	5.695
Nigeria	2.064	1.805	1.442	1.578	1.479	1.458	1.700	2.228	1.701	1.758	1.490	1.678	2.054
Pakistan	3.525	3.446	3.697	3.444	3.808	3.603	3.550	3.550	3.638	3.837	3.661	3.454	3.538
Philippines	3.559	3.686	3.688	3.856	3.694	4.151	3.704	3.667	4.047	3.823	3.972	3.688	3.847
Senegal	4.528	4.193	3.738	4.164	4.135	3.024	3.536	4.799	3.370	3.685	3.776	4.430	4.628
Sierra Leone	1.915	1.420	1.339	1.471	1.763	1.459	1.468	2.242	1.825	1.722	1.706	1.752	2.242
Thailand	2.803	2.855	2.930	2.772	2.946	2.869	2.913	2.747	2.870	2.842	2.874	2.764	2.763
Togo	2.252	2.870	2.497	3.461	3.013	2.720	3.061	1.818	2.502	2.467	2.385	2.292	2.144
United States	8.509	7.922	8.018	8.426	8.276	8.510	8.039	8.505	8.772	7.897	8.199	8.497	8.732
Uruguay	6.803	7.334	7.970	8.035	8.168	8.988	8.353	7.043	8.596	7.677	8.287	7.950	7.813
Vietnam	5.447	5.506	5.542	5.491	5.726	5.444	5.543	5.497	5.760	5.534	5.587	5.492	5.751

Appendix Table 6. 2013 Yield Simulation Iterations **(Continued)**

	92	93	94	95	96	97	98	99	100
Argentina	7.165	7.032	7.331	7.054	6.872	6.259	7.015	7.553	7.097
Australia	9.932	8.996	10.091	9.270	10.337	9.112	10.121	9.956	11.807
Bangladesh	4.272	4.358	4.435	4.057	4.667	4.348	4.322	4.390	4.401
Benin	3.303	3.540	3.564	4.082	2.682	3.405	3.424	2.904	2.936
Brazil	4.796	5.177	5.277	4.637	5.094	4.691	4.866	4.680	4.562
Burkina	1.576	1.574	2.889	1.923	2.477	2.562	2.031	2.365	2.207
Burma	2.454	2.344	2.782	2.358	2.679	2.683	2.721	2.714	2.938
Cambodia	2.429	2.344	2.631	2.656	2.298	2.456	2.429	2.289	2.437
China	6.855	6.760	6.766	6.766	6.586	6.693	6.757	6.767	6.761
Cote d'Ivoire	1.666	2.013	1.880	2.224	2.172	1.729	1.592	1.941	1.613
Gambia	0.943	1.350	1.609	1.452	1.657	1.300	0.944	1.651	1.535
Ghana	2.573	2.528	3.164	2.768	2.385	2.342	2.913	2.913	2.763
Guinea	2.250	1.878	1.879	1.832	1.882	1.801	1.911	2.034	1.981
Guinea-Bissau	2.539	1.774	1.573	1.350	1.635	2.448	1.835	1.867	1.755
India	3.747	3.526	3.674	3.493	3.666	3.741	3.668	3.860	3.769
Indonesia	4.850	4.644	4.753	4.605	4.748	4.876	4.784	4.860	4.642
Liberia	1.297	1.274	1.143	1.426	0.897	1.110	1.164	1.260	1.095
Mali	4.003	3.048	2.894	2.910	3.059	3.138	2.884	3.060	2.966
Niger	4.877	5.789	4.899	6.359	5.671	5.459	5.454	3.611	4.776
Nigeria	2.190	1.608	2.137	1.784	1.868	2.161	2.095	1.701	1.600
Pakistan	3.732	3.784	3.697	3.908	3.320	3.540	3.745	3.546	3.349
Philippines	3.966	3.995	4.001	3.706	4.124	3.769	3.784	4.062	3.687
Senegal	4.338	4.674	3.749	3.290	4.674	4.051	4.569	3.136	3.357
Sierra Leone	2.244	1.984	1.715	1.586	1.720	2.076	1.911	1.357	1.412
Thailand	2.801	2.875	2.750	2.868	2.859	2.833	2.740	2.866	2.824
Togo	2.547	2.659	2.475	2.868	2.912	2.029	1.859	2.676	2.347
United States	8.495	8.488	8.205	8.524	8.492	8.734	8.259	8.443	8.468
Uruguay	8.164	8.073	8.651	7.778	7.290	8.433	7.337	8.630	6.815
Vietnam	5.668	5.824	5.406	5.638	5.440	5.780	5.522	5.549	5.366

Appendix Table 7. 2018 Yield Simulation Iterations

Iteration	1	2	3	4	5	6	7	8	9	10	11	12	13
Argentina	6.889	6.746	6.758	7.436	6.449	6.686	7.616	6.537	7.321	5.636	6.824	6.531	7.388
Australia	9.387	9.182	10.629	11.207	10.668	9.582	10.595	9.512	8.687	11.360	7.643	9.598	9.792
Bangladesh	4.602	4.648	4.635	4.596	4.536	4.580	4.491	4.609	4.507	4.446	4.579	4.749	4.584
Benin	3.190	3.408	3.658	2.755	3.187	3.063	3.550	3.137	3.614	2.734	4.148	5.483	3.788
Brazil	5.443	4.760	5.299	4.749	4.954	4.737	4.734	5.134	4.721	4.824	4.887	5.471	4.831
Burkina	1.732	2.705	2.482	2.136	2.122	2.816	2.972	3.304	2.477	2.675	2.445	1.720	2.422
Burma	2.695	3.024	2.967	3.196	2.646	2.874	3.214	2.968	2.710	3.063	2.717	2.554	2.955
Cambodia	2.705	2.738	2.619	2.705	2.599	2.575	2.722	2.877	2.715	2.358	2.851	2.889	2.654
China	6.735	6.926	6.961	6.965	7.329	6.962	7.058	7.129	6.928	7.033	6.961	6.739	6.927
Cote d'Ivoire	1.986	2.375	2.118	1.900	2.005	2.439	1.966	2.028	2.089	1.936	2.127	2.474	1.746
Gambia, The	1.322	1.946	1.467	1.768	1.190	1.903	2.049	1.722	1.422	1.288	1.935	1.070	1.156
Ghana	3.413	3.361	3.043	2.741	3.020	2.676	3.411	3.205	2.864	3.382	3.076	1.861	3.142
Guinea	2.297	2.000	2.169	2.123	2.481	2.057	2.148	2.253	2.183	2.195	2.075	1.562	2.057
Guinea-Bissau	2.193	1.673	1.795	1.930	2.088	2.084	1.930	2.057	1.959	2.833	1.492	1.365	1.800
India	3.865	3.932	3.960	4.079	4.068	3.885	4.127	3.815	3.615	4.169	3.522	3.720	3.976
Indonesia	5.095	4.951	4.947	4.859	4.912	5.081	5.036	4.894	4.948	5.121	4.901	4.896	4.905
Liberia	1.461	1.482	1.618	1.552	1.758	1.573	1.482	1.555	1.755	1.314	1.611	1.734	1.215
Mali	3.570	3.011	3.168	3.030	3.545	2.792	2.962	3.174	2.877	3.047	3.362	3.334	3.006
Niger	7.833	5.115	6.548	5.007	6.448	5.100	4.662	6.213	5.274	5.024	5.352	9.896	5.254
Nigeria	2.449	1.781	1.972	1.734	2.395	1.869	2.018	1.748	1.996	2.435	2.349	2.332	2.361
Pakistan	3.817	3.832	3.682	3.407	3.901	3.669	3.379	3.914	3.982	3.411	3.775	3.817	3.674
Philippines	4.194	3.965	3.896	3.761	3.720	4.161	3.896	3.820	4.044	3.820	3.900	3.989	3.992
Senegal	4.988	4.012	3.539	3.892	5.007	4.394	3.424	5.019	3.373	4.762	4.604	4.902	4.314
Sierra Leone	2.302	1.466	1.907	1.662	2.483	1.891	1.601	1.754	1.617	2.176	1.993	2.507	1.585
Thailand	2.976	3.008	2.991	2.977	2.988	2.951	3.021	2.952	2.870	2.857	2.930	2.962	2.858
Togo	2.697	2.715	2.893	2.652	2.939	2.692	2.351	2.771	2.939	1.881	2.716	3.026	2.923
United States	8.652	8.596	8.411	8.657	8.006	8.845	8.415	8.106	8.738	8.470	8.445	9.039	8.403
Uruguay	7.643	7.476	8.406	7.143	8.383	7.879	8.721	7.855	8.017	7.583	7.590	8.534	7.361
Vietnam	5.896	5.780	5.800	5.562	6.217	5.562	5.561	5.724	5.643	5.611	5.665	6.199	5.609

Appendix Table 7. 2018 Yield Simulation Iterations **(Continued)**

Iteration	14	15	16	17	18	19	20	21	22	23	24	25	26
Argentina	7.493	6.777	7.451	7.238	6.606	7.328	7.414	6.029	7.277	7.426	6.719	5.713	7.411
Australia	9.037	8.657	10.657	10.756	9.147	10.178	8.953	10.620	10.626	10.210	10.210	10.679	9.854
Bangladesh	4.602	4.553	4.326	4.733	4.734	4.492	4.701	4.517	4.146	4.864	4.859	4.548	4.506
Benin	3.867	4.490	3.234	3.931	3.787	4.438	4.072	3.228	3.481	3.788	3.789	2.980	3.197
Brazil	6.052	4.987	4.700	5.336	5.435	5.482	5.408	4.666	4.814	5.464	5.371	4.744	4.788
Burkina	2.104	2.572	2.030	3.297	3.259	2.765	2.753	2.112	3.266	2.965	2.281	2.094	2.071
Burma	2.560	2.661	3.178	3.015	2.647	2.569	2.721	2.952	3.223	2.973	2.609	2.689	2.733
Cambodia	2.560	2.862	2.603	2.883	2.874	2.927	2.867	2.503	2.864	2.910	2.719	2.503	2.706
China	6.949	7.025	7.184	6.988	6.920	6.925	6.806	7.120	7.048	6.803	6.915	7.281	7.141
Cote d'Ivoire	1.948	2.372	1.757	2.323	2.245	2.126	2.063	1.819	1.864	2.101	2.377	1.820	2.067
Gambia, The	1.034	1.599	1.482	1.085	1.424	1.421	1.463	1.903	1.488	1.419	1.471	1.477	1.486
Ghana	3.069	2.875	3.032	3.038	2.864	2.772	1.979	2.508	3.228	2.641	3.205	2.419	2.838
Guinea	2.538	1.691	2.133	2.046	2.136	2.184	2.057	2.062	2.129	2.066	2.265	2.175	2.165
Guinea-Bissau	2.138	1.884	2.252	1.747	2.041	2.161	1.855	1.998	2.000	1.473	1.792	2.299	1.931
India	4.102	3.691	3.933	3.870	3.639	4.177	3.884	3.680	3.834	4.108	3.864	3.980	3.867
Indonesia	4.947	4.904	5.110	4.951	4.934	4.884	4.901	4.743	4.927	5.091	4.807	4.899	4.833
Liberia	1.669	1.653	1.543	1.726	1.540	1.922	1.656	1.343	1.620	1.698	1.482	1.686	1.719
Mali	4.081	2.538	2.972	2.561	2.867	3.251	3.065	2.466	2.736	3.748	3.168	3.231	2.840
Niger	5.998	6.493	4.379	7.410	8.637	9.174	6.492	8.858	5.148	5.360	8.147	7.043	5.201
Nigeria	1.984	2.114	1.867	2.057	2.331	2.351	1.676	2.025	1.735	2.361	1.985	2.438	1.747
Pakistan	3.812	3.887	3.379	3.841	4.134	3.979	3.616	3.467	3.819	3.817	3.871	3.560	3.853
Philippines	4.195	3.937	3.820	4.078	4.148	4.147	4.177	3.766	3.750	4.187	4.071	3.804	3.853
Senegal	5.099	4.030	3.425	3.603	4.210	4.569	4.741	4.418	3.159	4.737	5.083	5.188	4.118
Sierra Leone	2.482	1.946	1.587	1.891	2.148	2.567	1.928	2.167	1.564	2.086	1.952	2.548	1.607
Thailand	2.978	2.934	2.871	2.857	2.884	2.916	2.986	2.860	2.988	3.007	3.040	2.823	2.891
Togo	2.617	2.635	1.953	2.714	2.982	2.571	2.832	2.352	2.271	3.148	2.956	2.449	3.177
United States	7.920	8.655	8.663	8.654	8.464	8.856	8.655	8.798	8.417	8.518	8.072	8.788	8.416
Uruguay	8.545	9.003	8.383	8.741	9.265	8.815	8.085	7.104	8.814	8.535	8.067	6.963	7.497
Vietnam	5.953	5.783	5.529	5.450	5.822	5.878	5.723	5.608	5.543	5.897	6.109	5.773	5.613

