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Modelling the Impact of National Development Strategies for the East African Rice Sector

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Modelling the Impact of National Development Strategies for the East African Rice Sector

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by

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ABSTRACT

The 2008 food crisis prompted many food importing nations to reconsider the need to be self-sufficient especially in their staple food needs. This awakening led to the launch of the Coalition for Africa Rice Development (CARD) initiative with a goal to double rice production in Africa. Under the CARD umbrella member countries drafted individual National Rice Development Strategies (NRDS). This study is a quantitative assessment of four East African countries' NRDS: Kenya, Rwanda, Tanzania and Uganda within dynamic global rice economy models. The NRDS targets and strategies are not realistic and included under estimation of rice consumption for Kenya, an incorrect rice production area for Tanzania and overly ambitious production targets for Rwanda and Uganda. Under a business-as-usual scenario, based on historical baseline projections none of the four countries will attain rice self-sufficiency by 2018. Furthermore the area expansions and yield improvements required to attain self-sufficiency in these countries (with the exception of Tanzania) are unprecedented and highly unlikely to be achieved by the end of 2018. Imposing self-sufficiency through elimination of long grain rice imports would penalize the consumers extremely through high price increases and consequently rice consumption shrinkage in the four countries. In order to attain self-sufficiency without hurting consumers would require sizable improvements of production efficiency. Alternatively the governments could use output price subsidies to boost production, but the cost would be very large and unrealistic particularly for Kenya. This study concludes that attaining rice self-sufficiency in these countries in the intermediate time horizon is unrealistic. Very large changes in resource allocation, productivity, and consumption trends will be required. It is however important to note that the results obtained in this study may be extremely valued as they are

generated within a partial equilibrium framework and may be less dramatic if a general equilibrium framework was used.

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DEDICATION

I dedicate this thesis to my dear loving Mum for the unmatched sacrifice she made to put me through school. To my two brothers Dennis and Vincent, my only sister in love Florence, my nephew Joe and niece Abby. May this accomplishment in my life inspire you to always strive for greater heights. You are the reason for my hard work and ‘never give up’ attitude.

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LIST OF ABBREVIATIONS

AGRA	Alliance for a Green Revolution in Africa
AGRM	Arkansas Global Rice Model
CAADP	Comprehensive Africa Agriculture Development Programme
CARD	Coalition for Africa Rice Development
CRMP	Cooperative Reform and Modernization Programme
DRC/DRCR	Domestic Resource Cost Ratio
DSIP	Development Strategy and Investment Plan
EAC	East African Community
EDPRS	Economic Development and Poverty Reduction Strategy
ERS	Economic Recovery Strategy
ESA	East and Southern Africa
EUROCORD	European Cooperative for Rural Development
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistical Database
FAPRI	Food and Agricultural Policy Research Institute
FOB	Free on Board
GDP	Gross Domestic Product
GOANA	Great Agricultural Offensive for Food and Abundance
GRiSP	Global Rice Science Partnership
Ha	Hectare
JICA	Japan International Cooperation Agency
Kg	Kilogram
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MDG	Millennium Development Goals
MT	Metric Tons
MY	Marketing Year
NEPAD	New Partnership for Africa Development
NERICA	New Rice for Africa
NPC	Nominal Protection Coefficient
NRDS	National Rice Development Strategy
NSGRP	National Strategy for Growth and Reduction of Poverty
P S & D	Production Supply and Distribution
PEAP	Poverty Eradication Action Plan
PMA	Plan for Modernization of Agriculture

SDG	Sustainable Development Goals
SPAT	Strategic Plan for Agricultural Transformation
SRA	Strategy for Revitalization of Agriculture
SRI	Systems of Rice Intensification
SSA	Sub-Saharan Africa
SSR	Self Sufficiency Ratio
USDA-FAS	United States Department of Agriculture-Foreign Agricultural Service

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CHAPTER 1: INTRODUCTION

1.1 Status of Food Insecurity in Sub-Saharan Africa

The 1996 World Food Summit definition of food security connotes a multi-dimensional approach linking availability with accessibility (physical, social and economic) not only of adequate but also safe and nutritious food for all people at all times. In accordance with the United Nations Millennium Development Goal 1c target to halve the proportion of people suffering from hunger, great progress has been made in Africa with a reduction of 31% in the number of hungry people between 1990-1992 and 2014-2016 (UN 2015). This progress was however not uniform among the various sub-regions of Africa (FAO 2015). Great progress was noted in West Africa where the percentage of undernourished people fell from 24% to 9% thus attaining its MDG target. Moderate progress was made in in the East and South Africa regions with the proportion of undernourished decreasing from 47% to 32% and from 7% to 5%, respectively. However, in the Central Africa region the proportion of undernourished went up from 34% to 41% for the period between 1990-1992 and 2014-2016. It is also important to note that although the continent the proportion went down, the absolute number of undernourished increased from 175.7 million to 217.8 million over the same period. East Africa has the largest share of the undernourished in SSA; 59% in 1990-1992 and 57% in 2014-2016.

High food prices especially of food staples exacerbate the status of food insecurity and subsequently political instability and inflation in many countries (IFPRI 2008; FAO 2015). High grain prices have been linked to the growing biofuels demand to some extent alongside production and buffer stocks shortfalls (OECD 2008). Consistent with Engel's law, the proportion of income spent on food is higher in developing countries. African nations which rely heavily on imports are the most severely hit by rises in international food prices and with the paradox that most of the poor and food insecure people in SSA are the rural populace, most of whom are farmers but net buyers of food, it is no surprise that rising food prices significantly aggravate the levels of food insecurity in these areas most.

1.2 Increasing Importance of Rice in Africa

Rice is becoming an increasingly popular and important food staple in Africa. The increasing consumption may be attributed to income growth, population growth as well as changes in dietary patterns of consumption with the expanding number of urban dwellers preferring rice over the traditional coarse grains because of its relative ease of cooking and adaptability of preparation (Republic of Rwanda 2013; EUCORD 2012; GRiSP 2013). In 2009, total rice produced in Africa amounted to 14 million MT, barely 3% of total rice produced globally. In the same period, 9.8 million MT of rice was imported into Africa which represents 40% of the total rice consumption in the continent and accounts for one-third of total world rice trade (EUCORD, 2012). Rice production and consumption is highest in West Africa where it has been grown traditionally as a subsistence crop unlike Eastern and Southern Africa (ESA) where rice has become an important food crop only in the last two decades with small and large scale farmers growing rice as a cash crop (Eklou et al. nd; EUCORD 2012). Rice production in Sub-Saharan Africa increased from 2.2 million MT in 1960 up to 15.5 million MT in 2016. Similarly, but more dramatic, rice consumption in SSA has increased from 2.5 million MT to 27 million MT in the same period (P S & D online).

Rice is the fastest growing staple in Sub-Saharan Africa; in fact it is the main staple food crop in ten African countries and forms a major part of the diet in many others (EUCORD 2012). The Eastern Africa region is second only to the West Africa region in terms of rice production and consumption. In Kenya, rice is the third most important crop with an annual consumption growth estimated at 12% compared to 4% and 1% for the other two important food staple crops, wheat and maize, respectively (Republic of Kenya 2008). According to a household survey conducted in Rwanda in 2010, up to 6.7% of food purchases constituted rice, displacing traditional foods such as cassava (Kathiresan 2013). The per capita consumption of rice in Rwanda has risen quickly from about 3kg per capita per year in 2000 to about 10kg per capita per year as of 2013 (P, S & D Online). Figure 1 illustrates the evolution of average per capita daily calorie intake from traditional coarse grains (sorghum and millet) towards more wheat and rice.

Rice has emerged, furthermore, as a potential income earner for the Rwandan growers who retain only 15% for their consumption and sell the rest to the markets (Kathiresan 2013). In Rwanda, rice productivity in the marshlands justifies its production against low productivity of other crops in the uplands which suffers from reduced soil fertility and soil erosion (Republic of Rwanda 2013). In Uganda although rice is not a traditional staple, its adoption as a cash crop recently has been rapid especially following the introduction of upland rain-fed NERICA varieties contributing up to 40-60% of the rice small holder farmer' income (Haneishi 2014; Haneishi et al. 2013; Gitau et al. 2011; Mohapatra 2013).

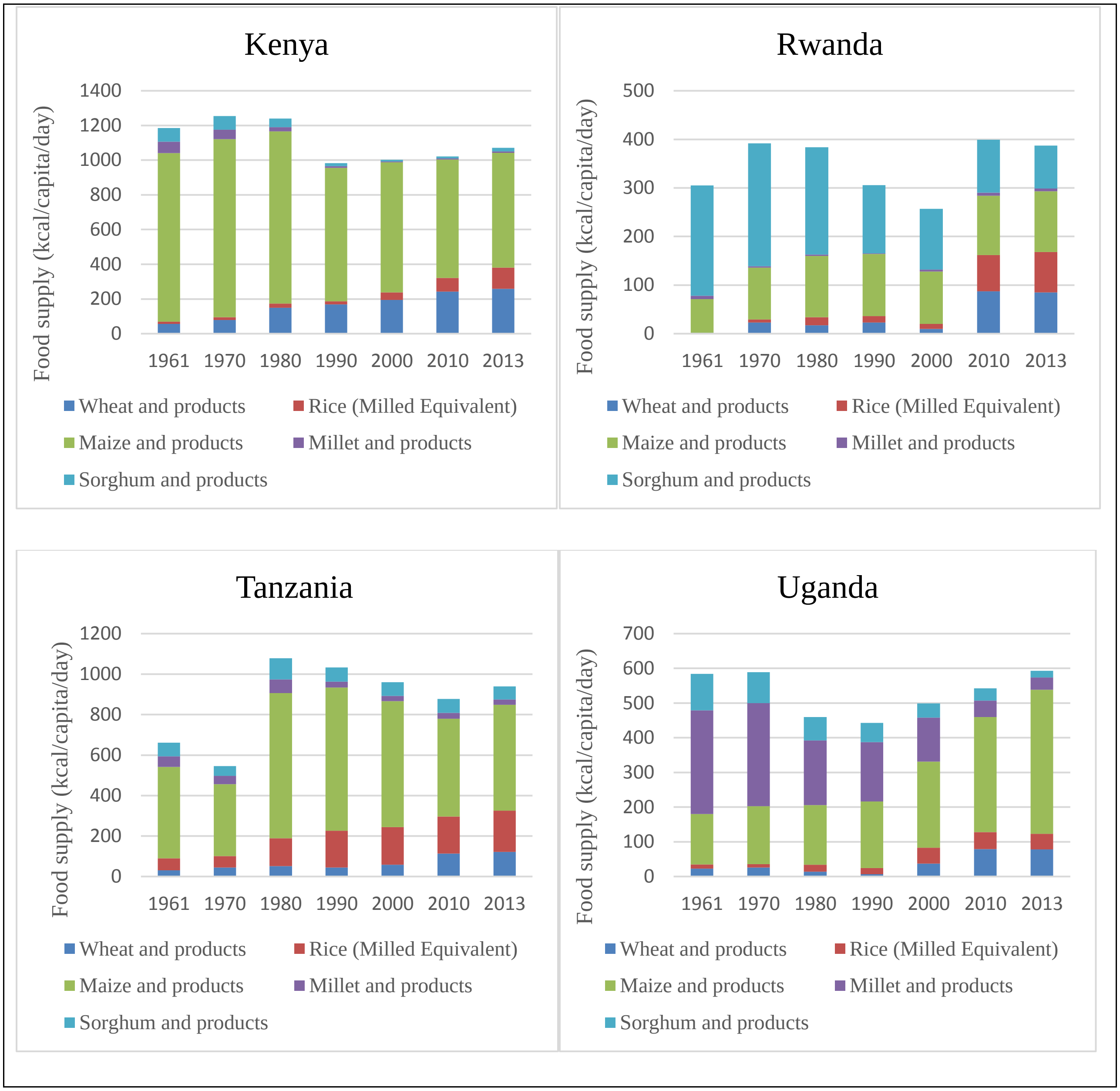

Figure 1. Evolution of the share of major cereals in the daily dietary calorie intake in Kenya, Uganda, Rwanda and Tanzania, 1961-2013.
Source FAO Food Balance Sheets.