Appendix Table 7. 2018 Yield Simulation Iterations **(Continued)**

Iteration	27	28	29	30	31	32	33	34	35	36	37	38	39
Argentina	6.716	6.554	7.914	6.892	7.354	7.603	6.848	7.310	6.613	6.708	6.514	7.820	7.320
Australia	8.597	10.697	7.336	8.988	8.046	10.741	7.965	9.512	10.611	10.718	9.511	10.918	8.388
Bangladesh	4.552	4.720	4.171	4.587	4.746	4.208	4.654	4.749	4.100	4.589	4.542	4.167	4.397
Benin	4.187	3.501	3.205	3.785	3.529	3.427	4.070	3.412	3.493	3.138	4.468	3.184	3.231
Brazil	5.451	4.987	4.938	5.255	5.468	4.749	5.097	6.052	4.805	4.810	5.129	4.593	4.834
Burkina	2.711	1.737	2.106	2.425	3.293	2.604	2.663	2.873	1.736	1.708	2.570	2.998	2.711
Burma	2.562	2.728	2.617	2.679	2.880	2.880	2.562	2.562	2.676	2.974	2.822	3.227	2.729
Cambodia	2.929	2.724	2.631	2.804	2.917	2.587	2.695	2.921	2.454	2.664	2.786	2.745	2.499
China	6.974	6.707	6.894	6.962	6.894	6.893	6.886	6.929	7.268	6.869	7.013	7.295	7.037
Cote d'Ivoire	2.294	2.103	2.047	2.028	2.376	1.972	2.608	2.125	1.796	1.989	1.743	1.632	1.851
Gambia, The	1.729	1.170	1.372	1.792	1.592	1.137	1.478	1.394	1.084	1.487	1.460	1.474	1.573
Ghana	2.594	3.038	2.515	2.790	1.958	3.074	2.454	3.043	3.054	3.404	2.704	2.857	3.164
Guinea	2.065	1.707	2.164	2.057	2.057	2.264	1.800	2.334	2.170	2.169	1.912	2.065	2.264
Guinea-Bissau	1.876	1.875	2.291	1.784	1.676	2.284	1.825	1.870	2.783	1.943	2.003	2.288	2.794
India	3.898	3.665	3.747	3.708	3.961	4.085	3.722	3.707	3.920	3.739	3.892	3.955	3.962
Indonesia	4.760	5.104	4.898	4.902	4.901	4.859	4.903	4.858	5.056	5.077	4.813	5.041	5.077
Liberia	1.663	1.482	1.698	1.540	1.738	1.753	1.739	1.699	1.739	0.984	1.349	1.752	1.613
Mali	3.045	3.285	2.829	3.256	3.505	2.642	2.452	4.065	2.981	3.440	2.851	2.635	3.082
Niger	9.342	6.327	5.093	6.341	5.995	5.361	5.866	9.718	6.288	5.325	8.735	4.637	5.073
Nigeria	2.097	2.450	1.627	2.019	1.748	1.748	1.857	2.434	2.436	2.423	2.168	1.983	2.410
Pakistan	3.978	3.619	3.654	3.669	3.724	3.473	3.868	3.954	3.885	3.420	3.853	3.659	3.866
Philippines	4.138	4.123	4.241	3.987	4.147	3.879	4.226	4.148	3.822	3.853	3.862	3.738	4.139
Senegal	5.042	5.139	3.917	5.011	3.984	3.433	3.588	5.314	3.688	5.070	4.989	3.375	4.446
Sierra Leone	2.440	2.255	1.651	1.901	1.962	1.884	1.906	2.568	2.127	2.259	2.054	1.713	2.212
Thailand	2.891	3.078	2.855	2.950	3.023	3.038	2.933	2.891	2.734	2.979	2.856	2.802	2.781
Togo	2.991	2.717	2.342	3.442	3.579	2.515	2.917	3.673	2.968	1.965	2.680	2.354	2.361
United States	8.657	8.922	9.088	8.407	8.413	8.097	8.874	8.196	8.699	8.807	8.594	8.696	8.466
Uruguay	8.252	7.374	8.017	7.581	8.922	8.826	8.463	8.551	7.410	7.283	7.428	8.746	8.513
Vietnam	5.722	6.169	5.342	5.769	5.665	5.615	5.667	5.893	5.706	5.663	5.808	5.291	5.561

Appendix Table 7. 2018 Yield Simulation Iterations **(Continued)**

Iteration	40	41	42	43	44	45	46	47	48	49	50	51	52
Argentina	6.673	7.271	7.596	7.712	7.464	6.714	7.320	7.348	7.413	7.481	7.326	7.416	6.530
Australia	11.339	10.673	9.694	10.016	9.637	10.580	9.369	10.603	10.602	8.755	11.406	9.567	9.067
Bangladesh	4.672	4.428	4.384	4.811	4.649	4.545	4.428	4.555	4.410	4.302	4.563	4.629	4.746
Benin	2.957	2.611	2.733	3.183	3.771	3.183	3.743	3.562	3.337	3.772	3.416	3.066	3.618
Brazil	5.122	4.998	4.582	5.469	5.137	4.924	4.752	5.378	5.125	4.914	5.367	4.754	5.041
Burkina	2.747	2.827	2.427	3.244	2.286	2.061	2.302	2.978	2.570	2.444	2.795	1.742	2.120
Burma	2.968	3.027	3.134	2.961	2.876	2.876	2.966	2.779	2.875	2.874	2.868	3.044	2.562
Cambodia	2.624	2.621	2.427	2.905	2.607	2.548	2.590	2.733	2.456	2.592	2.581	2.504	2.577
China	7.059	6.865	6.879	6.917	6.968	6.780	6.977	7.336	6.920	6.937	6.893	6.925	6.882
Cote d'Ivoire	2.146	1.823	1.770	1.969	1.889	1.730	1.841	1.980	1.756	1.877	1.973	1.743	2.375
Gambia, The	1.420	1.474	1.527	1.594	1.419	1.384	1.614	1.038	1.536	1.775	1.005	1.663	1.484
Ghana	2.853	3.419	3.039	2.761	3.400	3.070	3.093	3.043	2.685	2.761	3.040	3.072	2.013
Guinea	2.254	2.571	2.301	2.056	2.162	2.203	2.191	2.397	2.162	2.148	2.333	2.291	1.957
Guinea-Bissau	1.957	2.271	2.524	1.926	1.935	2.044	2.271	1.931	2.339	2.774	2.026	2.165	1.932
India	3.966	4.155	4.146	4.103	3.874	3.941	4.068	3.898	4.227	4.222	4.181	4.025	3.959
Indonesia	4.850	4.980	5.106	4.896	5.009	4.860	5.096	4.859	4.994	5.056	4.939	4.914	5.054
Liberia	1.653	1.552	1.617	1.678	1.603	1.214	1.698	1.763	1.554	1.609	1.937	0.885	1.547
Mali	3.010	4.356	3.171	3.419	3.041	3.326	3.029	3.099	3.184	3.218	3.478	3.554	2.863
Niger	7.149	5.334	3.871	5.194	5.554	9.302	5.051	5.616	5.466	5.053	5.538	5.021	7.239
Nigeria	1.776	1.748	2.074	1.995	2.434	2.431	2.334	1.643	2.221	2.367	2.015	1.983	2.405
Pakistan	3.868	3.720	3.376	3.645	3.847	3.681	3.587	4.035	3.608	3.438	3.819	3.468	3.669
Philippines	3.874	3.896	3.966	4.119	4.125	3.820	3.900	3.838	4.147	4.148	3.999	3.866	4.208
Senegal	4.545	3.985	3.401	5.135	4.078	5.019	3.367	3.900	4.444	4.229	3.920	4.598	5.087
Sierra Leone	2.036	1.861	1.645	2.033	2.058	2.553	1.902	1.624	2.392	2.298	2.253	1.701	2.298
Thailand	2.950	3.098	2.941	3.041	2.793	3.005	3.013	3.006	2.856	2.857	3.013	2.882	2.859
Togo	3.110	2.558	1.838	3.772	2.843	2.650	2.013	3.256	2.598	2.052	2.703	2.549	2.529
United States	8.419	7.807	8.650	7.970	8.658	8.099	8.420	7.799	8.888	8.950	8.468	8.406	8.761
Uruguay	7.924	7.673	7.536	8.839	8.486	8.072	8.813	8.816	8.207	8.172	7.814	7.194	8.019
Vietnam	5.563	5.903	5.534	5.893	5.648	5.853	6.075	5.897	5.630	5.598	5.895	5.610	5.664

Appendix Table 7. 2018 Yield Simulation Iterations **(Continued)**

Iteration	53	54	55	56	57	58	59	60	61	62	63	64	65
Argentina	6.871	6.784	6.427	6.843	6.982	7.315	7.619	6.568	6.706	5.377	7.329	7.323	5.566
Australia	7.595	9.068	10.654	9.746	10.733	10.636	9.663	10.694	10.663	10.610	7.786	9.786	9.512
Bangladesh	4.747	4.607	4.625	4.740	4.157	4.203	4.141	4.091	4.694	4.506	4.562	4.707	4.643
Benin	4.471	4.470	4.486	4.466	3.209	3.021	3.522	3.177	3.779	2.626	3.820	3.632	4.478
Brazil	4.846	5.460	4.685	4.694	5.004	4.834	5.332	4.611	4.916	4.599	4.757	5.691	5.469
Burkina	2.956	2.425	2.987	2.439	2.162	2.804	2.750	2.483	2.815	2.998	2.999	3.264	3.317
Burma	2.721	2.566	2.985	2.719	2.861	2.968	2.840	3.082	2.885	3.179	2.962	2.726	2.816
Cambodia	2.906	2.822	2.517	2.601	2.459	2.736	2.322	2.729	2.723	2.756	2.919	2.851	3.008
China	6.830	7.023	6.924	6.951	6.998	7.170	6.937	6.985	6.893	7.334	7.364	6.940	7.361
Cote d'Ivoire	2.319	2.379	1.976	2.612	1.901	1.746	2.026	1.743	2.374	1.539	2.369	2.339	2.299
Gambia, The	1.766	1.307	1.553	1.705	1.520	1.175	1.808	1.474	1.057	1.964	1.748	1.436	1.573
Ghana	1.776	2.489	2.628	1.784	3.072	3.205	3.486	3.035	2.759	2.761	2.761	2.433	2.400
Guinea	1.669	1.675	1.672	1.588	2.250	2.491	2.276	2.064	1.826	2.278	2.320	2.138	1.690
Guinea-Bissau	1.390	1.678	1.805	1.363	2.323	2.592	1.999	2.837	1.837	2.823	1.674	1.897	2.145
India	3.705	3.737	3.870	3.864	3.961	3.695	4.150	4.069	3.717	4.069	3.660	4.190	3.932
Indonesia	4.804	4.947	5.068	4.885	4.966	4.814	4.861	4.999	5.057	4.874	4.749	4.804	4.875
Liberia	1.584	1.733	1.538	1.754	1.542	1.625	1.540	1.482	1.693	0.879	1.724	1.957	1.750
Mali	2.846	2.870	2.393	2.455	2.906	3.085	2.607	2.651	2.781	3.205	2.636	3.019	2.436
Niger	7.655	7.424	5.303	5.225	6.228	6.442	5.059	5.199	6.266	6.348	5.984	9.234	9.607
Nigeria	1.760	2.179	2.070	1.607	2.121	1.838	1.748	1.991	2.006	2.436	1.585	1.872	2.267
Pakistan	3.868	3.849	3.396	3.499	3.411	3.918	3.613	3.407	3.845	3.648	4.205	3.904	4.104
Philippines	4.194	4.144	3.872	4.148	4.074	3.771	4.129	3.689	4.072	3.638	3.825	4.147	3.997
Senegal	4.497	4.954	3.901	3.952	4.383	4.008	3.490	3.979	3.859	5.144	3.411	3.966	4.868
Sierra Leone	1.820	2.075	1.906	1.477	2.177	2.242	1.797	2.141	1.906	2.249	1.458	2.194	2.243
Thailand	2.926	2.894	2.952	2.988	2.864	2.953	2.997	2.951	2.988	2.971	2.979	2.880	2.858
Togo	4.299	3.144	1.926	3.137	2.048	2.522	2.203	1.810	3.145	2.293	3.331	3.358	2.904
United States	8.660	8.662	8.676	8.975	8.662	8.108	8.073	8.962	8.661	7.967	8.060	8.576	8.663
Uruguay	7.597	8.553	7.781	7.302	7.665	8.664	9.048	7.672	8.814	7.083	8.767	8.382	8.198
Vietnam	5.333	5.772	5.665	5.554	5.565	5.587	5.672	5.615	5.651	5.774	5.566	5.562	5.693

Appendix Table 7. 2018 Yield Simulation Iterations **(Continued)**

Iteration	66	67	68	69	70	71	72	73	74	75	76	77	78
Argentina	6.532	7.402	7.518	7.614	7.465	6.908	7.593	7.239	6.865	6.712	7.450	7.385	5.988
Australia	9.503	10.918	10.670	9.647	10.611	10.924	9.535	9.562	10.230	10.604	9.535	9.444	11.276
Bangladesh	4.156	4.541	4.497	4.721	4.696	4.707	4.482	4.322	4.603	4.484	4.570	4.705	4.537
Benin	4.411	3.779	3.786	4.188	4.481	3.591	3.828	3.827	3.860	3.787	4.937	3.485	3.183
Brazil	4.989	5.347	4.699	5.419	5.473	5.390	5.370	4.988	5.447	4.762	5.424	5.300	4.989
Burkina	2.421	1.775	2.508	2.418	1.841	1.819	2.956	2.114	2.512	3.200	2.736	2.443	2.998
Burma	2.669	2.876	3.024	2.665	2.561	2.811	2.874	2.949	2.711	2.989	2.721	2.729	2.972
Cambodia	2.504	2.671	2.727	2.613	2.457	2.784	2.921	2.588	2.504	2.683	2.949	2.786	2.730
China	6.918	6.898	7.060	6.833	6.856	6.894	6.939	6.945	6.895	6.954	7.059	6.868	7.362
Cote d'Ivoire	1.983	2.097	1.750	2.093	2.308	1.839	2.027	1.893	1.986	1.969	2.381	2.126	1.975
Gambia, The	1.169	1.469	1.036	1.036	0.902	1.035	1.193	1.472	1.036	1.485	1.586	1.475	1.603
Ghana	3.038	3.347	2.908	2.915	2.580	2.761	2.858	3.135	2.954	2.484	3.452	2.599	3.243
Guinea	1.955	2.132	2.259	2.123	1.722	2.346	2.067	2.057	2.130	2.075	2.190	2.188	2.265
Guinea-Bissau	1.944	1.931	2.079	1.931	1.795	1.990	1.930	2.072	1.933	1.843	1.635	1.951	2.002
India	3.686	3.970	3.766	3.873	3.959	4.120	3.863	4.060	3.961	3.898	3.973	3.989	4.039
Indonesia	4.997	4.848	5.040	5.079	5.000	4.863	4.817	5.105	4.999	4.725	4.855	4.899	4.941
Liberia	1.483	1.536	1.698	1.733	1.763	1.693	1.743	1.547	1.596	1.489	1.727	1.615	1.621
Mali	2.450	3.025	2.913	3.044	2.656	3.716	2.964	3.167	3.099	2.451	2.970	3.471	3.203
Niger	7.211	6.069	4.922	6.431	6.820	9.219	6.415	5.100	7.933	6.458	6.676	7.454	5.843
Nigeria	2.281	1.696	2.013	2.434	2.361	2.414	1.662	2.436	2.407	1.589	1.870	1.870	2.381
Pakistan	3.832	3.670	3.663	3.961	3.722	3.756	3.904	3.385	4.028	3.566	3.903	3.805	3.689
Philippines	4.085	3.879	3.846	4.284	4.294	3.903	3.943	3.977	4.194	3.769	3.854	4.158	3.697
Senegal	3.349	4.494	3.492	3.536	4.368	4.941	3.966	4.480	4.204	3.493	4.089	4.690	5.137
Sierra Leone	1.904	1.870	1.904	2.141	2.161	2.514	1.906	2.179	2.258	1.734	1.914	2.096	2.262
Thailand	3.005	3.095	2.885	2.879	2.869	2.977	3.000	2.858	2.891	3.038	3.066	3.006	2.952
Togo	2.984	2.520	1.965	3.306	3.113	2.628	2.952	1.926	3.265	2.339	2.748	3.085	2.207
United States	8.417	8.450	8.882	8.783	9.018	8.472	8.588	8.645	8.645	8.147	7.814	8.678	8.013
Uruguay	8.838	8.315	8.222	9.411	8.532	7.364	9.025	8.018	8.690	8.527	9.689	8.258	8.055
Vietnam	5.850	5.933	5.581	5.753	5.720	5.856	5.669	5.571	5.678	5.644	5.897	5.857	5.849

Appendix Table 7. 2018 Yield Simulation Iterations **(Continued)**

Iteration	79	80	81	82	83	84	85	86	87	88	89	90	91
Argentina	7.311	7.250	7.385	7.392	7.290	6.718	7.020	7.436	7.486	6.014	6.880	6.813	7.393
Australia	9.533	8.975	10.635	10.730	8.783	7.789	9.513	10.157	7.580	10.599	9.513	9.483	9.829
Bangladesh	4.594	4.641	4.861	4.507	4.360	4.827	4.537	4.648	4.614	4.431	4.637	4.747	4.329
Benin	4.570	4.822	4.345	3.003	4.755	3.693	3.954	3.409	4.106	4.069	4.194	3.316	4.767
Brazil	4.880	5.255	6.047	4.690	4.993	6.058	5.454	4.990	5.547	4.835	5.159	5.351	4.988
Burkina	2.762	3.097	3.266	1.976	1.787	2.577	2.456	2.590	3.249	2.562	2.721	2.420	2.706
Burma	2.906	2.569	2.728	3.188	2.569	2.559	2.646	2.968	2.725	2.766	2.888	2.690	2.682
Cambodia	2.706	2.864	2.879	2.304	2.675	2.876	2.827	2.788	3.010	2.805	2.826	2.706	2.788
China	6.955	7.130	7.124	6.780	6.996	6.972	6.912	6.871	6.936	7.285	6.987	6.830	6.961
Cote d'Ivoire	1.822	2.436	2.260	1.931	1.966	2.449	2.064	1.969	2.144	1.873	1.743	2.139	1.997
Gambia, The	1.425	1.808	1.039	1.475	1.474	1.034	1.047	1.487	1.792	1.452	1.291	1.058	1.111
Ghana	3.040	2.039	2.857	3.013	2.007	1.904	2.579	3.205	2.031	2.683	2.588	3.040	2.669
Guinea	2.053	1.674	2.180	2.060	1.663	2.307	2.057	2.286	2.133	2.191	2.255	2.277	2.085
Guinea-Bissau	1.958	1.998	1.747	2.085	1.932	1.916	1.971	2.270	1.838	2.044	1.646	2.042	2.083
India	3.970	4.191	3.899	3.900	3.961	4.009	3.869	3.959	3.928	3.970	3.875	3.909	3.635
Indonesia	5.105	5.073	4.995	5.080	4.860	4.781	5.025	5.028	4.758	4.883	4.807	5.088	4.753
Liberia	1.655	1.769	1.766	0.880	1.674	1.648	1.715	1.676	1.695	1.698	1.687	1.540	1.690
Mali	3.049	2.877	3.030	2.648	2.706	3.754	3.019	3.419	3.253	3.413	3.556	3.526	2.438
Niger	5.112	6.201	7.649	5.056	7.207	9.843	8.341	5.145	9.180	8.344	8.785	7.204	8.154
Nigeria	2.404	2.399	1.812	1.721	1.754	1.742	2.105	2.403	1.700	2.398	1.868	2.458	1.635
Pakistan	3.711	3.724	4.232	3.388	3.757	4.236	4.033	3.641	4.039	3.724	4.048	3.977	3.862
Philippines	3.987	4.203	4.148	4.076	3.996	4.269	4.147	3.963	4.137	3.703	3.830	4.205	4.091
Senegal	4.518	5.157	4.639	3.270	4.605	5.334	4.428	3.770	3.879	5.018	4.294	4.752	3.406
Sierra Leone	2.055	2.344	1.984	1.572	1.926	2.261	2.315	1.984	2.028	2.495	2.063	2.371	1.692
Thailand	2.935	2.835	2.932	2.946	2.944	2.977	2.989	3.089	3.049	3.007	2.988	2.976	2.991
Togo	2.208	2.715	3.288	1.963	3.149	4.372	3.192	2.909	4.761	2.536	3.361	2.883	2.602
United States	8.570	8.751	8.263	8.947	8.765	8.008	8.828	8.270	8.380	8.148	8.119	8.580	8.652
Uruguay	8.752	9.343	9.582	7.701	8.040	8.553	8.843	8.552	9.692	8.299	8.043	8.871	8.816
Vietnam	5.900	5.638	5.949	5.445	5.897	5.746	5.912	5.952	5.728	5.940	5.909	5.926	5.645

Appendix Table 7. 2018 Yield Simulation Iterations **(Continued)**

Iteration	92	93	94	95	96	97	98	99	100
Argentina	7.392	7.308	6.422	6.251	7.297	6.936	7.408	6.826	7.191
Australia	10.773	8.595	10.642	10.536	8.854	9.671	7.705	9.762	10.734
Bangladesh	4.506	4.718	4.597	4.722	4.693	4.854	4.855	4.483	4.492
Benin	3.528	4.049	3.788	2.933	3.763	3.178	3.190	3.512	3.426
Brazil	6.054	5.833	4.973	4.988	4.834	5.308	5.450	4.701	4.834
Burkina	2.290	3.253	2.482	3.271	1.782	2.570	1.733	2.115	2.463
Burma	2.875	2.703	2.966	3.001	2.569	2.729	2.565	2.722	2.938
Cambodia	2.689	2.807	2.853	3.000	2.477	2.736	2.638	2.538	2.479
China	6.960	6.840	7.068	6.821	6.753	6.710	6.721	7.082	7.059
Cote d'Ivoire	1.965	2.078	2.353	2.447	2.024	2.139	2.309	2.614	1.981
Gambia, The	1.005	1.035	1.593	1.627	1.081	1.126	1.318	1.937	1.573
Ghana	3.070	2.428	2.649	1.986	1.833	2.879	1.798	2.845	3.205
Guinea	2.177	2.174	2.049	2.124	2.181	2.163	2.059	2.051	2.334
Guinea-Bissau	1.844	2.040	1.868	1.617	2.087	1.650	2.172	1.987	2.039
India	4.067	3.671	3.940	4.100	3.966	3.690	4.096	3.737	4.003
Indonesia	5.062	4.861	5.004	4.861	5.013	4.948	4.861	5.084	4.905
Liberia	1.844	1.603	1.693	1.741	1.575	1.482	1.545	1.741	1.670
Mali	3.555	2.969	3.009	3.777	3.257	3.357	3.349	2.472	3.021
Niger	7.121	9.431	8.209	7.446	6.679	8.223	7.038	5.020	5.990
Nigeria	2.139	1.637	2.148	1.743	2.357	2.168	2.361	1.838	2.201
Pakistan	3.865	4.038	3.844	3.850	3.819	3.942	3.433	3.502	3.692
Philippines	4.072	4.215	3.898	3.822	4.281	4.194	4.295	4.139	3.836
Senegal	4.005	4.754	4.342	4.843	4.532	4.511	5.195	3.494	3.951
Sierra Leone	2.259	2.011	2.058	2.010	2.511	1.906	2.507	1.697	2.361
Thailand	2.994	3.036	2.938	3.042	2.976	3.002	2.860	2.962	2.891
Togo	3.252	3.144	2.929	3.153	2.993	3.781	2.525	2.067	1.999
United States	8.475	8.646	8.928	8.650	8.969	8.647	8.960	9.017	8.462
Uruguay	8.713	8.814	7.571	7.057	8.128	7.864	7.258	8.549	8.200
Vietnam	5.956	5.872	5.612	5.656	5.768	5.776	5.562	5.560	5.620

Appendix Table 8. 2023 Yield Simulation Iterations

Iteration	1	2	3	4	5	6	7	8	9	10	11	12	13
Argentina	7.694	7.643	8.058	7.238	8.076	8.052	5.948	6.145	7.246	7.685	7.840	6.833	7.012
Australia	11.386	10.064	10.805	11.414	9.937	8.428	8.748	10.895	9.619	9.476	10.153	12.092	9.831
Bangladesh	5.222	4.760	4.979	5.031	5.141	4.941	4.952	4.897	4.975	5.018	5.223	5.023	4.868
Benin	4.221	5.031	3.365	4.153	5.129	4.352	4.319	4.001	4.085	4.002	4.405	2.933	3.424
Brazil	6.442	5.752	5.212	5.100	5.602	5.801	5.072	5.324	5.557	5.600	6.373	5.134	5.442
Burkina	2.577	3.433	2.866	2.091	2.589	2.357	2.627	3.422	2.306	3.417	2.859	3.141	2.242
Burma	2.800	2.845	3.161	3.143	2.759	2.736	2.897	2.897	2.715	2.905	2.906	3.433	3.070
Cambodia	3.213	3.345	3.290	2.667	3.172	3.127	3.132	3.088	3.290	3.343	3.324	2.769	3.127
China	6.936	7.558	7.195	7.054	7.094	7.050	7.233	7.326	7.263	7.053	6.912	7.173	7.053
Cote d'Ivoire	2.334	2.311	1.759	1.939	2.531	1.992	2.282	2.512	2.709	2.821	2.270	1.908	1.982
Gambia, The	1.531	1.231	1.500	1.404	1.071	1.505	1.633	1.543	1.449	1.604	1.092	1.500	1.687
Ghana	2.914	2.945	2.614	3.322	2.070	2.921	2.501	3.060	2.045	2.992	2.739	3.319	3.043
Guinea	2.160	2.516	2.562	1.869	2.270	2.576	2.270	2.409	1.851	1.841	2.393	2.344	2.275
Guinea-Bissau	1.348	1.906	2.162	2.204	1.561	2.024	2.196	2.040	2.065	1.884	1.901	2.927	2.113
India	4.117	3.945	4.337	4.188	4.181	4.199	4.115	4.209	4.143	4.112	4.211	4.252	4.111
Indonesia	4.983	5.178	5.023	5.422	5.137	4.991	5.224	5.273	5.089	5.177	5.430	5.371	5.055
Liberia	1.741	2.091	1.714	1.284	2.069	1.576	1.567	1.872	1.857	1.872	1.831	0.899	1.284
Mali	3.542	3.286	3.708	3.286	3.348	3.914	3.339	3.303	2.997	3.136	4.742	3.164	3.590
Niger	10.329	7.858	6.741	6.330	7.050	8.788	7.591	5.612	9.624	7.432	6.840	4.995	8.378
Nigeria	2.021	2.088	1.997	3.032	1.920	1.933	2.391	2.205	2.258	1.904	2.667	2.255	2.054
Pakistan	4.351	4.345	3.907	3.598	4.198	4.122	3.876	4.084	4.119	4.114	4.263	3.577	4.004
Philippines	4.284	4.029	3.989	4.288	4.337	4.294	4.034	3.956	4.293	4.122	4.407	3.949	3.981
Senegal	5.584	3.904	5.697	5.432	4.417	5.440	4.668	4.450	5.924	4.658	4.275	5.083	5.513
Sierra Leone	2.437	2.281	2.419	2.535	1.928	2.493	2.189	2.164	2.491	1.988	2.714	2.281	2.274
Thailand	3.162	3.145	3.038	3.118	3.085	3.144	3.042	3.103	3.020	3.164	3.184	3.119	3.171
Togo	4.745	3.361	3.296	2.669	3.600	3.335	2.251	2.705	3.415	3.282	3.549	1.946	2.839
United States	8.808	8.478	8.607	9.066	8.944	8.775	9.070	8.410	9.076	9.070	9.199	8.803	8.809
Uruguay	7.978	9.443	7.784	9.301	8.931	8.663	8.096	8.370	8.622	9.256	9.954	8.071	7.444
Vietnam	6.040	5.923	5.698	6.037	5.807	5.912	5.912	6.043	5.789	5.787	6.375	5.745	5.980