1.3 Rice Supply and Demand Balances in East Africa

Just like in many African countries, rice production in East Africa is not meeting consumption, with an increasing gap filled by imports. Figure 2 shows rice production, consumption, and imports trends for Kenya, Rwanda, Tanzania, and Uganda between 2000 and

2013. Among the four countries included in this study, Tanzania is by far the largest producer and consumer of rice. In 2015, rice produced in Tanzania totaled to 1.73 million MT against a consumption of 1.85 million MT. The per capita consumption has increased from 21.3Kgs in 2001 to 35.6Kgs in 2014 (P S & D online; AGRM). As of 2016 Tanzania was nearly self-sufficient in rice (94%). Whether Tanzania is actually a net rice exporter or a net importer remains unclear with estimates of unofficial cross-border trade suggesting it is a net exporter (Stryker & Amin 2012) while other report estimates suggest a net importer (P S & D online; FAOSTAT; Barreiro-Hurle 2012). In whichever any case, there is a proportional growth of production and consumption in Tanzania and consequently rice imports are rather constant. Perhaps most likely is that depending on the season, Tanzania during harvest may be a net exporter and during the remainder of the year it is a net importer. Second among the four countries in total level of rice consumption is Kenya with a total consumption of 520,000 MT in 2014. The per capita consumption has increased from 8.7Kgs in 2000 to 11.5 Kgs in 2014. Rice production in Kenya however falls short of consumption resulting on average with about 15% self-sufficiency. The gap is met by imports mostly from Pakistan. The value of rice imports into Kenya between the years 2010 and 2014 averaged USD 539 million annually (UN Comtrade 2016). In Uganda and Rwanda consumption growth surpassed production as in Kenya. Consumption in Uganda in 2014 stood at 234,000 MT against a production of 154,000 MT (65% self-sufficiency). In Rwanda 2013 rice consumption was 98,000MT against a production of 58,000MT (59% self-sufficiency).

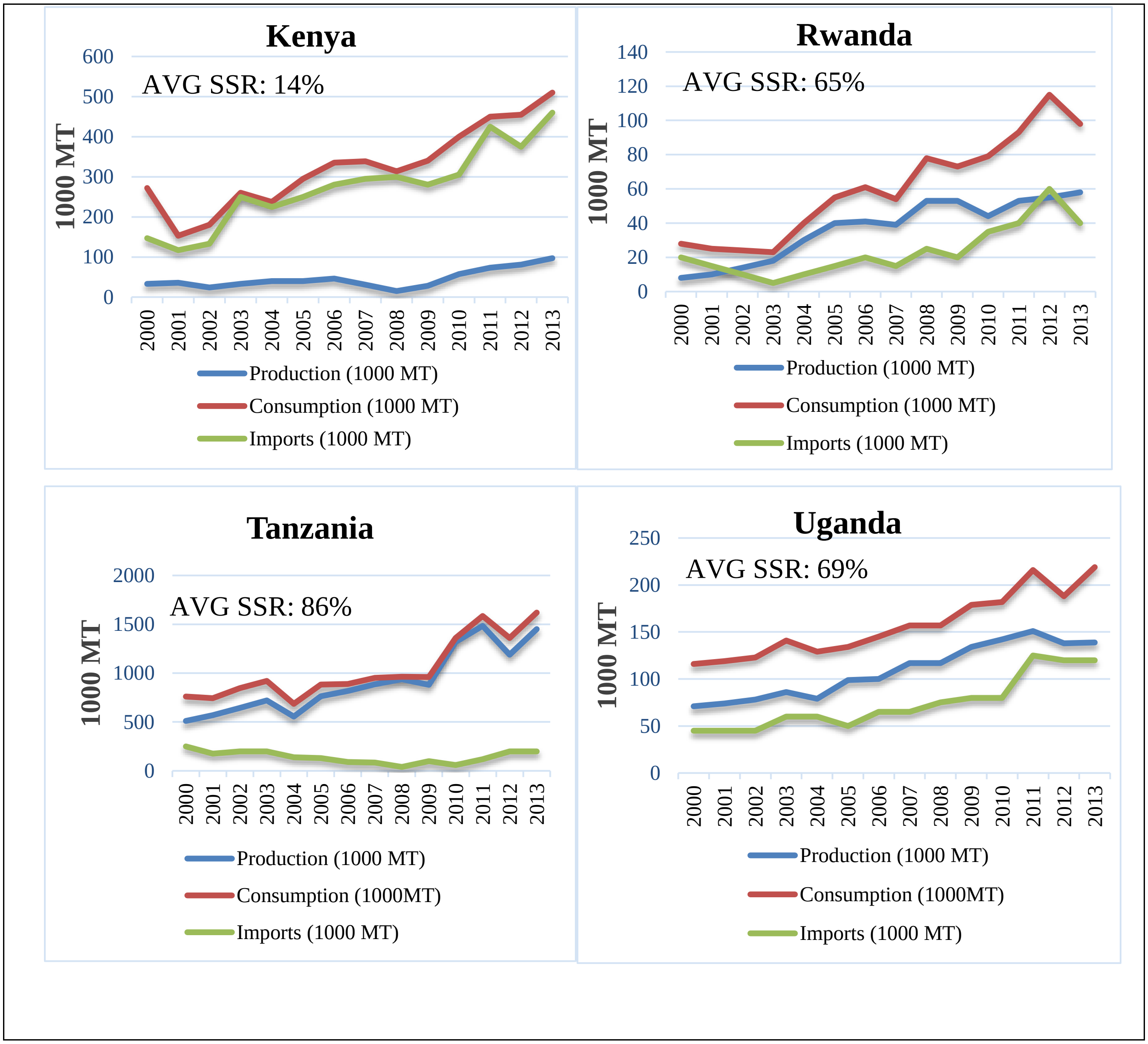

Figure 2. Rice Production, Consumption and Import trends in Tanzania, Kenya, Rwanda and Uganda 2000-2013.
Source: USDA, P S &D Online.

1.4 National and Regional Policies on Food Security and Rice Self-Sufficiency in East Africa

Following the 2008 food crisis, 21 African nations under the Coalition for Africa Rice Development (CARD) initiative, set out National Rice Development Strategies (NRDS) with the aim of doubling rice production between 2008 and 2018. CARD's ultimate goal is for the African countries to attain rice self-sufficiency, thus contributing to the food security as well as poverty reduction in the continent.

The NRDS are aligned with several other national and regional policies aimed towards food security and poverty reduction (Wailes et al. 2015). Firstly, they were aligned with the just concluded Millennium Development Goals (MDG) to alleviate poverty and hunger and improve the quality life through agricultural development, which is further extended in pillars 1 and 2 of the Sustainable Development Goals (SDG) (UNDP 2017). Secondly, the Comprehensive African Agriculture Development Program (CAADP) under the flagship of New Partnership for Africa Development (NEPAD) provides a framework for stimulating agricultural sector growth (6% annual agriculture GDP growth target) in Africa through both public and private investments with at least 10 % public expenditure for the agriculture sector. NEPAD recognizes the contribution of agriculture towards economic growth over and beyond the contribution of other sectors such as tourism, mining and others (FAO 2002). Rwanda was the first country to sign the CAADP compact in 2007 and consequently the Government of Rwanda (GoR) budget for agriculture increased from less than 2% in 2006/2007 to more than 7% in 2013/2014 (Republic of Rwanda 2013; IFPRI 2015). Forty additional African Union member states have signed the CAADP compacts between 2009 and 2015, while several have further developed the post-compact roadmaps and investment plans (NEPAD Planning and Coordinating Agency 2014). Consequently public expenditure on agriculture in Africa in general has increased by more than 7% per annum since 2003 when CAADP was launched. In addition to the national compacts, four regional compacts have been signed. The EAC CAADP Compact was endorsed by the East Africa Community (EAC) council of ministers in 2016 (UN 2016).

At the national level the respective governments of the EAC have in place programs and strategies towards economic development and poverty reduction namely: Economic Recovery Strategy (ERS) and Poverty Reduction Strategy Plan (PRSP) in Kenya; the Economic Development and Poverty Reduction Strategy (EDPRS) in Rwanda; National Strategy for Growth and Reduction of Poverty (NSGRP popularly known as MKUKUTA) in Tanzania; and the Poverty Eradication Action plan (PEAP) in Uganda. Similarly there are strategies to transform and develop the agricultural sector in these countries. These include: Cooperative Reform and Modernization Programme (CRMP) in Tanzania; Strategic Plan for Agricultural Transformation (SPAT/PSTA) in Rwanda; Strategy for Revitalization of Agriculture (SRA) in Kenya; and Plan for Modernization of Agriculture (PMA) in Uganda.

In 2002 the government of Rwanda pronounced rice a priority crop upon the acknowledgement of the potential for its production in the marshlands. Phase III of the PTSA (2013-2017) includes the rice sector among the priority value chains in Rwanda (Republic of Rwanda 2013). In 2004 the president of Uganda, launched the Upland Rice Project seizing the opportunity presented by NERICA upland rice varieties (Mohapatra 2013). The Uganda Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) identified rice as a strategic crop in the Development Strategy and Investment Plan (DSIP) for food security and poverty reduction (Government of the Republic of Uganda 2009).

1.5 Description of the Study

1.5.1 Problem Statement

Rapid growth in rice consumption against a slower expansion of rice production in Africa has left large gaps to be met by imports. Dependence on imports for an important staple food can be a major threat to national food security. The 2008 global food crisis exemplifies the magnitude of such a threat when some key rice and maize producing countries banned their exports (Davis et al. 2016; Diagne. 2012; Minot 2010). Kenya relies on imports to meet 86% of its national rice consumption even though rice is the third most important food in the country (USDA 2016). In Tanzania production would need to increase by 100,000 tons between 2008 and 2018 to meet the growing population and the high per capita consumption (25kg) of rice (Republic of Tanzania 2009). While Rwanda is 75% self –sufficient, the consumers especially in the urban areas prefer the long grain imported rice which is deemed of higher quality as compared to the short and medium grain domestic rice which has a higher percentage of brokens from poor milling infrastructure. The domestic rice is sold to the rural population who have less purchasing power (Republic of Rwanda 2013).

In the wake of the 2008 crisis several nations set ambitious goals to strive for self-sufficiency for their important food commodities. Many African countries under the Coalition for Africa Rice Development (CARD) set out National Rice Development Strategies (NRDS) with the goal of doubling rice production from 14 million MT in 2008 to 28 million MT in 2018 (JICA 2009). Whereas doubling production may be readily attainable, the question of being rice self-sufficient is questionable. With the consumption growth being more rapid than expected the production goals of CARD, the ability to attain self-sufficiency may be difficult. For example, while Kenya's NRDS rice consumption levels in 2018 are projected to be 248,000 MT, the actual consumption for the year 2013 was at 510,000 MT more than double the 2018 NRDS projections. Similarly Tanzania's NRDS projected 1.29 million MT rice consumption whereas the actual consumption as of 2013 exceeded this at 1.62 million MT. Furthermore simply increasing domestic rice production where it is less competitive in terms of price or quality will only lead to a surplus of local rice in the local markets and potentially subsequently domestic prices will decline relative imported rice and thereby harming the rice farmers while imports of rice persist (Wailes et al. 2015; Demont et al 2012). Moreover, if local rice production has no comparative advantage over imported rice then self-sufficiency will be at the expense of social welfare for the consumers who have to pay more for the local rice.

Demont & Rizzotto 2012; Demont & Ndour 2015, qualitative assessment of 19 NRDS propose value chain upgrades to enhance competitiveness against cheaper and more often higher quality imported rice (Demont et al. 2013).

This study entails a quantitative analysis of the strategies laid out in four East African Countries NRDS documents namely Kenya, Rwanda, Tanzania and Uganda. The feasibility of the targets and strategies to attain rice self-sufficiency in these countries will be analyzed using two partial equilibrium models of the world rice economy. In addition the spill-over effects on the national and global rice economy in terms of production, consumption, prices and trade will be analyzed. The Arkansas Global Rice Model (AGRM), which is a "multi-country statistical simulation and econometric framework" (Wailes & Chavez 2011) will be used to simulate the supply lifting strategies based on, area expansion and yield increase scenarios while the RICEFLOW model, which is based on a multi-region, multi-product, spatial partial equilibrium framework (Durand-Morat & Wailes 2010) will be used to evaluate the implications of self-sufficiency with regard to rice availability and affordability.

1.5.2 Objectives of the Study

1.5.2.1 Overall Objective

The overall objective of this research study is to evaluate the challenges in rice sector investments and development to achieve food security in the selected African countries: Kenya, Rwanda, Tanzania and Uganda.

1.5.2.2 Specific objectives

1. Assess and characterize National Rice Development Strategies (NRDS) investment plans in Kenya, Rwanda, Tanzania and Uganda.
2. Estimate a dynamic baseline for Kenya, Rwanda, Tanzania and Uganda national rice sectors within the global rice economy.
3. Evaluate alternative rice self-sufficiency strategies in Kenya, Rwanda, Tanzania and Uganda with regard to feasibility and impact.

The remainder of this study is organized as follows. Chapter 2 provides a review of relevant literature with regard to self-sufficiency goals, their feasibility and linkage to food security. The chapter ends with a review of the National Rice Development Strategies for the four countries covered in this study. Chapter 3 will give the analytical framework used to establish a dynamic baseline of the rice economy and evaluate the alternative scenarios to attain rice self-sufficiency in the four countries. The chapter also provides details on the various data used and the respective sources. Chapter 4 shows the results of the scenarios simulations and a discussion of the same. Chapter 5 gives the summary and conclusions of the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Pre-requisites for Rice Self-Sufficiency in SSA

There are several possible ways to increase rice production in Africa including increasing the area under rice cultivation; increasing rice yields; intensifying production by planting two or more crops per year and reducing losses that occur after harvest. Whereas a combination of such approaches has seen rice production in SSA grow at a rate of 3.2% per annum between 1961 and 2006, rice consumption increased by 4.52% accompanied with a population growth rate of 2.9% in the same period (Diagne et al. 2012). In order to close the consumption-production gap rice imports in SSA have been inevitable. Oort et al. 2015 assessed the feasibility of attaining rice self-sufficiency in eight African countries: Egypt, Burkina Faso, Ghana, Mali, Nigeria, Tanzania, Uganda and Zambia while factoring in the biophysical constraints of intensification potential and yield ceiling. Their findings showed that it is possible for the eight countries to achieve rice self-sufficiency by 2025 assuming the consumption trend between 2000 and 2012 is continued and population grows as per the World Bank medium growth variant. This would be achieved if the yield increases to 80% of the biophysical yield potential and a double crop on the current irrigated area. However with the more realistic yield increases, self-sufficiency is impossible and imports inevitable. Much of the rice production growth seen in Africa has been through area expansion and less of yields increase. The yield gap thus presents an untapped potential to increase rice production and attain rice self-sufficiency with the appropriate investments to improve yields such as improved varieties and irrigation investments (Stryker 2010)

The Government of Senegal initiated the GOANA program following the 2008 crisis with an ambition to attain rice self-sufficiency by 2015. The project incorporated recommendations to upgrade rice value chain through: upgrading post-harvest quality; advertising and generic promotion as well as productivity (Demont et al., 2013; Demont and Rizotto, 2012). However according to Diagne et al. (2012) there were institutional and biological constraints beyond intensification and extension strategies thus limiting productivity along the Senegal River Valley (SRV). These included organizational problems leading to delayed and inadequate fertilizer use, bird damage and irrigation rehabilitation problems. The recommendation to the Senegalese government was thus improvements in extension services to the rice farmers especially for bird and weed control which were the two most important factors limiting rice productivity along the SRV. Until these biological and institutional constraints are addressed, intensification efforts will not yield rice self-sufficiency (Diagne et al. 2012).

Muhunyu (2012) assessed the feasibility of Kenya's NRDS goal to double the rice production by 2018. From his survey of the Mwea irrigation scheme which supplies 86% of rice produced in Kenya, there were three main bottlenecks towards achieving this goal. First, water availability of irrigation has become limiting as the scheme expanded over time and the amount of rainfall received fell. This has necessitated rationing in the form of distribution schedules for the various blocks of the scheme thus there are some plots with no production in alternating schedules. In addition inefficiencies along the distribution canals and on the farmer's plots were identified. The second bottleneck is the unavailability of certified rice seeds and expensive fertilizers. Finally, the third challenge is bird damage. However even against a background of these constraints it is possible for Kenya to realize the goal of doubling its rice production. The actual production has since more than doubled from 28,000 MT in 2008 to 90,000 MT in 2015. However as shown in Figure 1, Kenya is far from being rice self-sufficient due to high consumption growth rates. The Kenya NRDS projection of consumption for 2015 was 347,044 MT however the USDA consumption estimate for the same year was 540,000 MT. This implies Kenya is off-track to attain rice self-sufficiency by 2030 as envisaged by the NRDS. Therefore the greater question is not whether rice production can be doubled but rather is it feasible to increase production at the same rate as consumption is increasing so as to attain rice self-sufficiency in Kenya by 2030 as stated in the NRDS.

2.2 Self-Sufficiency, Competitiveness and Food Security

The competiveness of local rice against imported rice as well as a country's comparative advantage in rice production calls for serious attention when striving for self-sufficiency. Furthermore, the welfare impacts are crucial. Oguntade (2011) analyzed the comparative advantage of Nigeria's rice production and value addition. The study concluded that Nigeria has no comparative advantage of producing rice over the imported rice mainly from the United States Domestic Resource Cost (DRC[1] ratio of 4.88). On the value addition, even though the private processers attained significant margins, this was only possible due to government intervention as evidenced by Nominal Protection Coefficients (NPC) of 1.74 and 1.27 for the value added rice and tradable inputs respectively. Policy interventions such as rice import tariffs are some of the government's efforts towards providing incentives for local rice production and processing with the ultimate goal of attaining rice self-sufficiency. During the MY 2015, Nigeria imported up to 2.1 million MT of rice representing about 40% of its total rice consumption (P S & D Online)

Kikuchi et al. (2016) estimated the international competitiveness (comparative advantage) of rice produced in Uganda using the domestic resource cost ratio (DRCR) derived from the social benefit less social cost of producing one unit of rice in Uganda. From their findings, the rain fed

[1] Domestic Resource Cost (DRC) ratio is a measure of the social profitability of an activity. In this case it was calculated from the Policy Analysis matrix as the social cost of factors divided by the social revenues net cost of tradable inputs. If DRC<1implies the activity is socially profitable and not if DRC>1.

rice which constitutes 95% of total rice produced in Uganda did not have a comparative advantage over rice imported from Pakistan, Vietnam and Tanzania. However, the extent of non-competitiveness was not high and with slight increases in rice yield levels, competitiveness would be attained. For example 0.3MT/ha and 0.5MTkg/ha yield increases in the lowland rain fed and upland rain fed rice production systems respectively would bring the DRCR to 1 implying equal competitiveness with the rice imported from Pakistan. For such increases to be realized under the rain fed system of rice production in Uganda, use of modern inputs along with labor productivity improvement are key. On the other hand, the irrigated rice which constitutes 5% of the production, showed a significant comparative advantage over imported rice. A distinction on the approaches to irrigation was drawn leading to the conclusion that small and micro irrigation or water harvesting were the more viable options for improving the comparative advantage of Uganda rice.

In the case of Rwanda marshland reclamation presents an opportunity to increase the domestic rice production. The Rwanda NRDS has set to reclaim 19,162 Ha for irrigated rice production between 2010 and 2018. The GoR has also made tremendous efforts to address the issue of domestic rice competitiveness against imported rice. In 2012 the GoR banned all small mills and set rules and regulations on the trading of rice, and introduced more modern mills to ensure quality domestic rice with lower percentages of broken rice (Republic of Rwanda 2012). Although initially faced with opposition from farmers due to delayed payments from the cooperatives and lower prices owing to the higher costs of running the modern mills (Stryker 2010), the policy succeeded in improving the quality of local rice. An increase of local/domestic rice consumption (expenditure) of 167% and 34% by the rural and urban consumers respectively was noted between 2005 and 2010 (EICV3 survey as cited by Kathiresan 2013). Despite improvements in milling quality, import bias of the urban consumers was apparent as their expenditure on rice imports increased by 157% in the same period. The explanation behind their preference for imported over local rice is that the local rice is mostly of the short and bold grain which tends to be sticky while the urban consumers prefer the slender, long grain which is not sticky. While 54% of consumers prefer long grain only 30% of the Rwanda rice farmers produce long grain and 70% produce short grain which is only preferred by 14% of the consumers (Republic of Rwanda 2013; Kathiresan 2013). There is thus clear need to realign production efforts to the consumers' preference. In addition the costs of rice production in Rwanda are significantly higher than in most of its rice imports' sources reducing Rwandan price competitiveness.

A Common External Tariff (CET) of 75% ad valorem was agreed upon by the East African Community (EAC) members in 2005 in an effort to protect domestic rice production, that is, relatively improve local rice price competitiveness against cheaper imports. Encouraging domestic production where there is no comparative advantage through protection policies such as import tariffs may result in dead weight losses in the social welfare. A study in the Eastern province of Rwanda showed that 25% of the rice co-operatives had no comparative advantage. Since labor costs are the highest contributors to the total production costs (52%), investments in labor saving technologies should be emphasized (Nkurunzisa 2015).

2.3 Policy Sequencing for Sustainable Rice Self-Sufficiency

According to Demont (2013) urban bias and subsequent import-bias is detrimental to the food security of several developing countries. He described a three-tier typology of the 21 CARD countries as follows: a) countries with a coastline and a dominant consumer preference for imported rice; b) countries with a coastline but the dominant consumer preference is for local rice; c) land-locked countries with transportation barriers offering some extra protection against cheaper imports. Demont (2013) further proposes three sets of strategies to upgrade local rice value chain.

These are supply-shifting, demand-lifting, and value addition strategies. The study moreover points out that there is a greater challenge in developing the local rice sectors in the first group of the countries against a consumer perception of imported rice as being superior to the local rice and therefore calls for value-addition and simultaneous demand lifting of local rice ahead of increasing local production. There are somewhat less challenges with the second group of countries since there is less bias towards imported rice over local rice. However since these countries have coastal lines where cheaper imports easily gain entry into the markets, there is need to maintain the 'superior' status of local rice, by investing in supply shifting strategies and progressively replacing the current imports with local rice.

Rwanda and Uganda belong to the third group of countries with transportation barriers offering some level of protection of the local rice against cheaper imports. World Bank estimates up to 40% of imported goods costs into Rwanda constitute transport costs (World Bank 2016). Rwanda rice production increased significantly in the year 2004 after the GoR realized potential for rice production in the marshlands and pronounced it as a priority crop. Rwanda's local rice production meets up to 75% of its demand (Republic of Rwanda 2013). However as discussed earlier in the chapter, consumers in Rwanda prefer the long grain type of rice although local rice production comprises of both the long grain and medium/short grain types. Aromatic rice from Tanzania along with other long grain imported rice is preferred by urban Rwandan rice consumers and fetches a premium over the local rice (Republic of Rwanda 2013). Greater emphasis in this case should be placed on value-addition and demand-lifting strategies. Such a strategy may involve development and release of long grain varieties with greater adaptability for the marshlands production along with building consumer awareness and preference for local rice (Kathiresan 2013).

Kenya and Tanzania belong to the second group of Demont's typology with the coastline in relatively close proximity to some of the major South Asian rice exporters. Kenya imports up to 86% of its rice consumption. (P S & D online 2000-2013 average) Most of the rice imported into Kenya comes from Pakistan at 35% tariff although in 2007 the East Africa Community (EAC) agreed on a 75% Common External Tariff for rice. However, Kenya has since then applied every year to accord preferential treatment for Pakistan to protect her tea exports to Pakistan (Kilimo Trust 2014). Tanzania on the other hand is up to 90% rice self-sufficient and exports substantial amounts of rice to the neighboring countries. In both Kenya and Tanzania a premium is charged on the local rice over the imported rice due to aroma superiority of the local rice. For this group of countries, value-addition strategies to create local rice demand are not crucial. More focus should thus be placed on availability and affordability of the local rice. For example, improving rice yields in Tanzania which currently fall below the average in Africa and Asia (1.5 t/ha compared to 2.5t/ha and 4.4t/ha average yields for Africa and Asia) is critical. Seventy-four percent of Tanzania rice production is from a rain-fed, saved uncertified seed and minimal input use production system (Wilson & Lewis 2015). While the rice yields in Kenya have seen a rise from an average of 2.7 t/ha in 2000 to an average 4t/ha in 2015 and area under rice more than doubled from 17,000 Ha to 35,000 ha over the same period; consumption growth has far outstripped production. According to Gitau et al. 2011 & Muhunyu 2012, yields could be further increased by rehabilitating the existing irrigation schemes and eliminating the associated inefficiencies.