Appendix Table 8. 2023 Yield Simulation Iterations **(Continued)**

Iteration	14	15	16	17	18	19	20	21	22	23	24	25	26
Argentina	7.846	7.742	7.760	7.877	6.713	7.885	7.800	7.781	7.850	7.762	7.087	6.831	6.606
Australia	9.709	11.456	11.658	11.432	11.472	11.490	11.379	10.281	9.763	8.688	10.153	11.316	11.433
Bangladesh	4.870	4.849	4.924	4.894	4.824	4.430	4.761	4.476	4.819	4.887	5.154	5.039	4.881
Benin	3.772	4.003	3.106	3.366	4.312	4.010	3.186	4.061	3.379	3.374	4.232	4.645	3.933
Brazil	5.090	5.137	5.342	5.328	5.726	5.077	5.040	5.470	5.126	5.467	6.447	5.732	5.161
Burkina	2.244	3.169	2.383	1.785	2.723	3.095	3.131	2.252	2.353	2.518	2.240	2.203	2.243
Burma	3.129	3.367	3.259	2.840	3.161	3.347	3.320	2.893	3.047	2.868	2.721	2.840	2.852
Cambodia	2.953	3.355	2.806	2.547	3.310	3.130	2.824	3.081	3.185	3.040	2.908	3.116	2.975
China	7.177	7.079	7.298	7.138	7.488	7.321	7.153	7.248	7.054	6.984	7.150	7.118	7.247
Cote d'Ivoire	2.524	2.312	2.056	1.956	2.002	1.690	2.145	1.987	2.172	2.291	2.599	2.630	2.347
Gambia, The	1.558	1.639	2.062	1.112	1.562	1.180	1.693	1.679	1.794	1.099	1.097	1.531	1.679
Ghana	2.955	2.830	3.736	3.797	3.012	3.506	3.355	3.695	3.472	2.392	2.250	2.634	2.972
Guinea	2.175	1.797	2.486	2.532	2.232	2.407	2.286	2.551	2.497	2.407	2.261	2.200	2.044
Guinea-Bissau	2.081	2.159	1.932	2.649	2.517	2.416	2.752	2.202	2.158	2.129	2.041	1.368	2.181
India	3.925	4.234	4.315	4.476	4.210	4.360	4.386	4.327	3.960	4.128	4.345	4.110	4.127
Indonesia	5.208	5.377	5.122	5.429	5.150	5.344	5.397	5.283	5.180	5.221	5.294	5.079	5.267
Liberia	1.567	1.817	1.285	1.622	1.741	1.794	1.631	1.823	1.793	1.506	1.838	1.834	1.759
Mali	2.709	2.935	3.257	3.668	3.611	3.351	3.159	3.345	3.592	3.346	3.927	3.464	3.197
Niger	5.436	5.514	5.438	5.343	10.172	5.395	4.393	6.333	5.715	5.787	8.785	9.970	8.842
Nigeria	1.871	2.217	1.940	3.055	2.672	2.490	2.159	2.688	2.453	1.765	2.609	1.917	2.642
Pakistan	3.834	3.581	3.845	3.751	3.891	3.593	3.578	3.924	3.941	4.061	4.178	4.072	3.844
Philippines	4.293	4.124	4.127	4.339	3.900	3.901	4.166	4.123	3.961	4.368	4.342	4.022	4.002
Senegal	3.913	4.127	4.682	5.844	5.721	4.470	3.869	4.441	4.291	4.000	5.962	5.501	5.153
Sierra Leone	1.763	2.148	1.793	2.457	2.910	2.218	1.725	2.776	2.132	1.781	2.833	2.287	2.642
Thailand	3.149	3.031	3.112	3.054	2.982	3.019	3.043	3.019	3.145	3.218	3.051	3.254	3.019
Togo	2.870	2.030	2.884	2.680	2.315	1.996	2.206	2.472	3.228	3.085	3.620	3.552	2.924
United States	9.077	9.550	8.647	8.438	9.235	8.875	9.060	8.808	8.886	9.083	9.047	9.047	9.366
Uruguay	9.202	8.381	7.369	8.023	8.070	8.377	8.371	8.667	8.364	8.520	9.138	7.430	8.498
Vietnam	5.497	5.434	5.783	6.094	5.723	5.697	5.690	5.909	5.895	5.944	6.314	6.083	5.859

Appendix Table 8. 2023 Yield Simulation Iterations **(Continued)**

Iteration	27	28	29	30	31	32	33	34	35	36	37	38	39
Argentina	7.849	6.721	6.668	7.823	7.354	7.741	8.378	7.838	8.021	8.060	6.478	6.968	7.741
Australia	9.286	9.698	11.589	10.255	9.937	9.405	9.162	11.650	11.113	9.402	11.402	11.389	9.153
Bangladesh	4.973	4.985	4.846	4.571	4.852	4.692	4.775	4.980	4.821	4.432	4.591	4.942	4.830
Benin	4.651	3.400	3.384	3.635	5.494	3.966	3.578	3.896	3.236	3.122	4.087	4.179	3.393
Brazil	5.841	5.783	5.167	5.392	5.935	5.781	5.776	5.646	5.249	5.088	5.324	5.282	5.161
Burkina	3.208	2.941	2.563	2.981	2.631	2.238	3.211	2.664	2.594	2.881	2.177	2.367	2.672
Burma	2.766	2.890	3.060	3.062	2.727	2.735	3.076	3.155	3.055	3.174	2.884	3.142	2.883
Cambodia	3.424	3.181	2.802	3.220	3.238	3.102	3.203	3.071	2.963	3.127	2.738	2.980	3.129
China	7.484	6.873	7.377	7.248	7.162	7.054	7.249	6.894	7.215	7.151	7.053	7.027	7.074
Cote d'Ivoire	2.326	2.721	1.911	1.933	1.928	2.514	2.135	2.155	2.260	1.912	2.194	2.150	2.512
Gambia, The	1.473	1.556	1.229	1.109	0.664	1.199	1.562	1.097	1.501	1.491	1.543	1.540	2.087
Ghana	2.801	2.813	3.077	3.345	2.886	3.054	3.708	3.397	3.362	3.496	3.657	3.019	3.011
Guinea	2.575	2.270	2.170	2.703	2.528	2.512	2.779	2.344	2.591	2.752	2.144	2.371	2.279
Guinea-Bissau	2.152	1.911	2.981	2.383	2.169	2.419	2.157	2.148	2.324	2.115	2.923	2.385	2.950
India	4.115	4.184	4.207	3.870	4.210	4.211	4.119	4.211	4.371	3.967	4.113	4.212	4.316
Indonesia	5.066	5.140	5.348	5.140	5.286	5.318	5.026	5.334	5.382	5.184	5.397	5.425	5.380
Liberia	1.827	1.626	1.567	1.720	1.949	1.823	1.795	1.626	1.823	1.785	1.696	1.629	1.795
Mali	3.338	3.872	2.922	3.340	4.003	3.737	3.186	3.696	3.818	3.796	2.706	3.558	3.842
Niger	10.192	9.451	6.450	6.405	9.702	7.613	5.438	8.836	4.935	5.028	8.777	6.767	5.399
Nigeria	1.924	1.838	2.678	1.915	2.673	2.269	1.765	2.666	2.005	1.857	2.852	2.678	2.653
Pakistan	4.374	4.079	3.593	4.054	4.423	4.083	4.121	3.757	3.759	4.061	3.968	3.713	3.876
Philippines	4.254	4.128	4.030	3.991	4.211	4.338	4.132	4.282	4.228	4.032	4.165	4.209	4.280
Senegal	5.239	4.456	5.604	3.919	5.604	4.623	3.902	4.423	4.131	3.781	4.439	4.727	5.270
Sierra Leone	2.794	2.298	2.524	2.132	2.919	2.742	1.903	2.617	2.110	1.721	2.797	2.802	2.777
Thailand	3.039	3.275	2.899	3.114	3.045	3.200	3.117	3.177	3.116	3.152	3.025	3.176	3.172
Togo	3.269	3.371	1.981	2.349	3.088	3.044	2.508	3.089	2.677	3.084	1.991	2.108	3.063
United States	8.865	9.050	9.064	8.806	8.807	9.076	8.202	9.316	8.815	8.402	9.377	9.206	9.288
Uruguay	10.128	8.736	7.963	8.909	9.388	9.363	9.494	9.255	9.202	8.370	8.489	9.069	9.269
Vietnam	5.751	6.107	5.803	5.876	6.185	6.039	5.698	5.804	5.825	5.742	6.047	6.073	5.918

Appendix Table 8. 2023 Yield Simulation Iterations **(Continued)**

Iteration	40	41	42	43	44	45	46	47	48	49	50	51	52
Argentina	6.785	7.245	6.890	6.986	7.110	5.933	7.679	7.211	7.945	5.909	7.670	7.759	6.957
Australia	11.347	9.436	11.650	11.603	12.098	11.300	11.348	11.304	8.241	11.320	11.356	8.389	11.302
Bangladesh	4.937	4.822	5.005	4.993	4.833	4.980	4.805	4.857	4.996	5.103	5.018	4.979	4.543
Benin	4.453	2.648	3.951	3.861	3.409	4.648	3.953	3.576	4.803	3.281	3.790	3.086	3.330
Brazil	5.939	4.982	5.638	5.439	5.235	5.234	5.328	5.078	5.732	5.130	5.123	5.329	5.783
Burkina	2.848	2.903	3.128	2.631	2.563	3.133	2.558	3.348	2.721	2.954	2.954	3.058	2.677
Burma	2.728	3.165	2.898	2.898	3.160	3.074	3.057	3.143	2.715	3.161	3.262	3.076	3.054
Cambodia	3.092	3.182	2.813	3.079	3.108	3.131	2.887	3.278	3.183	2.919	3.290	3.191	3.107
China	6.963	7.215	7.053	7.274	7.082	7.103	7.559	7.491	7.106	7.083	7.249	7.079	7.273
Cote d'Ivoire	2.361	2.512	2.164	2.464	1.993	2.530	2.147	2.313	2.331	2.476	2.509	2.452	1.988
Gambia, The	1.091	2.103	1.304	1.584	1.554	2.138	1.558	1.559	1.065	1.642	1.242	1.882	1.500
Ghana	3.015	3.012	3.108	3.035	3.765	2.177	3.357	2.829	2.767	3.023	3.304	3.327	3.798
Guinea	2.257	2.482	2.128	2.271	2.409	1.765	2.484	2.386	2.485	2.170	2.402	2.528	2.741
Guinea-Bissau	1.925	2.950	2.217	1.934	2.161	1.780	2.700	2.168	2.049	1.591	1.521	2.041	2.194
India	4.111	4.285	4.496	3.942	4.211	4.209	4.207	4.115	4.118	4.203	3.825	3.859	3.924
Indonesia	5.180	5.293	5.408	5.183	5.226	5.170	5.302	5.137	5.159	5.280	5.170	5.345	5.116
Liberia	1.807	1.640	1.788	1.749	1.723	1.566	1.702	1.826	1.946	1.642	1.853	1.626	1.671
Mali	3.334	3.507	3.192	2.843	3.721	2.710	3.191	3.167	3.509	3.283	3.250	3.926	3.639
Niger	10.349	5.162	6.325	8.845	6.972	9.177	5.493	6.080	8.361	6.622	5.792	5.261	9.230
Nigeria	2.640	2.025	2.911	2.642	3.144	2.053	2.674	2.023	2.052	2.639	1.912	1.848	2.619
Pakistan	4.033	3.873	3.649	3.960	3.868	3.612	3.913	3.854	4.346	4.031	4.202	4.084	4.400
Philippines	4.293	4.026	4.336	4.248	3.954	3.972	4.212	3.946	4.348	4.037	3.957	4.214	3.954
Senegal	5.602	4.464	5.589	5.440	5.041	4.702	4.488	5.302	5.192	5.054	3.608	4.101	4.613
Sierra Leone	2.847	1.888	2.770	2.520	2.690	2.387	2.422	2.197	2.429	2.149	1.635	1.643	2.439
Thailand	3.208	3.168	3.017	3.053	3.113	3.150	2.823	3.172	3.035	3.119	3.270	3.251	3.104
Togo	3.328	2.481	2.124	3.163	2.874	2.870	2.446	3.016	3.202	3.324	4.029	4.101	2.870
United States	9.048	9.050	9.061	9.308	8.796	9.059	9.083	8.934	9.054	8.701	8.432	8.480	8.414
Uruguay	8.696	8.393	8.043	8.010	7.926	8.880	8.749	8.683	9.308	7.541	8.783	8.568	8.010
Vietnam	6.065	5.748	6.014	5.780	5.866	5.800	5.680	5.698	5.843	5.811	5.915	6.060	6.003

Appendix Table 8. 2023 Yield Simulation Iterations **(Continued)**

Iteration	53	54	55	56	57	58	59	60	61	62	63	64	65
Argentina	7.834	7.210	8.382	7.075	7.850	7.033	7.086	8.044	7.758	8.328	7.218	7.657	7.476
Australia	10.153	10.403	8.365	8.340	10.285	9.983	11.478	10.152	10.261	11.348	11.428	10.286	10.616
Bangladesh	4.960	4.810	5.072	5.233	4.896	5.232	4.937	4.854	5.221	5.037	5.072	4.997	4.456
Benin	3.960	3.998	4.252	4.371	3.087	4.013	4.001	4.093	4.034	3.385	3.954	4.002	3.339
Brazil	5.888	5.277	5.731	5.836	5.036	5.831	5.798	5.151	5.802	5.639	5.272	5.679	5.031
Burkina	2.875	2.101	2.015	2.717	2.305	3.141	3.169	2.238	2.726	3.136	3.167	3.155	2.717
Burma	2.906	2.873	2.728	2.731	3.178	2.848	3.160	2.892	2.874	3.239	3.175	3.145	3.093
Cambodia	3.288	3.078	3.182	3.183	2.818	3.121	3.092	3.050	3.343	3.119	3.100	3.271	3.123
China	7.088	7.326	6.960	6.878	6.878	7.143	7.250	7.301	6.953	7.231	7.204	7.150	7.098
Cote d'Ivoire	2.169	2.148	2.292	2.770	2.288	2.861	2.318	2.345	2.563	2.014	2.583	2.364	2.165
Gambia, The	1.498	1.121	1.126	1.559	1.648	1.423	1.377	1.501	1.242	1.238	2.022	1.571	1.728
Ghana	3.227	3.012	2.723	2.013	2.684	2.944	3.596	3.240	3.129	3.309	3.396	3.035	3.127
Guinea	2.597	2.408	2.342	2.150	2.270	2.253	2.343	2.440	2.170	2.830	2.412	2.261	2.344
Guinea-Bissau	2.236	2.153	1.779	1.383	2.025	1.660	2.034	2.298	1.550	2.084	2.164	1.920	2.851
India	4.345	4.190	4.018	4.115	4.323	4.089	4.287	4.326	3.685	4.211	4.359	3.918	4.323
Indonesia	5.188	5.243	5.269	4.996	5.178	5.374	5.139	5.226	5.008	5.148	5.361	5.279	5.252
Liberia	1.786	1.796	1.827	1.574	1.284	1.866	1.750	1.828	1.627	1.791	1.625	1.795	1.792
Mali	4.011	3.384	3.523	3.597	3.403	3.182	3.140	3.477	3.262	3.935	3.128	2.949	3.318
Niger	7.527	5.714	5.847	10.390	5.374	6.776	7.789	5.389	10.300	5.775	5.428	6.978	5.379
Nigeria	1.926	2.478	1.967	1.834	1.818	2.187	2.179	2.456	1.940	1.894	2.177	2.265	2.190
Pakistan	4.224	4.030	3.965	4.279	3.757	4.260	4.032	4.082	4.245	4.030	3.861	4.121	3.600
Philippines	4.267	3.994	4.444	4.395	4.333	4.329	3.992	4.294	4.252	4.288	4.181	4.300	3.959
Senegal	5.540	4.985	5.615	5.603	4.013	4.657	4.673	4.327	5.682	4.101	4.466	3.865	4.459
Sierra Leone	2.301	2.397	2.312	2.190	1.868	2.297	2.131	2.213	2.296	2.245	2.083	2.201	2.296
Thailand	3.267	3.019	3.163	3.269	3.159	3.171	3.178	3.052	3.267	3.144	3.161	3.023	3.088
Togo	3.240	2.490	3.286	5.231	2.873	3.229	2.869	2.667	3.553	2.872	2.367	2.792	1.986
United States	8.434	9.064	9.072	9.060	9.443	9.065	8.328	9.060	8.980	8.637	8.866	9.347	9.118
Uruguay	8.930	7.806	9.207	8.006	7.303	9.850	9.203	9.388	8.919	9.206	8.929	8.923	7.772
Vietnam	6.304	5.921	5.863	6.040	5.466	6.040	5.998	5.718	6.038	5.696	5.970	5.697	5.698