2.4 Review of the National Rice Development Strategies in Kenya, Rwanda, Tanzania and Uganda

The overall objective of the NRDS for all the CARD members is to double domestic rice production between the year 2008 and 2018 with the exception of Rwanda which seeks to increase its rice production three-fold. Table 1 summarizes the production targets as outlined in the four countries' NRDS. The NRDS further envisages that by doubling rice production, self-sufficiency and probably a surplus for export will be attained by 2018 except for Kenya where self-sufficiency is anticipated to be attained in 2030 in line with Vision 2030.Whereas the NRDS ultimate goal is the same for all the four countries', the areas of priority differ among them. It is however important to note great emphasis placed on the rice area expansion and yield improvement for most of the NRDS. Table 2 shows the NRDS investments in the four countries following the Demont 2013 categorization.

Table 1. NRDS Rice Production Targets 2008-2018 for Kenya, Rwanda, Tanzania and Uganda.

	Production (1000 Tons)			**Area Expansion (1000 Ha)**			**Yield Improvement (Tons/Ha)**		
Country	2008	2018	% Δ	2008	2018	% Δ	2008	2018	% Δ
Tanzania	899	1,963	100%	681	695	2%	1.3	2.8	115%
Kenya	73	178	144%	18	35.15	97%	4.1	5.1	24%
Rwanda	66	374	467%	12	54.5	354%	5.5	6.9	25%
Uganda	251	728	190%	110	240	118%	2.3	3.3	43%

Source: CARD NRDS Documents.

Table 2. Investment portfolios of the four countries' NRDS [Adapted from Demont (2013)]

Country	Supply-shifting investments				Demand-lifting investments			
		Value-adding investments						
	Area expansion, irrigation and infrastructure	R&D, extension, innovation, capacity building	Intensification, access to land, seed, credit, inputs, mechanization	Processing and storage	Quality upgrading, capacity building, governance	Branding and labeling, identity creation, certification	Market infrastructure linkages	Promotion, advertising, communication, awareness creation
Kenya	X	x	x	x	?	?	?	?
Rwanda	39%	9%	15%	8%	1%	?	28%	?
Tanzania	X	x	x	x	x	?	x	?
Uganda	X	x	x	x	x	x	x	_

Symbol "x" indicates investment is planned for in the NRDS but the budget for the same is not provided. A Question mark (?), indicate that the investment is not clearly defined in the NRDS.

2.4.1 Kenya NRDS

The goal of Kenya NRDS is to improve food security and income of Kenyans through sustainable rice production, marketing and utilization. Specifically the NRDS seeks to:

Increase rice productivity/yield through:

- High yielding and pest resistant rice varieties
- Better agronomic and soil management practices
- Pest and diseases control technologies
- Systems of rice intensification (SRI)

Increase production area by:

- Expanding irrigation infrastructure
- Expanding area under rain-fed rice cultivation

Reduce field and storage losses through:

- Better cultural practices (timing) of harvesting, and post-harvest handling
- Introduction of harvesting and post-harvest technologies
- Increase farmer access to affordable credit and high quality inputs by:
- Facilitating affordable credit
- Ensuring sufficient production, distribution of good quality inputs
- Increase timely access to certified rice seed for the rice farmers
- Enhance provision of extension, advisory support services and technology application
- Develop participatory monitoring and evaluation for technology uptake, production and value-addition chains
- Develop rice markets and marketing channels

- Mainstream rice stakeholder fora at all levels
- Strengthen human resource development

2.4.2 Rwanda NRDS

The Rwanda NRDS goals are to achieve rice self-sufficiency by 2018 and improve the competitiveness of the local rice both locally and regionally through improvement of quality. The specific objectives are:

- Expand area under rice cultivation by reclaiming new marshlands and extending the tail-ends of the current marshlands as well as introducing rain-fed lowland rice areas.
- Productivity improvement through:
  - Land consolidation and thus greater efficiency of land, water and other natural resources
  - Farmers' access to improved seeds, fertilizers and pesticides
- Quality enhancement through:
  - Better harvesting, drying and storage practices (reduce post-harvest losses to less than 5%)
  - Rice trade regulations (to ensure uniform quality product)
  - Milling quality regulations

Table 3 shows details of the individual components of the Rwanda NRDS along with the budget for each strategy.

Table 3. Rwanda NRDS components and budget

Target Item	Outputs/Activities	Budget (USD)
Seed	Develop and diffuse 8 rice varieties that are high-yielding, mature early, tolerant to low temperature and disease resistant	1,096,000
	Develop and diffuse 5 lowland rain-fed varieties	218,000
	Capacity development to maintain the released rice varieties (stakeholders sensitization)	6,987,000
	Certified seed multiplication to cover the additional area (demand)	71,000
Fertilizers	Procurement and distribution: 545,000 MT of organic manure; 10900 MT NPK and 5,450 MT Urea	1,372,000
	Privatization of Fertilizer Import and Distribution: 5 providers	108,000
	Training of fertilizer traders	69,000
	Provision of specific fertilizer recommendations for the various schemes	1,235,000
Irrigation	5,330 ha new marshland	50,000,000
	New installations and rehabilitation of irrigation infrastructures in current marshlands	8,430,000
	Private sector involvement (encouragement/sensitization) on reclaiming marshlands for rice cultivation	122,000
	Rehabilitate old rice schemes infrastructure	121,000
	Establish Irrigation Water Users Association and train members on efficient and equitable water use	1,590,000
Technology	Extension and training of farmers through Farmer Field Schools on appropriate/modern rice production technologies	5,151,000
	Public-Private-Partnerships to extend extension services	1,468,000
	Setup farmer service centers in the rice schemes	4,425,000
	Major pest identification/characterization every three years	351,000
	Pest and Diseases control measures-design and implement	3,076,000
Mechanization	Land consolidation in the rice schemes to allow mechanization	1,942,000
	Promote mechanized harvesting and post-harvest	1,957,000
	Increase farm machineries and implements availability	7,519,000

Table 3 (Cont.) Rwanda NRDS components and budget

Target Item	Outputs/Activities	Budget (USD)
Quality Enhancement	Improve milling quality	921,000
	Reduce harvest and post-harvest losses from 20% to less than 5%	11,789,000
Market Access	Improve transport infrastructure to enable physical access to national/regional markets	42,842,000
	Enhance producer –processor - markets linkages for enhanced local rice marketability in the national, regional and international markets	475,000
Access to Finance	Increase access to finance from 30% to 100%	910,000
	Introduce working capital credit for traders	299,000
Policy Tools for Sustainable Development of Rice Sub-sector	Increase human capacity in the rice sub-sector (rice researchers, technicians and extension officers	1,584,000
	NRDS Taskforce and stakeholder forum activities	394,000
	Grand Total	**156,521,000**

2.4.3 Tanzania NRDS

The United Republic of Tanzania envisages transforming the current subsistence-dominated rice sector into a commercially profitable one through modernization and commercialization strategies.

In the short term Tanzania NRDS seeks to:

- Increase production/productivity
- Reduce losses pre and post-harvest
- Increase farm inputs availability (improved seeds, fertilizers and pesticides)
- Rehabilitate old irrigation schemes and set up new ones

In the medium and long term Tanzania NRDS emphasis is on:

- Rice area expansion (irrigated lowland, rain-fed lowland and upland)

- Farm machinery and post-harvest technologies access
- Investment in the medium and large scale processing

The components of Tanzania NRDS are:

- Access to improved seeds through: production and distribution of certified seeds; creating farmers' awareness of available certified seeds; capacity enhancement of public and private seed companies
- Fertilizer marketing and distribution through: enhanced access to input credits and skills for the agro-dealers; input vouchers
- Proper input use to increase rice yields
- Irrigation investments: rehabilitation of irrigation structures (569,000 Ha); construction of storage dams for rain water harvesting (101,400 Ha); expand area under irrigation (new irrigation schemes – 183,900 Ha); increase irrigation efficiency among the smallholder farmers – switch from flooding to pivot centered irrigation.
- Equipment-Labor saving technologies: medium size tractors; power tillers which contain rotavator, plough, ridgers, water pumps and power sprayers; trans-planters; weeders; rippers, combine harvesters; threshers; milling and grading machines.
- Post-harvest and Marketing
- Facilitate use of Warehouse Receipt System
- Support formation of producer groups: producer capacity building to raise their confidence, bargaining power and access to credit
- Research, Technology Dissemination and capacity Building on: genetic resources conservation and use; soil health and fertility management; crop management and protection options; advisory services extension

2.4.4 Uganda NRDS

The goal of Uganda NRDS is twofold: to increase household food security and to reduce household poverty by increased production of quality rice.

Components of the Uganda NRDS are:

- Strengthen institutional framework for increased and improved rice production
- Production, multiplication and dissemination of certified seed
- Research, technology dissemination and capacity building
- Fertilizer marketing & distribution; and sustainable soil management
- Improve irrigation and water management
- Post-harvest handling, processing and marketing
- Maintenance and access to agricultural equipment
- Access to finance
- Policy development for promotion of rice production

CHAPTER 3: ANALYTICAL FRAMEWORK

The goal of this study is to quantitatively assess the rice self-sufficiency goals outlined in the Kenya, Rwanda, Tanzania and Uganda National Rice Development Strategies. First, a dynamic baseline for the four countries was established within the Arkansas Global Rice Model (AGRM) modelling framework (described in section 3.1). Alternative self-sufficiency strategies scenarios were then simulated and analysed in the context of the global rice economy. Second, impacts of self-sufficiency on the rice value chain and particularly with regard to food security (availability and affordability) were analysed using the RiceFlow model (described in section 3.2)

3.1 ARKANSAS GLOBAL RICE MODEL (AGRM)

3.1.1 Introduction

AGRM (Wailes & Chavez 2011) is a non-spatial partial (rice sector) equilibrium modelling framework based on six multi country sub-region models representing the world rice economy. The six sub-regions are the Americas, United States, South Asia, North Asia & Middle East, Africa and Europe. Each sub-region model is composed of individual countries models and an aggregate of the countries not individually modelled as the rest-of-region, for example, Rest-of-Africa for the countries in Africa that are not modelled individually. Each country model includes econometric estimations of the demand sector, supply sector, trade, stocks and price linkages. The estimates are based on exogenous macroeconomic factors such as income, population, inflation, policies and technological development. Currently AGRM has 61 countries individually modelled (EU modelled as one country). The individual countries models are then inter-linked through trade. The international rice markets are cleared using Thai Free On Board (FOB) 5% broken, Bangkok and California No.1 medium grain ex-mill prices.

AGRM is used to provide ten year projections for the international FAPRI model. Additionally AGRM is used to assess regional and/or national policies, and their impacts on national and/or global rice economy including production (rice area and yield), consumption, net trade, stocks and prices.

3.1.2 AGRM Theoretical structure

3.1.2.1 Supply Sector

The supply sector is based on the assumption of profit-maximizing producers, that is, producers seek to maximize their net revenue from rice production subject to technical and regulatory constraints. Consequently, the area planted (and harvested) with rice is a function of the expected input and output prices as expressed in the equation below:

$$AH_t = f_1(AH_{t-1}, P_t^e, W_t^e, e_{1t}) \qquad (1)$$

Where: AH_t, is the area harvested in hectares, P_t^e is the expected price received by farmers, W_t^e is the expected input price and e_{1t} is the error term. It would be expected that the lagged area and producer price coefficients be positive while that of input price would be negative.

Similarly, yield is specified as a function of expected input and output prices and additionally technological change as in the below equation:

$$Y_t = f_2(P_t^e, W_t^e, T_t, e_{2t}) \qquad (2)$$

where Y_t is the yield in tons per hectare and T_t represents technological change.

3.1.2.2 Demand Sector

The demand sector is based on the assumption of utility-maximizing consumers that is, consumers seek to maximize their utility from rice consumption subject to their budget constraint. Subsequently, the per capita rice consumption is expressed as a function of the per capita income, rice price and substitute commodity such as wheat or maize price as in the equation below:

$$D_t = f_3(M_t, RP_t, WP_t, e_{3t}) \tag{3}$$

Where D_t is the per capita rice demand, M_t, is the real per capita income, RP_t is the retail rice price and WP_t is the price of wheat or maize. Total demand is expressed as a product of the per capita demand and the population.

3.1.2.3 Price Linkages

Producer price and retail price are specified as a function of the international rice reference price[2].

3.1.3 Modelling Method and Evaluative Statistics

To allow analysis of the rice development strategies of the four countries in this study using AGRM, individual country models of rice supply and demand were estimated as described in the sections above. The models were estimated using Ordinary Least Squares Method in Excel. Several models for each dependent variable were estimated and the best model selected based on the goodness of fit (adjusted R^2) measure, expected signs of the coefficients and the significance levels of the coefficients (p values). R^2 measures the proportion of variation in the dependent

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[2] The international reference price from Rice Outlook follow the Thai 5% broken FOB price but was adjusted with Vietnam FOB for 2011 and 2012 due to distortions in the Thai rice market in these years. The former was resumed from 2013 as the new Thai government revised the previous government rice stocks policies.

variable that is explained by the explanatory (independent) variables. However R^2 tends to increase as the number of the explanatory variables increase. Therefore, when comparing models with multiple independent variables the adjusted R^2 which has been adjusted for number of independent variables was used. Statistical significance of the coefficients was tested using the p-values at three significance levels: $p<0.1$, $p<0.05$ and $p<0.01$ in the order of increasing significance.

3.1.4 Scenario Simulations

Four Scenarios were simulated. The first scenario was a projection of the baseline, that is, business as usual trend. In the second scenario, area and yield levels were shocked to match the targets laid out in the individual country NRDS for the year 2018 (2030 for Kenya) and the self-sufficiency levels evaluated assuming baseline consumption projection. In the third scenario, area harvested was shocked (while letting yield to follow the baseline trend) until production equalled consumption by 2018 (2030 for Kenya). In fourth scenario yield was shocked while letting area harvested to follow the baseline trend until production equalled consumption by 2018 (2030 for Kenya). Due to a limitation of the AGRM model simultaneous area and yield shocks could not be implemented.

3.1.5 AGRM Data Sources

Estimates of the area harvested, yields, rough and milled production, consumption, imports, exports and stocks were obtained from the U.S. Department of Agriculture Foreign Agricultural Service (USDA-FAS) Production Supply and Distribution (P S & D Online) for the years 1990-2016 for Kenya and Tanzania and years 2000-2016 for Rwanda and Uganda. Earlier years data for the latter was not available. Maize and rice producer prices were obtained from FAOSTAT while the retail prices for the same were obtained from the respective country annual statistical yearbooks. Population and GDP (income proxy) along with the GDP deflator and Consumer Price Indices were obtained from AGRM based on Global Insight estimates.

3.1.6 Country Sub-Models: Equations Specifications

Appendix Table 1 provides a summary of the four countries' sub-models for area-harvested, yield, per capita rice consumption, and price-linkage equations.

3.1.6.1 Kenya Sub-Model

Area Harvested

The rice area in Kenya as of 2014 was estimated to 35,000 Ha which slightly more than double the area in the year 2000. A relationship between the lagged area and the ratio of prices that producers received for rice and maize was estimated as expressed in the equation below:

$$Ln\ (Area_t) = f\ Ln\left(Area_{t-1}, \frac{RicePr_{t-1}}{MaizePr_{t-1}}, Dummy_{1994}, Dummy_{2008}\right) \qquad (4)$$

Values for the years 1994 and 2007 were dummied following political instability in the country which significantly adversely affected rice production areas in these two years.

The resulting elasticities were 0.68 and 0.29 for lagged area and rice to maize price ratio respectively with statistical significance at ($p<0.01$).

Yield

The yield function was estimated using the trend variable and the years 2007-2009 dummied for post-election violence that occurred in the country (using the rice prices did not yield sensible estimates).

$$LnYield = f(LnTrend, Dummy_{2007-2009}) \qquad (5)$$

The resulting coefficient for the trend variable was 0.26 and statistically significant at $p<0.01$.

Per Capita Consumption

Per capita rice consumption in Kenya has been on the rise in the past one and a half decade rising from 5kg/person/year in 2001 to about 12 kg/ person/ year in 2013. The per capita rice consumption equation was estimated as a double log function of real per capita GDP and the domestic rice retail price as expressed in the equation below:

$$Ln\ Cons\ per\ capita = f\big(Ln(\ Real\ GDP\ per\ capita, RiceRetailPr)\big) \qquad (6)$$

The estimated coefficients for real per capita GDP and real rice retail price were 2.19 ($p<0.01$) and -0.93 ($p=0.08$) respectively. This indicates high sensitivity (close to unitary elasticity) of rice consumers in Kenya to prevailing retail prices.

Price Linkage Equations

Rice and Maize Producer Price Linkage

Kenya rice and maize producer prices were linked to the international rice reference price and the USA FOB gulf corn price respectively as expressed in the equations below:

$$Ln\ RiceProducerPr = f(Ln\ IntlRicePr) \qquad (7)$$

$$Ln\ MaizeProducerPr = f(Ln\ IntlMaizePr) \qquad (8)$$

The resulting coefficients indicate strong international price transmission to Kenyan rice and maize markets: 1.17 ($p<0.01$) and 0.65 ($p<0.01$) for rice and maize respectively.

Rice Retail Price Linkage

The retail rice price was linked to the international rice reference price as below:

$$Ln\ RiceRetailPr = f(IntlRicePr) \tag{9}$$

The resulting coefficient was 0.88 and statistically significant at $p<0.01$.

3.1.6.2 Rwanda Sub-Model

Area Harvested

The area under rice cultivation in Rwanda increased four-fold from 4,000 Ha in 2000 to 16,000 Ha in 2013. It is important to highlight that the area had been at 6,820 Ha in 1990 but had since gone down to 630 Ha during the 1994-1995 political crisis in the country (FAOSTAT figures)

Area harvested was estimated as a double log[3] function of lagged area harvested and lagged producer prices in deflated local currency:

$$Ln\ Area_t = f\big(Ln\ (Area_{t-1}, RealProducerPr_{t-1})\big) \tag{10}$$

Lagged area elasticity captures the habitual persistence effect as farmers progressively expand the area cultivated with rice. The lagged producer prices were assumed to be the basis for farmers' expectations of current prices on which they make the decision to plant more or less rice.

Estimated elasticity for lagged area was 0.775 and that of lagged producer prices was 0.283. The former was statistically significant at $p=0.01$ and the latter at $p=0.05$.

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[3] Double log function coefficient estimates are directly interpreted as elasticities, that is, percentage change in the dependent variable when the independent variable changes by 1 %.

Yield

Rice yields in Rwanda have increased from 3 MT/Ha to 5.6 MT/Ha on paddy basis over the 2000-2013 years (average annual increase of 5%).

Yield was estimated as a double log function of lagged producer prices and a trend variable:

$$LnYield = f\left(Ln(RealProducerPr_{t-1}, Trend, Dummy_{2009})\right) \qquad (11)$$

Use of lagged producer prices as an explanatory variable was based on the assumption that when farmers receive higher prices they plough back some in the next season through purchase of inputs while the trend variable was used to explain gradual technological progress as farmers continually gain awareness on and access to inputs. A dummy for 2009 was included since there was an unexplainable drastic drop in 2008 prices. The prices rice farmers receive in Rwanda are usually jointly set by the MINICOM, MINIAGRI, farmer co-operatives and processors based on estimated costs of production and market realities for every season (Kathiresan A. 2013; Republic of Rwanda, 2012)

The estimated elasticity for lagged producer prices was 0.205 although not statistically significant at p=0.1 while that of the trend variable was 1.105 and was statistically significant at p=0.01.

Per Capita Consumption

The per capita rice consumption in Rwanda increased from 3kg/person/year in 2000 to 8.3kg/person/year in 2013 (10kg/person/year in 2012), that is an average annual increase of 9.8%.

Per capita consumption was estimated as a double log function of per capita GDP (proxy for income) and the ratio of rice to maize deflated retail prices:

$$LnCons\ Per\ Capita = f\ Ln\left(GDP\ Per\ Capita, \frac{RiceRetailPr}{MaizeRetailPr}\right) \quad (12)$$

Maize is a traditional staple for most of the East African countries. It is perceived as inferior to rice and as income grows maize consumption is substituted with rice. Subsequently if the price of rice increases relative to maize price there is a shift back to maize.

The estimated elasticities for per capita GDP and the rice to maize price ratio were 1.334 (p=0.001) and -0.757 (p=0.011) respectively. The latter may be interpreted as: with 1% increase in rice price relative to maize price, rice consumption goes down by 0.757%.

Price Linkage Equations

Rice Producer Price Linkage

Price received by Rwandan rice farmers was linked to the International Reference Rice price[4] through the following equation:

$$LnRiceProducerPr = f\big(Ln(IntlRicePr, Dummy_{2008})\big) \quad (13)$$

The year 2008 was dummied due an unexplained rapid decrease in producer prices received in Rwanda. The estimated producer price transmission elasticity was 0.6 (p=0<0.01) implying that with 1% increase in international rice price 0.6% is transmitted to rice producers in Rwanda.

[4]The international reference price from Rice Outlook follow the Thai 5% broken FOB price but was adjusted with Vietnam FOB for 2011 and 2012 due to distortions in the Thai rice market in these years. The former was resumed from 2013 as the new Thai government revised the previous government rice stocks policies.

Retail Rice Price Linkage

Similarly, the price Rwandan rice consumers pay was linked to International Reference Rice price as in the following equation:

$$LnRiceRetailPr = f(Ln\ IntlRicePr) \quad (14)$$

The estimated elasticity was 0.65 ($p<0.01$) meaning that with 1% increase in international rice price 0.65% is transmitted to the rice consumers in Rwanda.

Maize Retail Price Linkage

Maize retail prices were linked to the USA FOB gulf corn price as in the equation below:

$$LnMaizeProducerPr = f(Ln\ IntlMaizePr) \quad (15)$$

The resulting estimated elasticity was 0.95($p<0.01$) implying that a 1% increase in the US fob corn price, 0.95% is transmitted to maize retail prices in Rwanda.

3.1.6.3 Tanzania Sub-model

Area Harvested

The area under rice cultivation in Tanzania has gradually increased in the last two decades and with particular significant increases pre and post the 2008 crisis whereby it increased from 558,000 Ha in 2007 to 1.1 Million Ha in 2011. About 74% of rice area in Tanzania is rain-fed and therefore farmers have a greater flexibility to respond to prevailing rice prices (Wilson & Lewis, 2015).

The area harvested was estimated as a double log function of lagged area and lagged international rice reference price plus the EAC CET (75% ad valorem) as follows:

$$LnArea_t = f(LnArea_{t-1}, (IntlRicePr + Tariff)_{t-1}) \quad (16)$$

The estimated lagged area elasticity was 0.33, that is, a yearly increase of 0.33% while the price elasticity was estimated at 0.25, that is, area increased by 0.25% with every 1% increase in the international rice reference price. Both estimates were significant at ($p<0.1$) and ($p<0.01$) respectively.

Yield

Up to 74% of Tanzania's rice production is based on a low input, low technology and rain-fed system. As such the average rice yield in Tanzania is low compared to the world average and the neighboring countries. The average yield on a milled basis between 2000 and 2016 was 1.3 MT/Ha (P S & D Online). Owing to unavailability of data on input use and domestic producer prices, the yield equation for Tanzania was estimated using TREND variable as below:

$$LnYield = f(LnTrend) \qquad (17)$$

The resulting elasticity was 0.3725 with a p-value 0.0004.

Per Capita Consumption

Among the four countries in this study, Tanzania is the largest rice consumer with an estimated per capita consumption of 36 kg/person/year as of 2014 (P S & D Online).