Appendix Table 8. 2023 Yield Simulation Iterations **(Continued)**

Iteration	66	67	68	69	70	71	72	73	74	75	76	77	78
Argentina	7.659	7.167	7.805	7.083	7.191	7.115	7.586	7.204	6.285	7.102	6.148	7.741	7.100
Australia	11.347	10.896	8.660	11.480	11.293	11.319	9.944	9.358	11.261	11.334	11.474	11.456	10.195
Bangladesh	4.923	4.992	4.669	4.837	4.937	4.853	4.975	4.611	5.049	4.939	5.002	5.106	4.858
Benin	3.410	4.064	4.119	3.950	3.119	3.402	3.129	3.671	5.070	5.308	3.287	4.015	3.382
Brazil	5.326	5.890	5.336	5.046	5.159	5.451	5.001	5.276	5.904	5.785	5.082	5.282	5.076
Burkina	2.547	3.429	2.240	3.336	2.554	2.235	2.745	3.162	2.930	2.866	2.620	3.187	2.544
Burma	3.060	2.897	2.810	3.346	3.066	2.819	3.313	2.736	2.736	3.064	3.357	3.245	3.142
Cambodia	3.106	3.314	2.978	3.010	2.843	2.814	3.289	2.931	3.127	3.154	2.944	3.257	3.115
China	7.188	7.281	7.248	7.071	7.052	7.126	6.955	7.156	7.149	7.327	7.307	7.325	7.285
Cote d'Ivoire	1.908	2.218	2.278	2.140	2.051	2.292	2.155	2.317	2.171	2.149	2.157	1.908	2.526
Gambia, The	1.091	1.020	1.914	1.751	1.595	1.404	2.106	2.019	1.240	1.548	2.133	1.686	1.570
Ghana	3.322	3.247	3.719	2.834	2.989	3.008	2.853	2.668	2.842	3.443	3.390	2.786	2.039
Guinea	2.598	2.589	2.275	1.995	2.394	2.345	2.406	2.344	2.153	2.265	2.260	2.512	2.396
Guinea-Bissau	2.038	2.051	2.070	2.415	2.332	2.436	2.063	2.073	2.060	1.658	2.115	1.669	2.979
India	4.197	3.926	4.239	4.399	4.258	4.322	4.193	4.323	3.948	4.197	4.201	4.128	4.289
Indonesia	5.110	5.092	5.226	5.397	5.259	5.192	5.179	5.081	5.397	5.087	5.393	4.995	5.397
Liberia	1.786	1.853	1.643	1.766	1.567	1.785	1.284	1.865	1.767	1.698	1.285	1.795	1.818
Mali	4.001	3.523	2.899	3.107	3.354	3.407	3.752	3.158	3.361	2.951	3.358	3.432	3.697
Niger	7.113	7.844	6.032	5.297	6.286	6.713	5.619	6.591	10.058	9.761	5.398	7.696	6.420
Nigeria	2.645	1.918	2.547	2.022	2.641	2.291	1.961	2.030	3.144	2.273	2.646	2.381	2.447
Pakistan	4.055	4.511	3.964	3.591	3.828	3.886	3.605	4.067	3.965	4.077	3.581	4.084	3.655
Philippines	3.899	4.122	4.290	4.020	4.293	4.214	3.993	4.296	4.294	3.883	3.903	3.951	4.293
Senegal	5.576	4.039	4.170	4.359	4.972	5.292	4.973	3.974	5.590	3.960	5.624	4.361	4.973
Sierra Leone	2.594	1.946	2.085	2.131	2.436	2.475	2.224	2.080	2.933	2.212	2.278	2.313	2.459
Thailand	3.145	3.178	3.009	3.018	3.019	3.052	3.191	3.024	3.017	3.116	3.037	3.022	3.023
Togo	3.217	3.938	2.589	1.977	2.478	2.764	2.258	3.548	2.664	3.156	2.066	3.293	2.760
United States	8.189	8.440	8.884	9.390	9.073	9.050	9.335	9.064	9.069	8.499	8.897	8.418	9.570
Uruguay	8.362	9.139	8.922	7.627	7.581	8.049	7.581	7.609	9.917	9.394	7.503	7.979	8.413
Vietnam	5.993	6.341	5.802	5.673	5.704	5.775	5.732	5.746	6.040	6.100	5.862	5.768	5.572

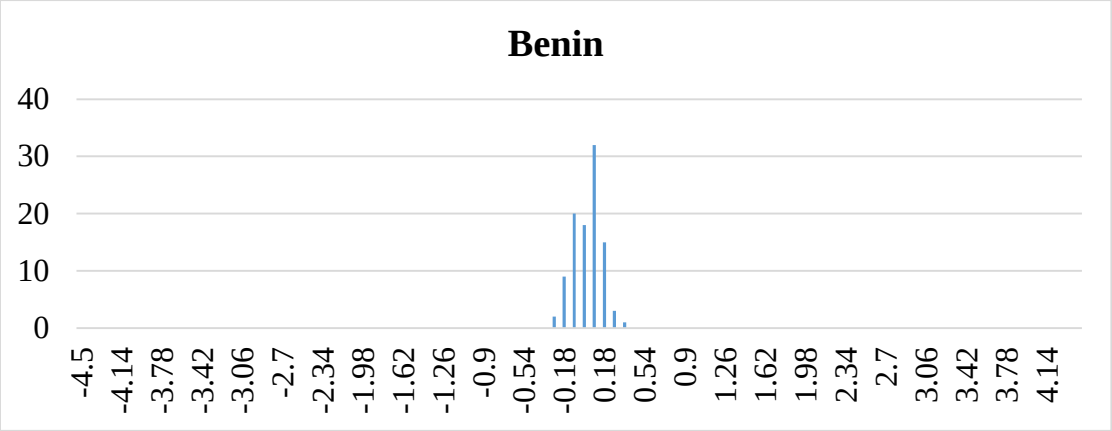
Appendix Table 8. 2023 Yield Simulation Iterations **(Continued)**

Iteration	79	80	81	82	83	84	85	86	87	88	89	90	91
Argentina	7.009	6.930	7.842	7.958	7.234	8.329	8.062	7.051	7.118	7.051	7.820	7.120	7.669
Australia	11.283	11.408	11.295	9.264	10.897	7.840	9.820	11.676	9.935	9.846	10.191	11.549	10.180
Bangladesh	4.825	4.852	4.948	5.167	4.987	4.910	4.899	4.960	5.045	4.427	4.836	4.856	5.037
Benin	4.211	3.553	3.964	4.018	4.314	4.699	3.701	3.712	4.006	3.396	3.969	3.911	4.448
Brazil	5.149	5.084	5.348	5.442	5.694	5.794	5.342	5.124	5.479	5.325	5.670	5.142	5.308
Burkina	3.159	3.386	3.371	2.936	3.421	2.824	2.288	1.894	2.241	2.597	2.201	2.606	1.855
Burma	3.289	3.160	3.218	3.161	3.141	2.736	3.144	3.160	2.857	2.906	3.076	3.075	2.851
Cambodia	3.434	3.093	3.281	3.231	3.348	2.896	3.291	3.093	2.956	2.952	3.085	2.974	3.110
China	7.102	7.262	7.294	7.156	7.278	6.902	7.125	7.312	7.053	7.160	7.297	7.429	7.123
Cote d'Ivoire	2.091	2.290	2.284	2.279	2.292	2.570	2.349	1.961	2.637	2.056	2.139	2.191	2.130
Gambia, The	2.059	1.802	1.572	1.890	1.681	1.189	1.909	1.482	1.505	1.559	1.161	1.662	1.011
Ghana	3.321	3.266	3.340	1.977	2.057	2.034	3.693	3.361	2.838	3.746	2.806	3.113	2.034
Guinea	2.151	1.883	2.291	1.997	2.275	2.390	2.445	2.126	2.189	2.579	2.554	2.180	2.283
Guinea-Bissau	2.038	1.899	1.771	1.561	2.034	2.064	1.832	2.171	2.082	2.420	2.905	2.159	2.199
India	4.250	4.429	4.105	4.465	4.286	4.238	3.944	3.899	3.929	4.120	4.261	4.318	4.243
Indonesia	5.080	5.167	5.018	5.149	4.996	5.292	5.159	5.186	5.390	5.099	5.179	5.140	5.350
Liberia	1.632	1.707	1.748	1.697	1.825	1.778	1.767	1.527	1.631	1.106	1.580	1.605	1.782
Mali	3.536	2.711	2.867	3.591	3.181	3.028	3.874	2.938	3.146	3.602	3.522	3.145	3.736
Niger	8.485	5.640	6.221	5.473	9.042	5.436	5.647	6.727	6.710	7.263	6.610	6.664	6.604
Nigeria	2.491	2.179	1.740	1.904	1.786	1.760	2.052	2.689	2.053	2.123	1.799	2.026	2.480
Pakistan	3.844	3.758	4.032	3.756	4.153	3.930	3.872	3.872	3.967	4.184	3.992	3.767	3.859
Philippines	3.819	3.954	3.957	4.137	3.963	4.454	3.974	3.934	4.342	4.101	4.262	3.957	4.127
Senegal	5.431	5.029	4.483	4.994	4.959	3.627	4.241	5.755	4.042	4.419	4.528	5.313	5.550
Sierra Leone	2.370	1.758	1.657	1.820	2.182	1.805	1.817	2.775	2.259	2.132	2.111	2.169	2.775
Thailand	3.088	3.146	3.227	3.054	3.246	3.160	3.209	3.027	3.162	3.131	3.166	3.045	3.043
Togo	2.612	3.328	2.896	4.014	3.494	3.154	3.549	2.109	2.901	2.861	2.765	2.658	2.487
United States	9.065	8.440	8.542	8.977	8.817	9.066	8.564	9.061	9.345	8.413	8.735	9.053	9.303
Uruguay	7.430	8.009	8.704	8.775	8.920	9.816	9.122	7.691	9.387	8.383	9.050	8.681	8.532
Vietnam	5.702	5.764	5.802	5.748	5.995	5.700	5.803	5.755	6.030	5.794	5.849	5.750	6.022

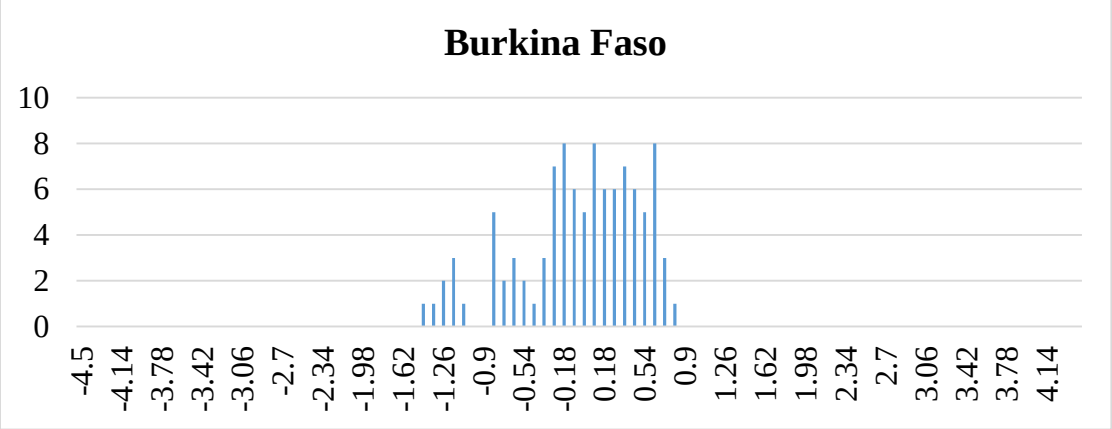
Appendix Table 8. 2023 Yield Simulation Iterations **(Continued)**

Iteration	92	93	94	95	96	97	98	99	100
Argentina	7.922	7.775	8.105	7.799	7.598	6.920	7.756	8.351	7.847
Australia	10.171	9.213	10.334	9.493	10.586	9.331	10.365	10.196	12.092
Bangladesh	4.798	4.896	4.982	4.557	5.243	4.884	4.855	4.932	4.944
Benin	3.830	4.106	4.133	4.734	3.110	3.948	3.971	3.368	3.405
Brazil	5.254	5.671	5.780	5.080	5.580	5.139	5.330	5.126	4.997
Burkina	1.828	1.826	3.350	2.230	2.873	2.971	2.356	2.743	2.560
Burma	2.843	2.716	3.224	2.733	3.104	3.110	3.153	3.145	3.404
Cambodia	3.055	2.948	3.309	3.341	2.891	3.089	3.055	2.880	3.066
China	7.249	7.149	7.155	7.155	6.964	7.078	7.145	7.156	7.149
Cote d'Ivoire	1.996	2.413	2.253	2.665	2.602	2.072	1.908	2.325	1.932
Gambia, The	1.093	1.565	1.865	1.684	1.922	1.508	1.094	1.915	1.780
Ghana	3.088	3.033	3.797	3.322	2.862	2.810	3.496	3.496	3.316
Guinea	2.725	2.275	2.276	2.219	2.280	2.182	2.316	2.464	2.400
Guinea-Bissau	2.944	2.057	1.825	1.565	1.896	2.839	2.128	2.165	2.035
India	4.196	3.948	4.114	3.912	4.105	4.189	4.107	4.323	4.220
Indonesia	5.367	5.139	5.260	5.097	5.255	5.396	5.294	5.378	5.137
Liberia	1.855	1.823	1.635	2.040	1.283	1.589	1.665	1.803	1.566
Mali	4.373	3.330	3.161	3.179	3.342	3.428	3.151	3.343	3.240
Niger	5.655	6.714	5.681	7.374	6.577	6.331	6.325	4.187	5.539
Nigeria	2.643	1.941	2.580	2.154	2.255	2.609	2.530	2.054	1.931
Pakistan	4.070	4.127	4.032	4.262	3.621	3.860	4.084	3.866	3.652
Philippines	4.256	4.287	4.293	3.976	4.425	4.044	4.059	4.358	3.956
Senegal	5.202	5.605	4.496	3.945	5.605	4.859	5.479	3.761	4.026
Sierra Leone	2.778	2.456	2.122	1.963	2.129	2.569	2.365	1.680	1.748
Thailand	3.085	3.168	3.029	3.159	3.149	3.121	3.019	3.158	3.111
Togo	2.954	3.084	2.871	3.326	3.377	2.353	2.156	3.104	2.721
United States	9.050	9.043	8.741	9.082	9.047	9.305	8.799	8.994	9.021
Uruguay	8.916	8.816	9.447	8.494	7.961	9.210	8.013	9.425	7.442
Vietnam	5.934	6.097	5.660	5.902	5.695	6.052	5.781	5.810	5.618