The per capita consumption equation was estimated as a double log function of real per capita GDP (proxy for income) and the international reference price. The effective import tariff of 75% ad valorem was then added and the resulting price converted to local currency in real terms (2000 prices).

$$LnCons\ Per\ Capita = f(Ln(GDP\ Per\ Capita\ , (IntlRicePr + Tariff)_{t-1})) \qquad (18)$$

The resulting elasticities were 1.59 and -0.26 for real per capital GDP and the reference price respectively. Both were statistically significant at ($p<0.01$).

No linkage equations were estimated for Tanzania since the international reference price (local prices were unavailable) in the area harvested and per capita consumption equations.

3.1.6.4 Uganda Sub-Model

Area Harvested

A significant shift in Uganda rice production was recorded from 2009 onwards with a decrease in rice area as yields increased. Therefore the rice area equation included a shift trend variable in addition to the prices and the lagged area. Furthermore data on producer prices in the country was unavailable and the retail prices were used instead.

$$LnArea_t = f(Ln(Area_{t-1}, RiceRetailPr_{t-1}, ShiftTrend_{2009})) \quad (19)$$

The resulting coefficients were 0.57 (p<0.01), 0.97 (p=0.04) and -0.32 (p=0.011).

Yield

Similar to the area harvested equation a trend variable was used to capture the upward shift in yields from 2009 onwards. The increase in yields may be attributed to increased adoption high-yielding upland NERICA varieties introduced in the country in 2002 (Haneishi et al. 2013) and an Upland Rice Project later launched by the president in 2004 (Mohapatra, 2013).

The yield equation is presented below with the resulting coefficient being 0.5 and statistically significant at p<0.01:

$$LnYield = f\left(Ln(ShiftTrend_{2009})\right) \quad (20)$$

Per Capita Consumption

Per capita rice consumption in Uganda is slower than in the other three countries in this study ranging between 4kg/person/year and 6kg/person/year over the years 2000 to 2016. Up to

50% of rice grown in Uganda is for commercial purposes mostly exports within the EAC region which is tariff free for the member countries.

The per capita equation was estimated as a double log function of the per capita GDP and rice to maize retail prices ratio as below:

$$Ln\ Cons\ Per\ Capita = f\ Ln\left(GDP\ Per\ Capita, \frac{RiceRetailPr}{MaizeRetailPr}\right) \quad (21)$$

The resulting elasticities were 0.64 and -0.54 respectively. Both coefficients were statistically significant at $p<0.01$.

Price Linkages

Rice and Maize Retail Price Linkages

The average rice retail price in Uganda was linked to the international rice reference price as below:

$$Ln\ RiceRetailPr = f(Ln\ IntlRicePr) \quad (22)$$

The resulting coefficient was 0.72 and was statistically significant at $p<0.01$

Similarly the average maize retail price was linked to the USA fob gulf corn price as below:

$$Ln\ MaizeRetailPr = f(Ln\ IntlMaizePr) \quad (23)$$

The resulting transmission coefficient was 0.52 and statistically significant at $p<0.01$

3.2 RICEFLOW MODEL

3.2.1 Description

RiceFlow is a spatial, partial equilibrium model of the world rice economy that simulates the behavior of the entire rice supply chain, from input markets all the way up to the aggregate final demand, in multiple countries/regions (set R) around the world. In RiceFlow non-linear functions are linearized so that the variables in the model are in percentages rather than nominal values. The production "tree" consists of a value-added nest and a final output nest (Fig. 3)

```
                  Y(c,r)
                  /    \
                 /------\-> Leontief, CD, or CES
                /        \
               /          \
              /            \
             /              \
        QVA(c,r)         QIC(i,c,r)
          /   \
         /-----\--> Leontief, CD, or CES
        /       \
       /         \
QFC(f,c,r) QFC(f,c,r)
```

Figure 3. Representation of a nested production tree as specified in RiceFlow

Production of endogenous rice commodities (set CE[5]) is specified as a weak-separable, constant return to scale production function:

$$Y_{c,r} = H_{c,r}\{G_{c,r}(FAC_{c,r}), INT_{c,r}\}\ \forall c \in CE, r \in R \tag{24}$$

[5] $CE = \{LGP, LGB, LGW, MGP, MGB, MGW, FRP, FRB, FRW\}$, where LG, MG, and FR stand for long grain, medium/short grain, and fragrant rice respectively, and P, B, W stand for paddy/rough, brown/whole, and white/milled rice.

Where Y represents output, H and G are technology functional forms, FAC[6] is the set of factors of production, and INT[7] is the set of intermediate inputs.

Defining G in (23) as a constant elasticity of substitution (CES) function, the derived demand for factor of production, QFC, is

$$QFC_{f,c,r} * AFC_{f,c,r} = QVA_{c,r} * SVA_{f,c,r} * \left[\frac{PFC_{f,c,r}}{PVA_{c,r} * AFC_{f,c,r}}\right]^{-\sigma VA_{c,r}} \quad \forall f \in FAC, c \in CE, r \in R \qquad (24)$$

$$PVA_{c,r} = \left[\sum_{f} SVA_{f,c,r} * \left(\frac{PFC_{f,c,r}}{AFC_{f,c,r}}\right)^{1-\sigma VA_{c,r}}\right]^{\frac{1}{1-\sigma VA_{c,r}}} \quad \forall c \in CE, r \in R \qquad (25)$$

Where AFC, PFC, and SVA are a factor-, sector-, and region-specific augmenting technical change variable, factor price variable, and cost share in value added, respectively, and QVA and PVA are a sector- and region-specific derived demand and price for the value added composite, respectively. Finally, σVA is the sector- and region-specific elasticity of substitution in value added.

Defining H in (23) as a constant elasticity of substitution (CES) function, the derived demands for intermediate inputs QIC, and for the composite value added $QVA_{c,r}$, are:

$$QIC_{i,c,r} * AIC_{i,c,r} = \frac{Y_{c,r}}{AY_{c,r}} * SITC_{i,c,r} * \left[\frac{PIC_{i,c,r}}{PY_{c,r}} * AIC_{f,c,r} * AY_{c,r}\right]^{-\sigma Y_{c,r}}, \forall i \in INT, c \in CE, r \in R \quad (26)$$

$$QVA_{c,r} * AVA_{c,r} = \frac{Y_{c,r}}{AY_{c,r}} * SVATC_{c,r} * \left[\frac{PVA_{c,r}}{PY_{c,r}} * AVA_{c,r} * AY_{c,r}\right]^{-\sigma Y_{c,r}}, \qquad \forall c \in CE, r \in R \qquad (27)$$

Where AIC, PIC, and $SITC$ are input-, sector-, and region-specific input augmenting technical change variable, input price variable, and input cost share in total cost, respectively.

[6] $FAC = \{L, T, K\}$, where L is land, T labor, and K capital.
[7] $INT = \{seeds, herbicides, pesticides, water, energy, LGP, LGB, MGP, MGB, FRP, FRB\}$

Furthermore, AVA, AY, and PY, and $SVATC$ are sector- and region-specific value-added augmenting technical change variable, output augmenting technical change variable, output price variable, and value-added cost share in total cost, respectively. Finally, σY is the sector- and region-specific elasticity of substitution in final output.

The model assumes zero profits in production (Equation 28) and equilibrium in output markets (Equation 29i for paddy rice commodities[8], and 29ii for other rice commodities[9]).

$$PY_{c,r} = \frac{\left[SVATC_{c,r} * \left(\frac{PVA_{c,r}}{AVA_{c,r}}\right)^{1-\sigma Y_{c,r}} + \sum_i SITC_{i,c,r} * \left(\frac{PIC_{i,c,r}}{AIC_{i,c,r}}\right)^{1-\sigma Y_{c,r}}\right]^{\frac{1}{1-\sigma Y_{c,r}}}}{AY_{c,r}}, \qquad \forall c \in CE, r \in R \qquad (28)$$

$$Y_{c,r} = QD_{c,r} + \sum_s QBX_{c,r,s} + QK_{c,r}\,, \qquad \forall c \in CP, r \in R \qquad (29i)$$

$$Y_{c,r} = QD_{c,r} + \sum_s QBX_{c,r,s}\,, \qquad \forall c \in CCP, r \in R \qquad (29ii)$$

Where QD represent the volume of output c sold in the domestic market, QK is the change in stocks[10] of good c, and QBX is the volume of bilateral exports of c from region r to region s.

Import demand follows the Armington approach (Armington, 1969), by which imports by source and domestic production are treated as heterogeneous products. Agents first decide on the

[8] Set $CP = \{LGP, MGP, FRP\}. CP \in CE$
[9] Set $CCP = CE - CP = \{LGB, MGB, FRB, LGW, MGW, FRW\}$
[10] Only stocks of paddy rice are allowed. Thus $QK_{c,r}$ is defined over the commodity subset CP.

sourcing of imports (Equation 30) based on the relative level of prices from each source (Equation 31).

$$QBX_{c,s,r} = QM_{c,r} * SMS_{c,s,r} * \left[\frac{PMMS_{c,s,r}}{PMM_{c,r}}\right]^{-\sigma M_{c,r}}, \ \forall c \in CE, r \in R, s \in R \tag{30}$$

$$PMM_{c,r} = \left[\sum_{s} SMS_{c,s,r} * PMMS_{c,s,r}{}^{1-\sigma M_{c,r}}\right]^{\frac{1}{1-\sigma M_{c,r}}}, \qquad \forall c \in CE, r \in R \tag{31}$$

Where $PMMS$ is the market price of import good c into region r from source s, PMM is the composite market price of import good c in r, QM is the demand for the composite import good c in r, and SMS is the value-share of good c's import into r by source s. $\sigma M_{c,r}$ is the elasticity of substitution of imported good c in r by source.

After sourcing imports, then agents decide on the optimal mix of imported and domestic products (Equation 32 and 33) based on their relative price levels (Equation 34).

$$QM_{c,r} = QQ_{c,r} * SMQ_{c,r} * \left[PMM_{c,r}/PQ_{c,r}\right]^{-\sigma Q_{c,r}}, \ \forall c \in CE, r \in R \tag{32}$$

$$QD_{c,r} = QQ_{c,r} * SDQ_{c,r} * \left[PY_{c,r}/PQ_{c,r}\right]^{-\sigma Q_{c,r}}, \ \forall c \in CE, r \in R \tag{33}$$

$$PQ_{c,r} = \left[SMQ_{c,r} * PMM_{c,r}{}^{1-\sigma Q_{c,r}} + SDQ_{c,r} * PY_{c,r}{}^{1-\sigma Q_{c,r}}\right]^{\frac{1}{1-\sigma Q_{c,r}}}, \ \forall c \in CE, r \in R \tag{34}$$

Where PQ is the market price of composite good c in region r, QQ is the output of composite good c in r, and SMQ and SDQ are the value-shares of the import composite and domestic good c in r. $\sigma Q_{c,r}$ is the elasticity of substitution between domestic and imported good c in r.

Final demand for milled rice $c \in CFC$[11] in region r, is the product of population and per-capita demand $D_{c,r}$, which is specified as a double log function of income and prices (Equation 35). Z_r represents income by region, φ_r is the income demand elasticity, and $\omega_{c,g,r}$ is the matrix of own and cross-price demand elasticities.

$$\log D_{c,r} = \varphi_r * \log Z_r + \sum_{g \in FC} \omega_{c,g,r} * \log PQ_{g,r} \ , \ \forall c \in CFC, r \in R \qquad (35)$$

The supply of exogenous intermediate inputs (seeds, fertilizers, pesticides, energy, and water), capital, and labor are specified as perfectly elastic, thus their prices (PFC) are treated as constant, exogenous variables. Land is considered the only factor with limited supply. Hence, sectoral output Y is constrained only by the supply of land $L_{c,r}$ used in the production of paddy rice, which is represented by a double log function of land rental rates $PL_{c,r}$.

$$\log L_{c,r} = \theta_{c,r} \log PL_{c,r} \ , \ \forall c \in CP, r \in R \qquad (36)$$

The land own-price supply elasticity $\theta_{c,r}$ are calibrated following Keller (1976) to reflect rice supply elasticities found in the literature.

3.2.2 RiceFlow Database

RiceFlow database currently comprises of 76 regions (defined as set R), 70 of which are individual countries and 6 are regional aggregates of the otherwise not individually modelled countries (Table 4).

[11] Set $CFC = \{LGW, MGW, FRW\}. CFC \in CE$

Table 4: Regions in RiceFlow model

ARGENTINA	EU	MALI	SRILANKA
AUSTRALIA	GAMBIA	MEXICO	SURINAME
BANGLADESH	GHANA	MYANMAR	TAIWAN
BENIN	GUATEMALA	NICARAGUA	TANZANIA
BOLIVIA	GUINEA	NIGER	THAILAND
BRAZIL	GUINEA-BISSAU	NIGERIA	TOGO
BURKINAFASO	GUYANA	PAKISTAN	TURKEY
CANADA	HAITI	PANAMA	UAE
CAMBODIA	HONDURAS	PARAGUAY	UGANDA
CAMEROON	HONGKONG	PERU	URUGUAY
CHILE	INDIA	PHILIPPINES	USA
CHINA	INDONESIA	RWANDA	VENEZUELA
COLOMBIA	IRAN	RUSSIA	VIETNAM
COSTARICA	IRAQ	SAUDI-ARABIA	OAFRICA
COTEDIVOIRE	JAPAN	SENEGAL	OASIA
CUBA	KENYA	SINGAPORE	OCARIBBEAN
ECUADOR	LAOS	SIERRALEONE	OEUROPE
EGYPT	LIBERIA	SKOREA	OMIDDLEEAST
ELSALVADOR	MALAYSIA	SOUTHAFRICA	OOCEANIA

Bilateral trade flows for the base period 2013-2015 were obtained from the United Nations Commodity Trade Statistics database (UN Comtrade) and further dis-aggregated by rice type and milling degree based primarily on exporting countries' trade databases (e.g., Thailand's Ministry of Commerce, USDA GATS Global, India's Agricultural and Processed Food Products Export Development Authority, and Pakistan Bureau of Statistics). Demand and supply elasticities were obtained from FAPRI and AGRM. Rice production and milling costs for the four countries were obtained from: Federation of Rice Growers Cooperatives in Rwanda (FUKORIRWA) and Rwanda Federation of Rice Millers for Rwanda; Mwea Irrigation Agriculture Development (MIAD) guidelines for Kenya; EAC Africa Rice secretariat for Tanzania; and Kikuchi et al. 2016 for Uganda.

A limitation of the RiceFlow model is that it does not allow for creation of new production activities, consumption and bilateral trade flows. Therefore shocks on the baseline only results to expansion or contraction of existing production, consumption and trade (Durand-Morat & Wailes 2010).

3.2.3 Establishing the 2018 and 2030 Baselines

Rwanda, Tanzania and Uganda NRDS aim to attain rice self-sufficiency by the year 2018 while the Kenya NRDS aims to attain self-sufficiency (currently at 14% SSR) by the year 2030. As such baselines for the respective years were estimated by shocking the model with the projected income growth and population growth in all the regions. The projections were obtained from the AGRM model obtained from Global Insight projections. For the 2030 baseline, the period was divided into three periods 2020, 2025 and 2030 and the respective baselines estimated from the previous baseline update in order to avoid very large shocks.

3.2.4 Scenario Simulation

After establishing the baseline, the self-sufficiency scenario was simulated as 99% elimination of long grain rice (paddy, brown and white) imports into the four countries. This was achieved through a change in the closure of the model by exogenizing the relevant bilateral trade flows and endogenizing the bilateral import tariff. Since a Leontief function was assumed for both stages of paddy production, intuitively the production efficiency gain required to attain self-sufficiency without hurting consumers is the percentage production increase. In addition, the producer subsidy that would be sufficient to boost production to sufficiency levels was obtained as the product of the production increase and the price increase of the long grain paddy from the baseline to the sufficiency level.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 AGRM Scenarios Simulations Results

Table 5 shows the production and consumption levels for the four scenarios simulated in AGRM. Additionally Appendix Table 2 shows supply-demand baseline level projections for the next ten years (2017-2027).

4.1.1 Baseline Scenario

With business as usual, Kenya's rice self-sufficiency is projected to be at only 16% in 2030. In this scenario, production and consumption are projected to increase by 88% and 89% respectively from the base[12] to 2030. For Rwanda, under business as usual trend, the rice self-sufficiency in the country is projected at 58% in 2018 following 13% and 16% increase in production and consumption respectively. Tanzania is projected to be 90% self-sufficient in 2030 under the business as usual scenario. In this period production and consumption growth are 15% and 17% respectively. In Uganda the projected SSR in the baseline scenario is projected to be 64% in 2018 with production and consumption growth of 11% and 14% respectively.

4.1.2 NRDS Scenario

Attaining the production targets for area and yield in the Kenya NRDS will see the country at only 16% SSR, same as in the baseline scenario. The goal for Kenya was to attain at least 48% SSR by 2018 with eventual self-sufficiency by 2030. However, the targets which were laid out in 2008 underestimated both production and particularly consumption compared to the estimates that later followed (refer to tables 1 and 5 for the levels). The NRDS assumed a constant per capita

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[12] Reference base as used in the AGRM framework includes the average of three years 2014, 2015 and 2016

consumption of 8 kg/person/year and annual population growth of 2.7% across the years 2008 to 2030. On the contrary per capita consumption has increased from 8.2 kg/person/year in 2008 (when the NRDS was drafted) to 11.7 kg/person/year by 2013 and is projected to increase to 15.7 kg/person/year by the year 2030.

If Rwanda NRDS production targets are attained the country will be more than self-sufficient (213%) and will have surplus to sell in the EAC region in line with her National Rice Policy 2010-2020 (Kathiresan 2010). Compared to the baseline projections the targets seem too high though. In fact, NRDS mid-term (2013) targets for area, yield and production fall short of the historical PS&D estimates for the same year by 48% and 8% and 59% respectively (refer to tables 1 and 5 for the levels)

Tanzania NRDS base (2008) and production estimates were not consistent with historical PS&D estimates and subsequently the target (2018) production estimates for 2018 were incomparable with the AGRM projections which are based on PS&D historical data. (Note: -

-PS&D estimates are consistent with FAO estimates). For this reason, a sensible quantitative analysis of Tanzania NRDS targets, at least within the AGRM framework, could not be made.

In the case of Uganda, if the NRDS target production is attained the country will have a 99% surplus for sale to the neighboring countries in the region (Republic of Uganda 2008). Just as in Rwanda, the targets are too high compared to the observed growth trend and hence the baseline projections for 2018. Between 2008 and 2013 rice production in Uganda only increased by 19% yet the NRDS target 'expects' the production to increase by 250% between 2014 and 2018.

Table 5 AGRM Scenarios Simulation results

Kenya*	Baseline Projection			NRDS Targets				Area Expansion Scenario		Yield Growth Scenario	
	2014-2016 Average	2018 Level	2030 Level	2018 Level	% Diff from Baseline 2018	2030 Level	% Diff from Baseline 2030	2030 Level	% Diff from Baseline 2030	2030 Level	% Diff from Baseline 2030
Area Harvested (1000 Ha)	34.4	46.9	55.6	35.2	-25%	_	_	344.2	519%	55.4	0%
Milled Yield (MT/Ha)	2.6	2.7	3.0	3.3	25%	_	_	3.0	0%	18.7	517%
Production (1000 MT)	89.5	124.4	168.6	116.1	-7%	337.0	100%	1043.9	519%	1036.7	515%
Consumption (1000 MT)	542.5	622.5	1025.3	244.3	-61%	336.4	-67%	1038.4	1%	1037.9	1%
Self-Sufficiency (%)	16%	20%	16%	48%		100%		101%		100%	

Rwanda	Baseline Projection		NRDS Targets		Area Expansion Scenario			Yield Growth Scenario		
	2014-2016 Average	2018 Level	2018 Level	% Diff from Baseline 2018	2018 Level	% Diff from Baseline 2018	% Diff from NRDS Target	2018 Level	% Diff from Baseline 2018	% Diff from NRDS Target
Area Harvested (1000 Ha)	16	17.0	54.5	220%	29.7	75%	-46%	17.0	0%	-69%
Milled Yield (MT/Ha)	3.6	3.8	4.46	16%	3.8	0%	-14%	6.7	73%	49%
Production (1000 MT)	58.0	65.4	243.1	272%	114.2	75%	-53%	113.4	73%	-53%
Consumption (1000 MT)	98.7	113.6	204.11	80%	113.6	0%	-44%	113.6	0%	-44%
Self-Sufficiency (%)	59%	58%	119%		100%			100%		

Table 5 (Cont.) AGRM Scenarios Simulation results

Tanzania		**Baseline Projection**	**NRDS Targets**		**Area Expansion Scenario**			**Yield Growth Scenario**		
	2014-2016 Average	2018 Level	2018 Level	% Diff from Baseline 2018	2018 Level	% Diff from Baseline 2018	% Diff from NRDS Target	2018 Level	% Diff from Baseline 2018	% Diff from NRDS Target
Area Harvested (1000 Ha)	1008.3	1123.1	685.0	-64%	1250.5	11%	83%	1121.7	0%	64%
Milled Yield (MT/Ha)	1.8	1.7	1.4	-24%	1.7	0%	24%	1.9	11%	37%
Milled Production (1000 MT)	1760.0	1893.7	935.0	-103%	2108.6	11%	126%	2100.9	11%	125%
Consumption (1000 MT)	1899.1	2099.5	–		2102.9	0%		2102.7	0%	
Self-Sufficiency (%)	93%	90%			100%			100%		

Uganda		**Baseline Projection**	**NRDS Targets**		**Area Expansion Scenario**			**Yield Growth Scenario**		
	2014-2016 Average	2018 Level	2018 Level	% Diff from Baseline 2018	2018 Level	% Diff from Baseline 2018	% Diff from NRDS Target	2018 Level	% Diff from Baseline 2018	% Diff from NRDS Target
Area Harvested (1000 Ha)	95.0	102.2	240	135%	160.3	57%	-33%	102.1	0%	-57%
Milled Yield (MT/Ha)	1.6	1.6	2.145	33%	1.6	0%	-25%	2.5	58%	18%
Milled Production (1000 MT)	151.3	164.4	514.8	213%	257.9	57%	-50%	258.9	57%	-50%
Consumption (1000 MT)	232.7	258.7	499.2	93%	259.0	0%	-48%	259.0	0%	-48%
Self-Sufficiency (%)	65%	64%	103%		100%			100%		

4.1.3 Area Expansion and Yield Growth Scenarios

The area and yield growth required for the four countries to attain rice self-sufficiency are shown more clearly in Fig 3 (a-d)

For Kenya to attain rice self-sufficiency by 2030 through area expansion whilst holding yield growth at the baseline 1% annual growth then area needs to increase to 344,155 Ha by 2030. This corresponds to an annual area expansion rate of 18%. On the other hand, employing a yield driven strategy while letting area to increase in the baseline 3% annual growth, requires a unfeasible yield of up to 18.7MT/Ha.

In Rwanda, seeking rice self-sufficiency by 2018 through rice area expansion, while holding yield growth at the baseline 13% annual growth, calls for a compounded average annual area expansion of well over 90%. Conversely, if Rwanda seeks to attain self-sufficiency through yield growth while letting area to expand at business as usual rate 3%, then the yield needs to increase to 7MT/Ha by 2018 (milled basis). This implies an annual yield growth of 36%.

For Tanzania to achieve 100% rice self-sufficiency requires an annual 6.6% growth in area, while holding yield growth at baseline annual growth of 1.5%. Alternatively, if area expansion is held at the baseline annual growth (1%) and a yield driven strategy is sought then an annual yield growth of 7%.

For Uganda to attain 100% rice self-sufficiency by 2018 through area expansion while holding yield growth at the baseline annual growth of 1% the rice area needs to almost double between 2016 and 2018, that is, an annual 30% growth. Otherwise a yield-driven strategy calls for an annual yield growth of 27%.