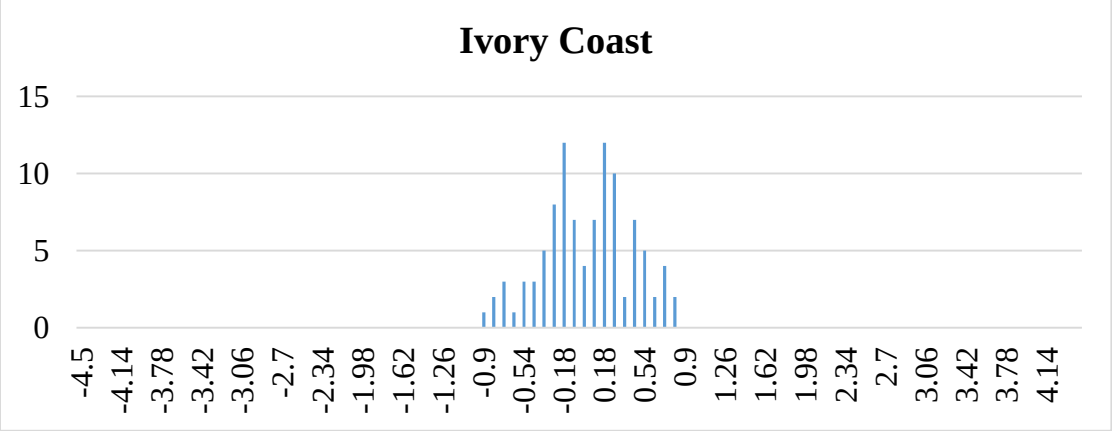
Appendix Figure 13. Probability Distribution of Consumption Change in Benin 2018



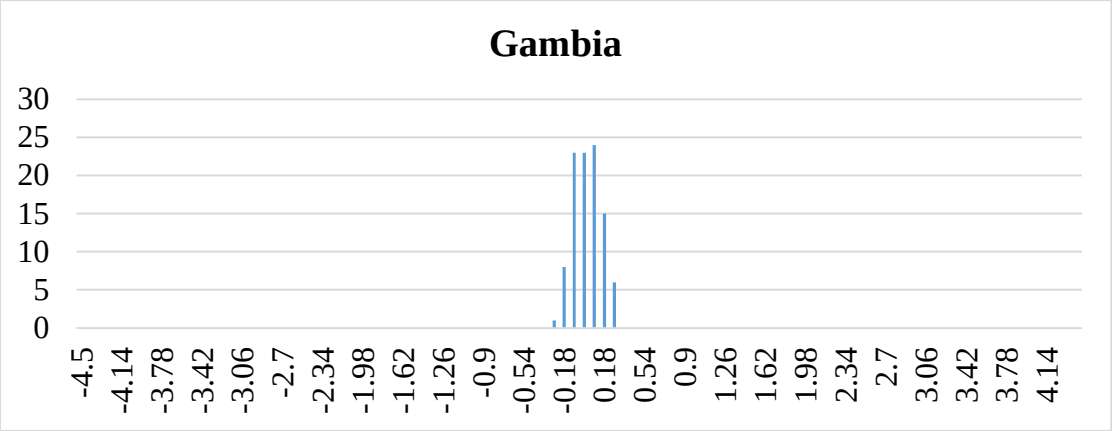
Appendix Figure 2. Probability Distribution of Consumption Change in Burkina Faso 2018



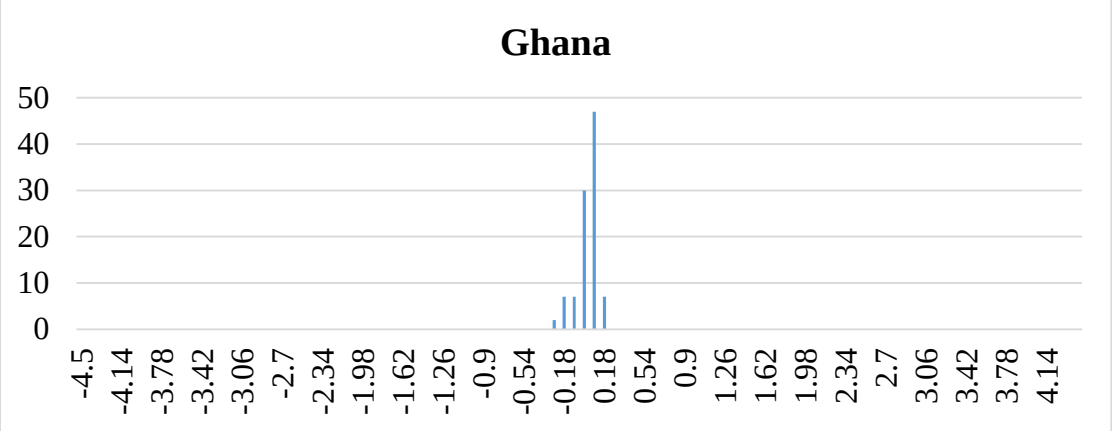
Appendix Figure 3. Probability Distribution of Consumption Change in Ivory Coast 2018



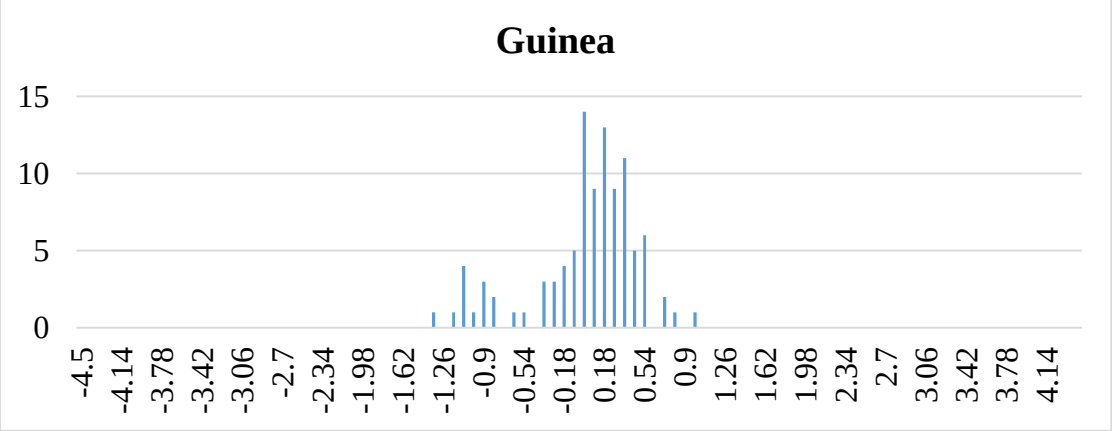
Appendix Figure 4. Probability Distribution of Consumption Change in Gambia 2018



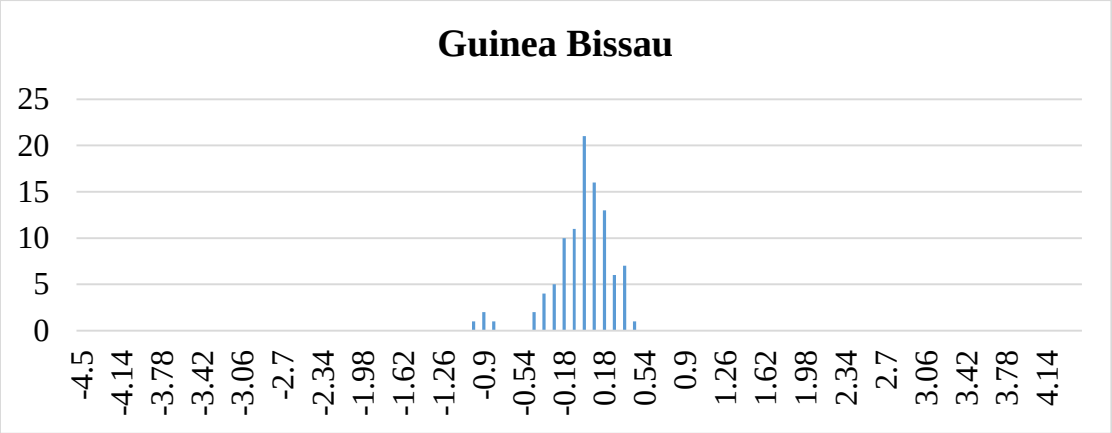
Appendix Figure 5. Probability Distribution of Consumption Change in Ghana 2018



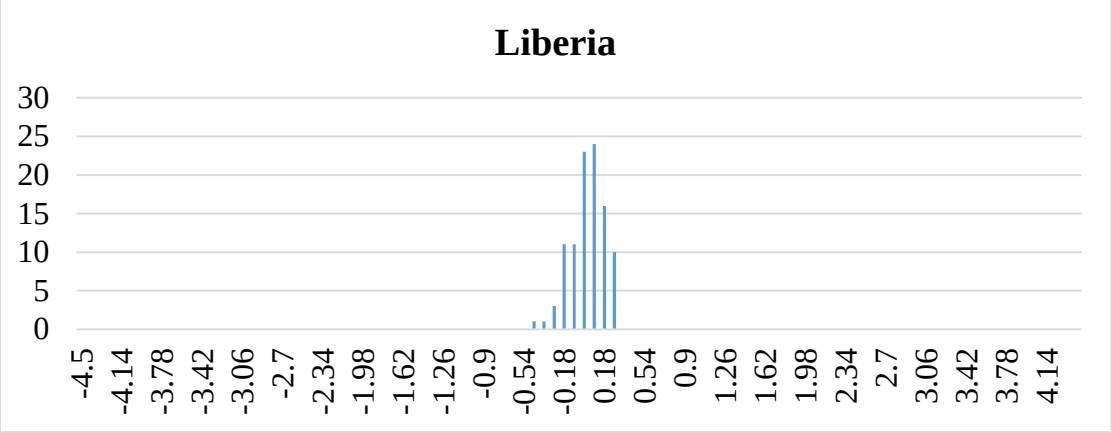
Appendix Figure 6. Probability Distribution of Consumption Change in Guinea 2018



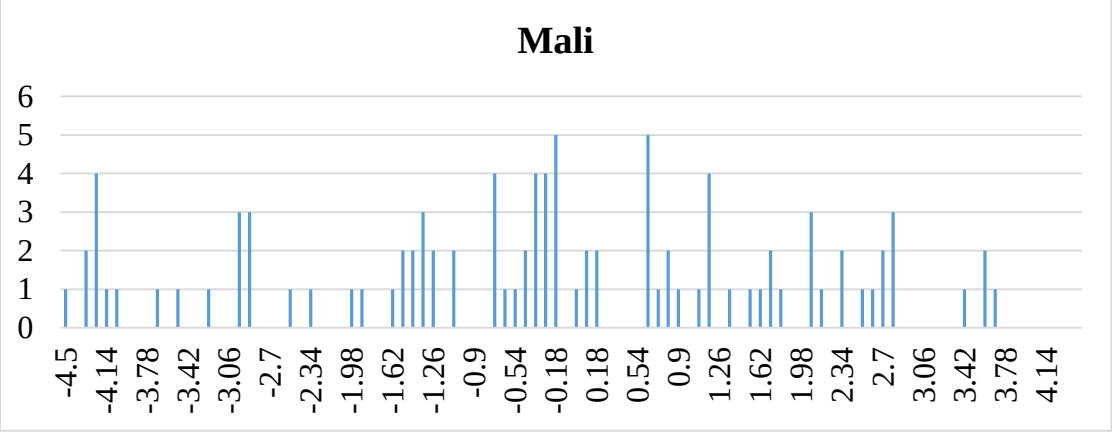
Appendix Figure 7. Probability Distribution of Consumption Change in Guinea Bissau 2018



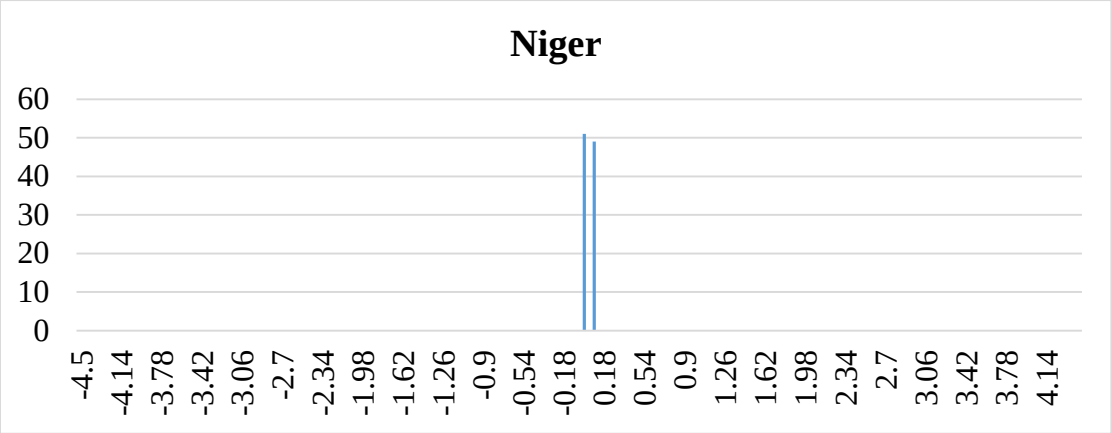
Appendix Figure 8. Probability Distribution of Consumption Change in Liberia 2018



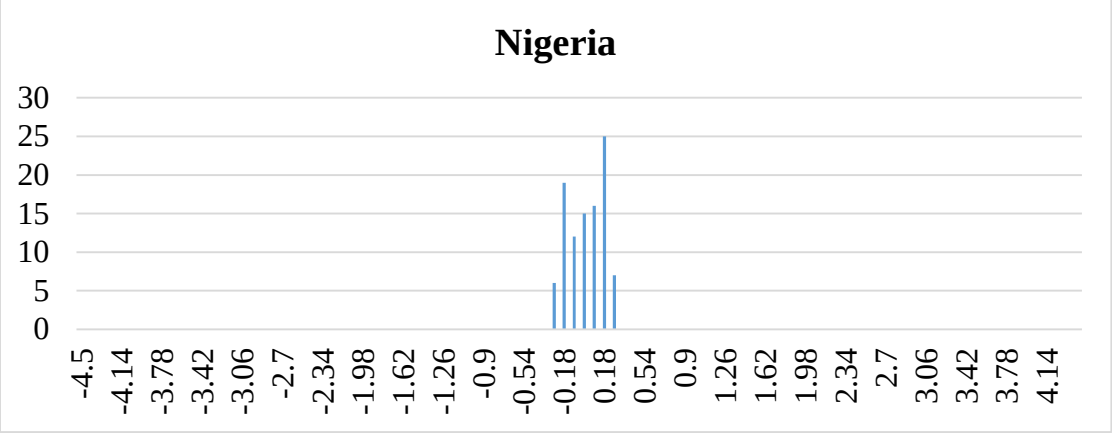
Appendix Figure 9. Probability Distribution of Consumption Change in Mali 2018



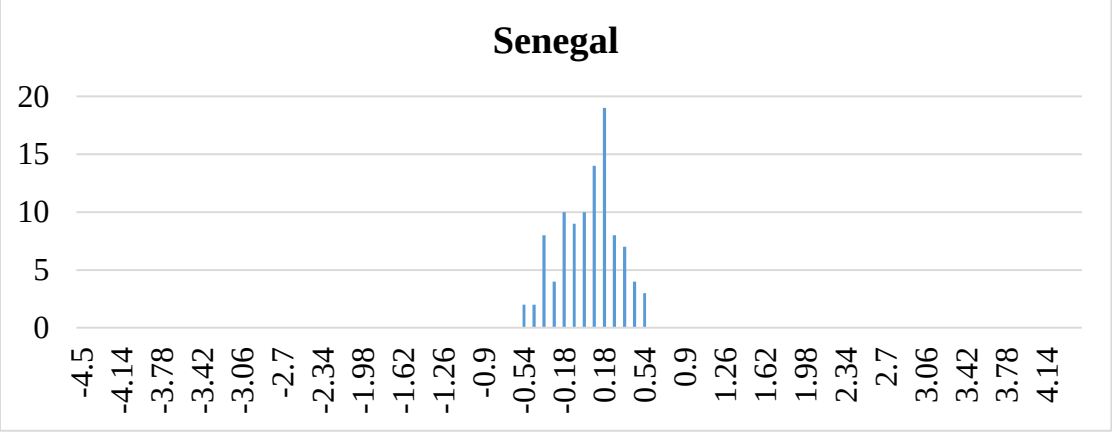
Appendix Figure 10. Probability Distribution of Consumption Change in Niger 2018



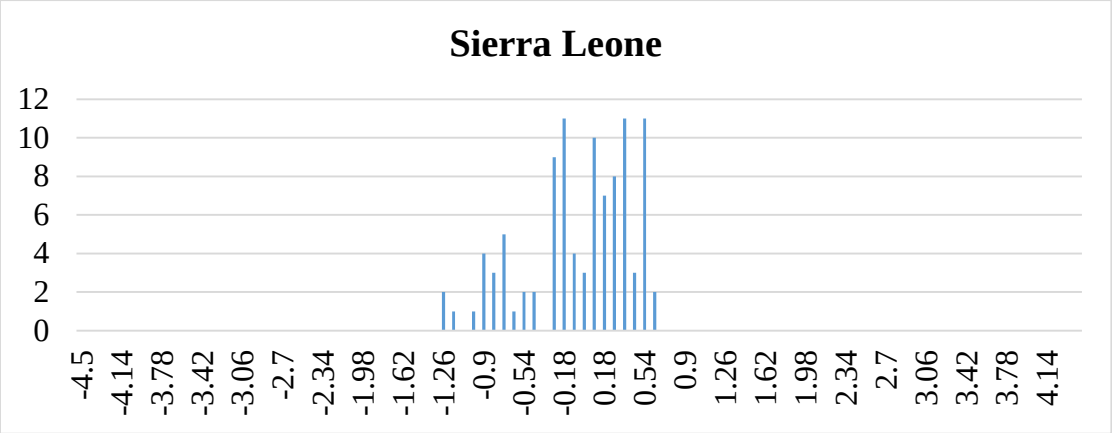
Appendix Figure 11. Probability Distribution of Consumption Change in Nigeria 2018



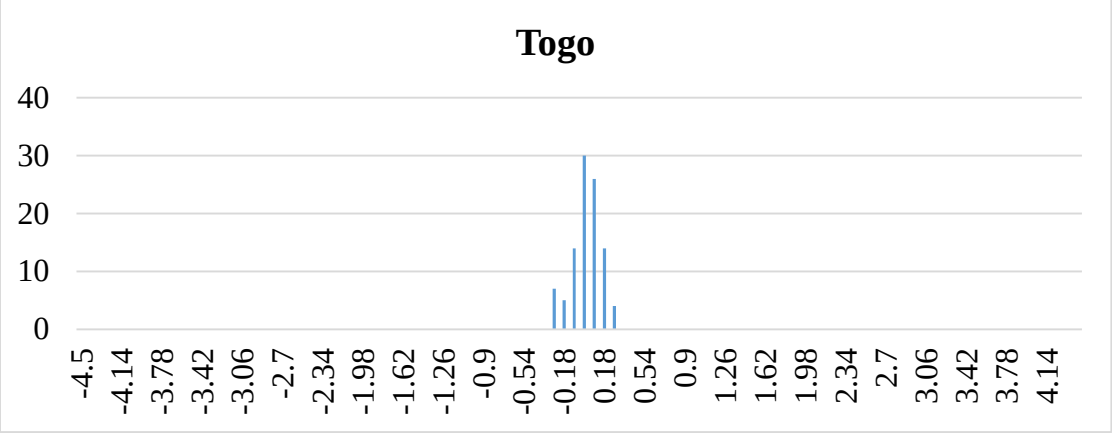
Appendix Figure 12. Probability Distribution of Consumption Change in Senegal 2018



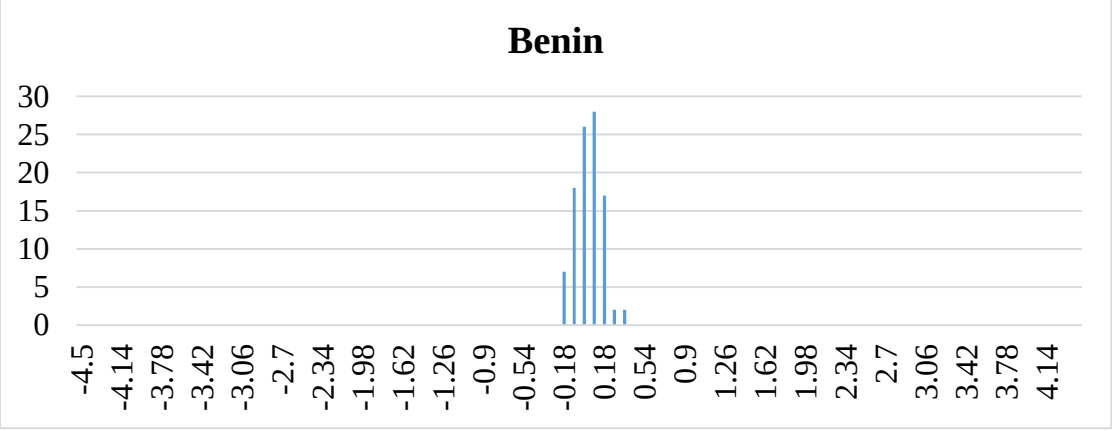
Appendix Figure 13. Probability Distribution of Consumption Change in Sierra Leone 2018



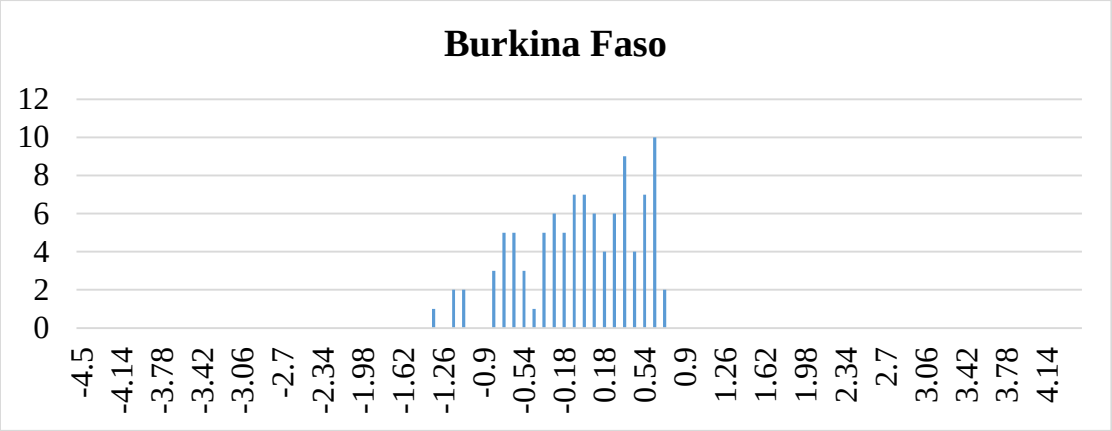
Appendix Figure 14. Probability Distribution of Consumption Changes Togo 2018



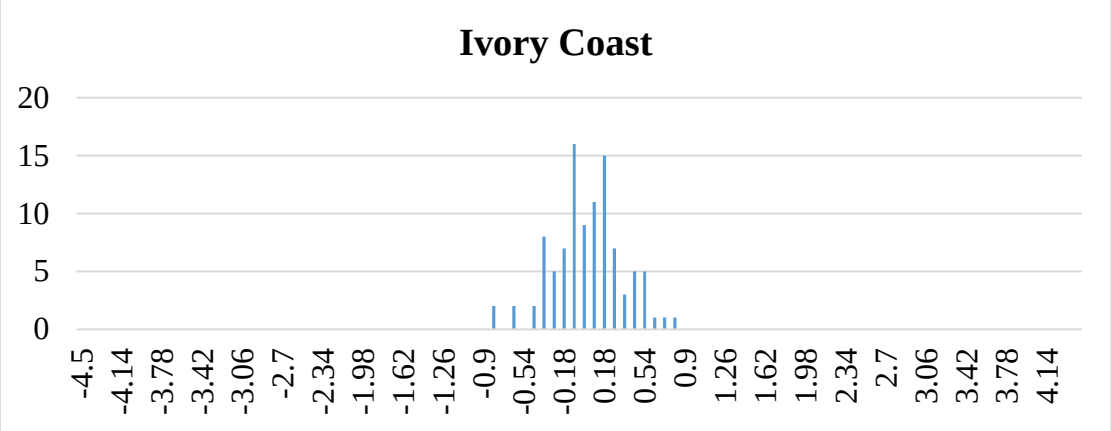
Appendix Figure 15. Probability Distribution of Consumption Change in Benin 2023



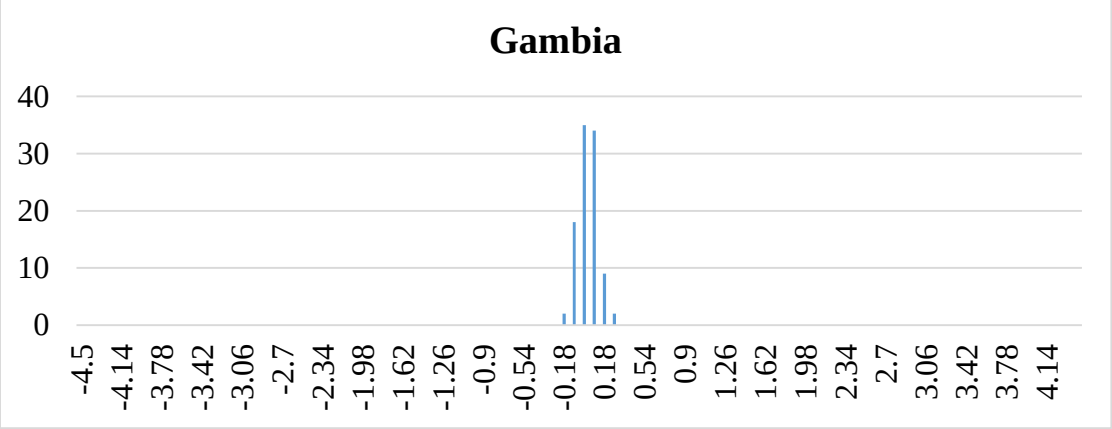
Appendix Figure 16. Probability Distribution of Consumption Change in Burkina Faso 2023



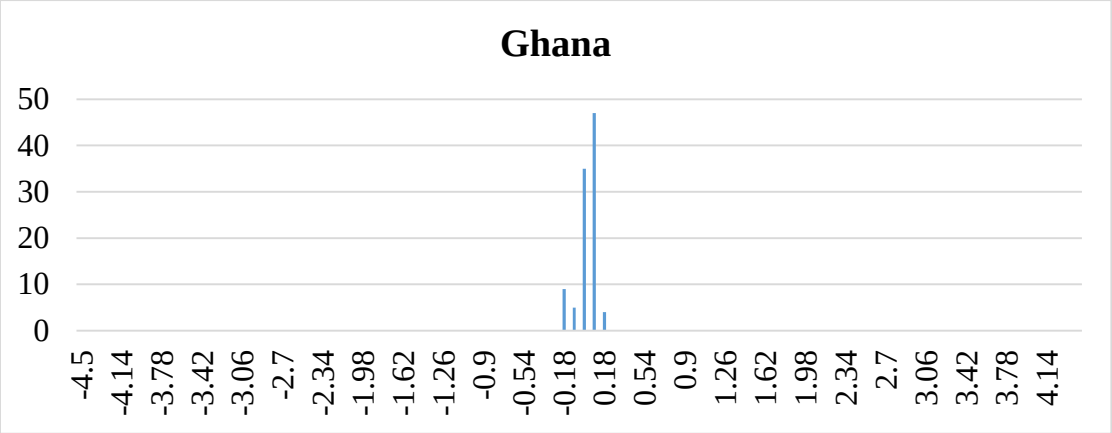
Appendix Figure 17. Probability Distribution of Consumption Change in Ivory Coast 2023



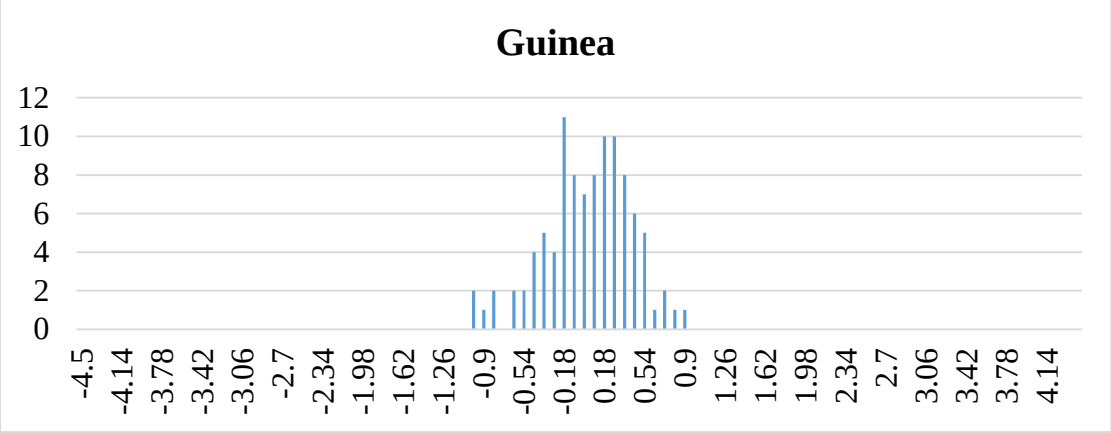
Appendix Figure 18. Probability Distribution of Consumption Change in Gambia 2023



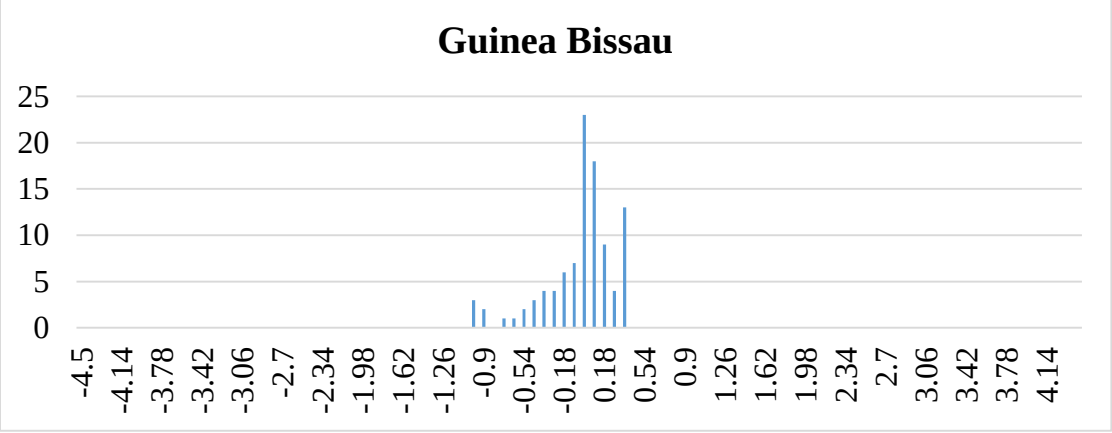
Appendix Figure 19. Probability Distribution of Consumption Change in Ghana 2023



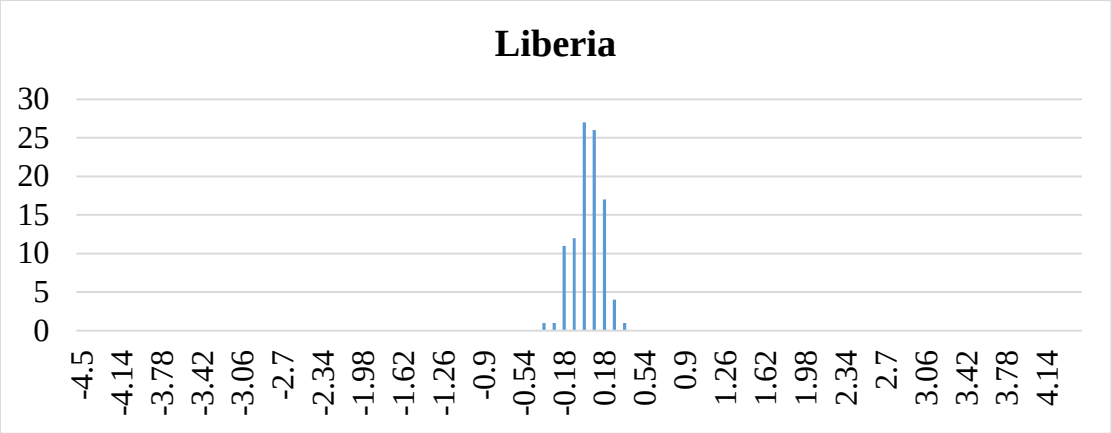
Appendix Figure 20. Probability Distribution of Consumption Change in Guinea 2023



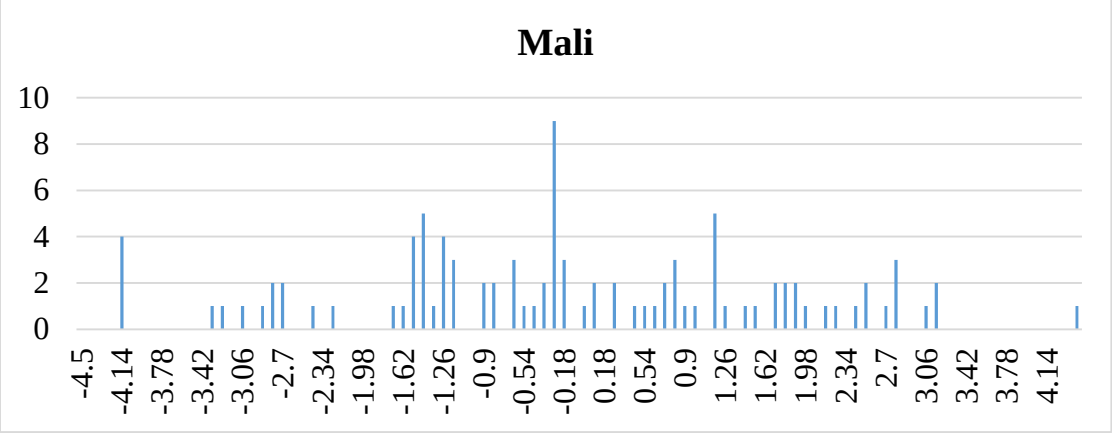
Appendix Figure 21. Probability Distribution of Consumption Change in Guinea Bissau 2023



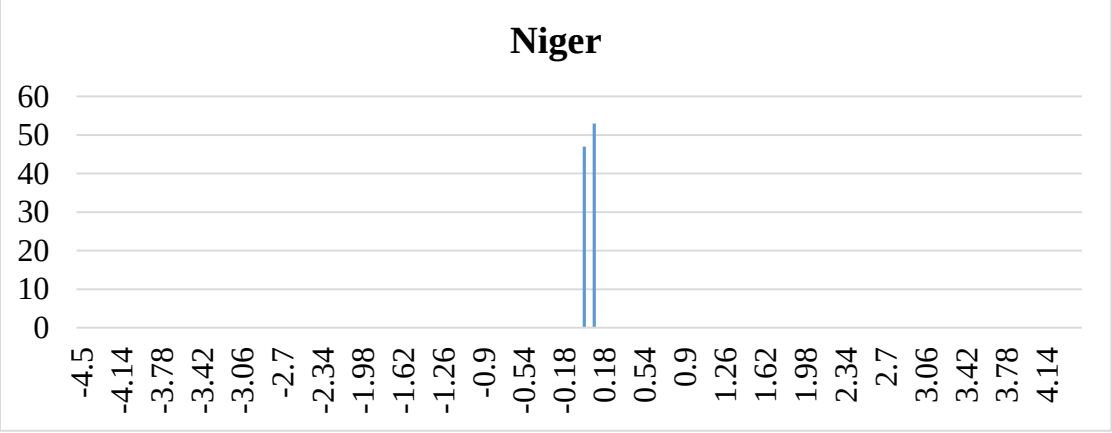
Appendix Figure 22. Probability Distribution of Consumption Change in Liberia 2023



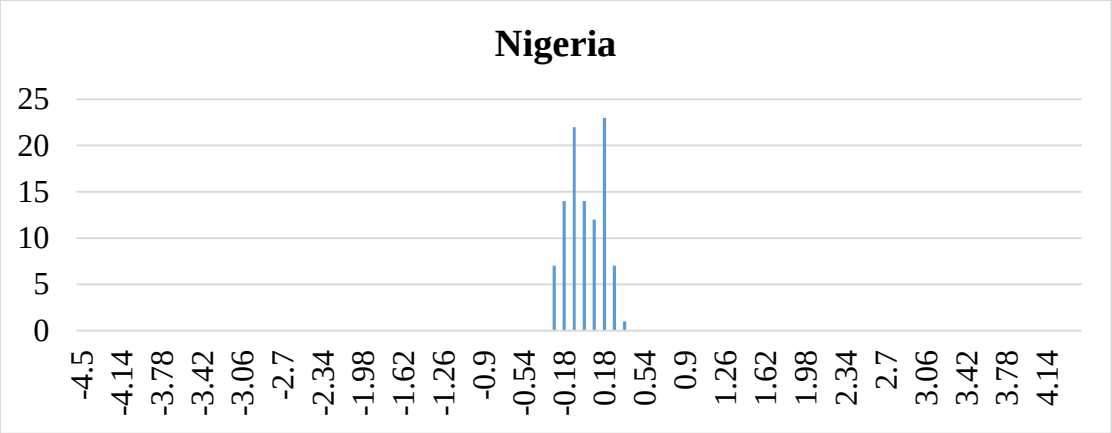
Appendix Figure 23. Probability Distribution of Consumption Change in Mali 2023



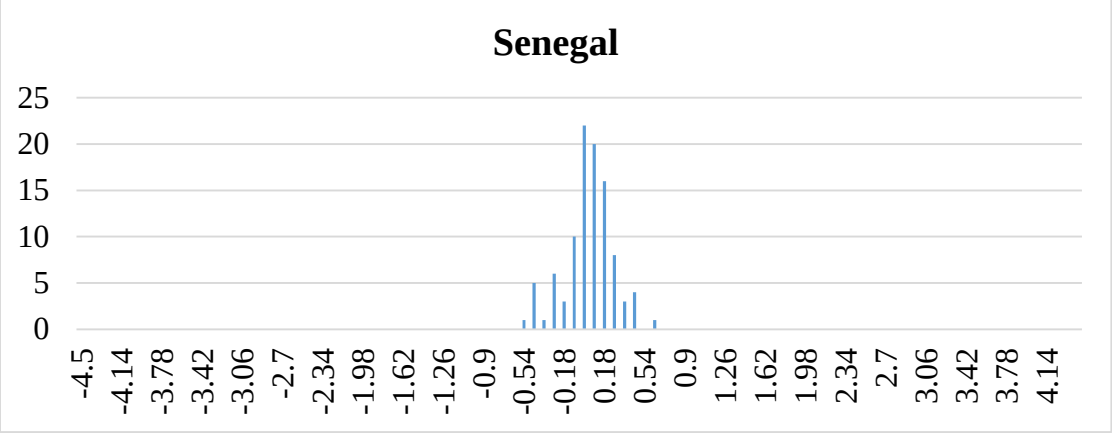
Appendix Figure 24. Probability Distribution of Consumption Change in Niger 2023



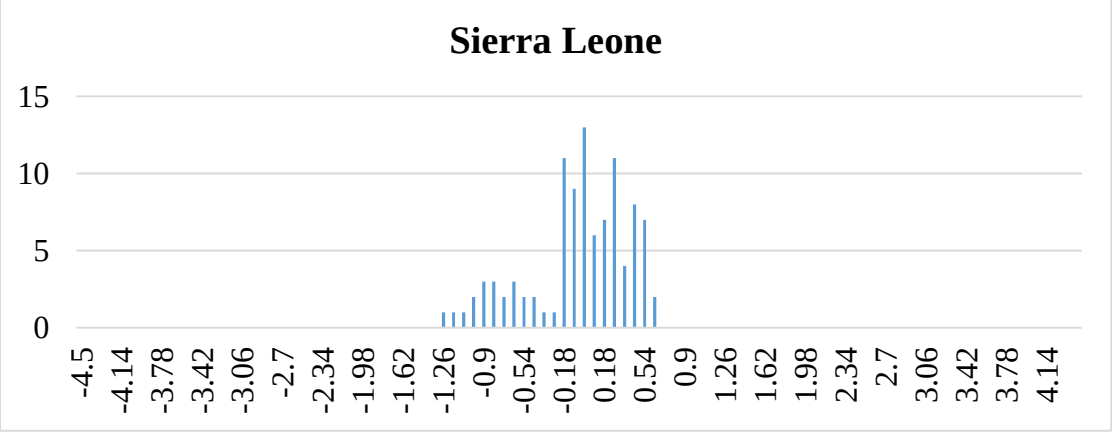
Appendix Figure 25. Probability Distribution of Consumption Change in Nigeria 2023



Appendix Figure 26. Probability Distribution of Consumption Change in Senegal 023



Appendix Figure 27. Probability Distribution of Consumption Change in Sierra Leone 2023



Appendix Figure 28. Probability Distribution of Consumption Change in Togo 2023