Fig 3(a-d) for historical and projected rice area and yield in the four countries

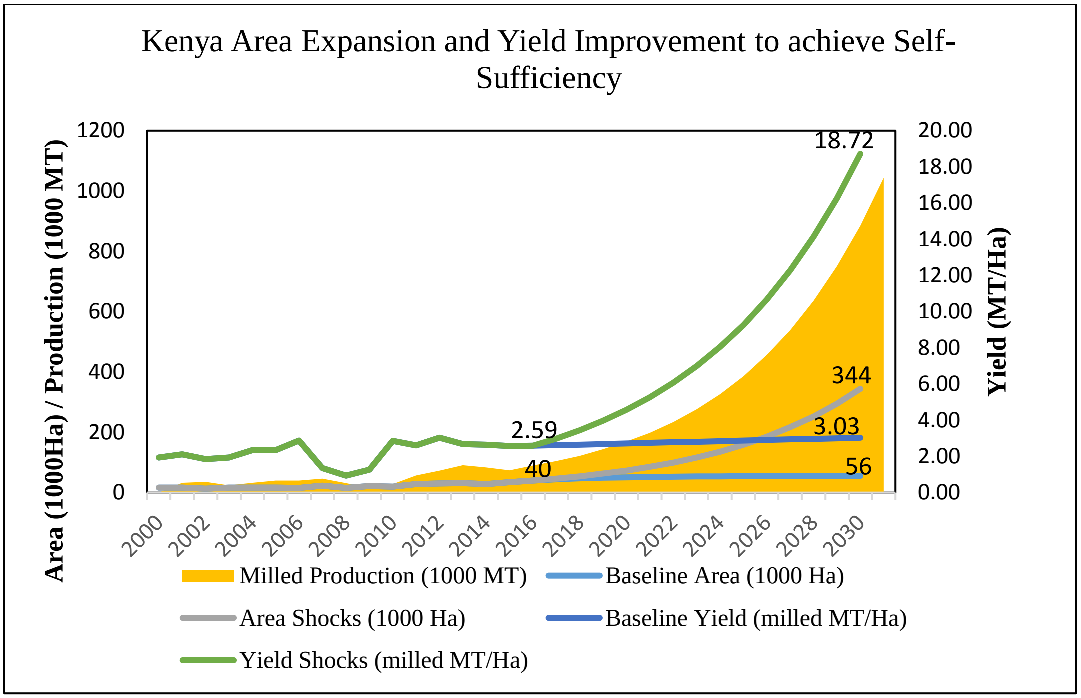

Fig 4 a. Historical and projected rice area and yield in Kenya

* Kenya NRDS aims to attain rice self-sufficiency by 2030; Rwanda, Tanzania and Uganda aim to attain self-sufficiency by 2018.

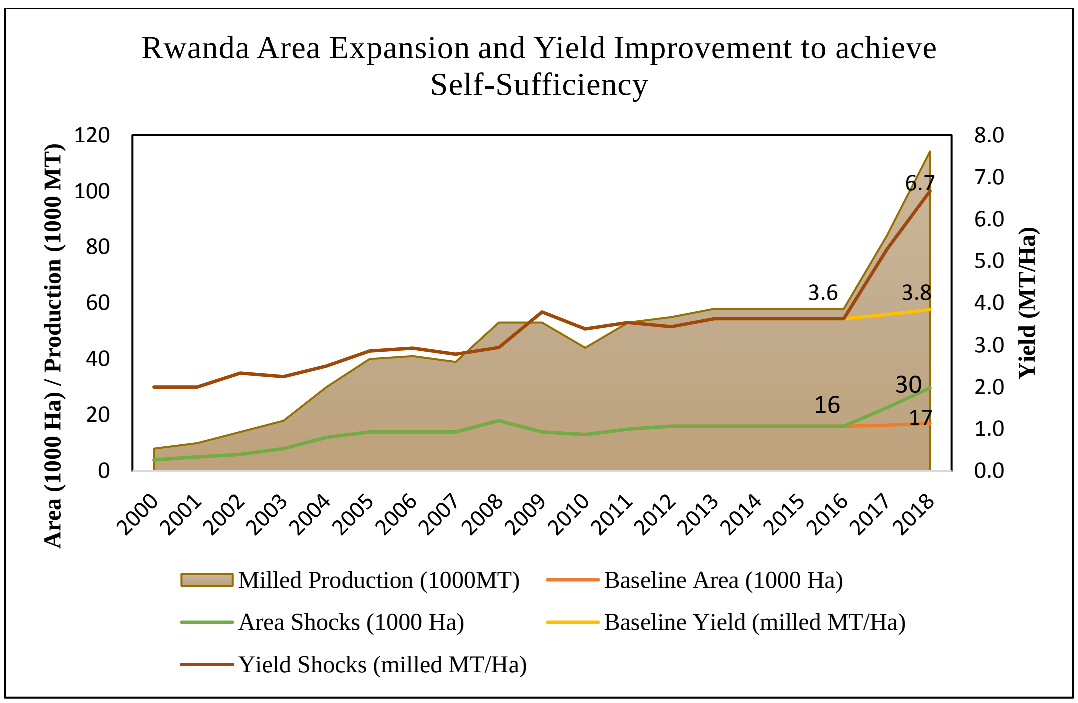

Fig 4 b. Historical and projected rice area and yield in Rwanda

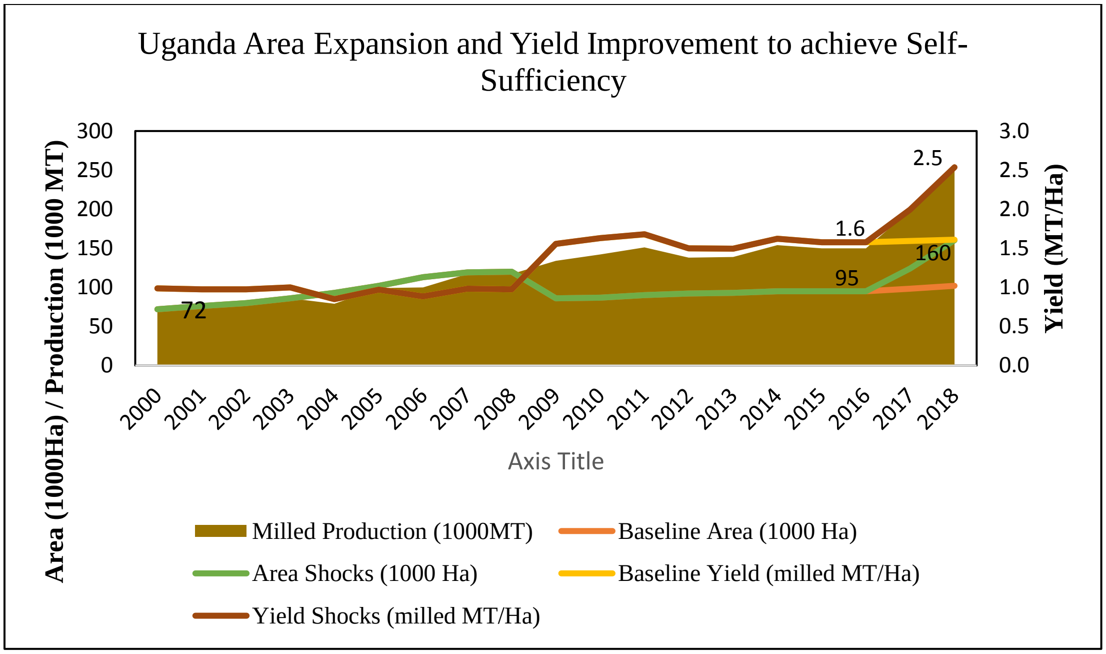

Fig 4 c. Historical and projected rice area and yield in Uganda

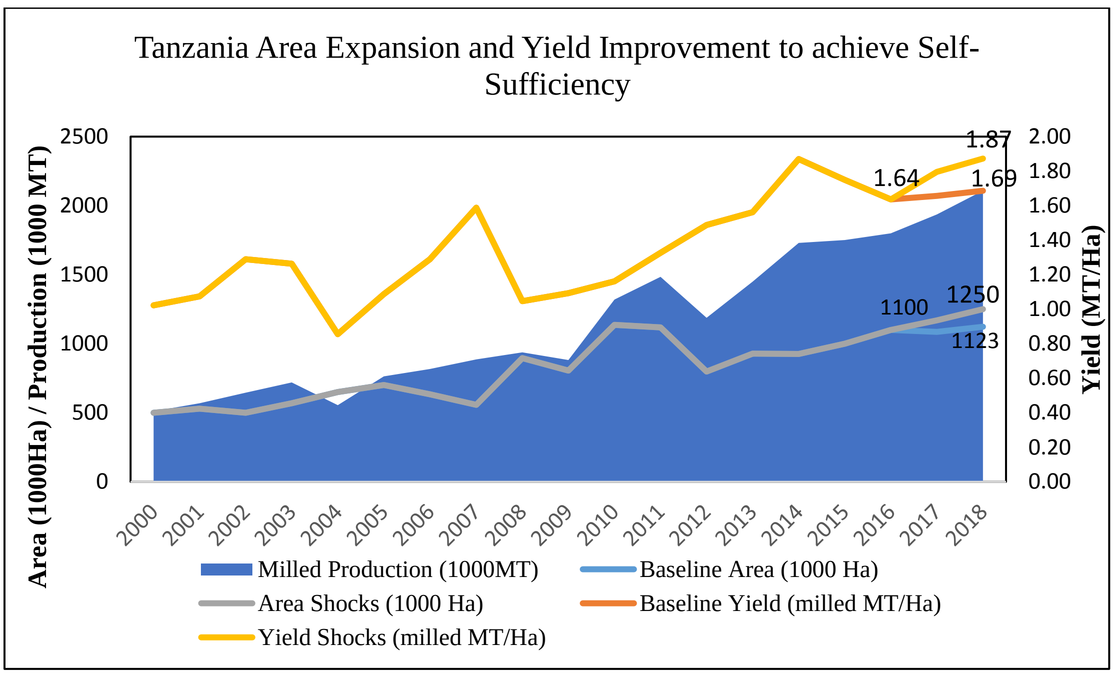

Fig 4 d. Historical and projected rice area and yield in Tanzania

4.1.5 Trade-off between Area Expansion and Yield Improvement Strategies

Owing to limitations of the AGRM framework, simultaneous area expansion and yield improvement scenarios could not be simulated. However area and yield equivalents were calculated from the two separate scenarios (see Table 6). This presents the four countries with an option to partly substitute either of the two strategies with the other depending on the ease/feasibility of both. For instance, in Kenya where relying on yield improvement solely is unrealistic, a blend of yield improvement alongside area expansion is more realistic. In Tanzania where average yields are currently low, a yield improvement of 1 MT/Ha may be more feasible relative to an area expansion of up to 650, 000 Ha. Some of the measures to improve yield as highlighted in the NRDS include investments in higher yielding varieties, use of inputs such as fertilizers and pesticides, research and extension among others. In Rwanda, although the average yields are relatively high an additional 1 MT/Ha may save the country the need to reclaim 4,516 Ha marshland at a cost estimated at US$ 8000 per Ha (Republic of Rwanda 2013). In Uganda a yield improvement of 1 MT/Ha is equivalent to 70,000Ha area expansion.

Table 6. Yield Improvement-Area Expansion Equivalent

Country/Equivalent	**1 MT/Ha**	**1000 Ha**
Kenya	18,846 Ha	0.053 MT/Ha
Rwanda	4,516 Ha	0.22 MT/Ha
Tanzania	652,173 Ha	0.0015 MT/Ha
Uganda	72,222 Ha	0.014 MT/Ha

4.1.6 Price Subsidy Scenario

Although not a very popular policy option in the EAC region, scenarios of the level of output price subsidies that would incentivize domestic rice production to self-sufficiency levels in the four countries were simulated.

One hundred percent and four hundred percent rice producer price subsidy improves Kenya SSR from 16% in the base period (201-2016 Average) to only 20% and 23% in 2030 respectively. It is thus not a feasible option to achieve 100% rice self-sufficiency for the country. On the other hand, 40% producer price subsidy is adequate to drive production to self-sufficiency levels in Tanzania and Uganda. In Rwanda a 100% price subsidy would lead to 81% self-sufficiency while at 200% subsidy 100% self-sufficiency would be attained by the year 2018.

Table 7. Price Subsidies required to attain rice self-sufficiency in Kenya, Rwanda, Tanzania and Uganda

Country	**Kenya***			**Rwanda**		**Uganda**	**Tanzania**
Variable / Subsidy level	**100%**	**200%**	**400%**	**100%**	**200%**	**40%**	**40%**
Area Harvested	69	78	92	21	23	142	1256
Yield	3.03	3.03	3.03	4.44	4.82	1.61	1.69
Production	209	237	278	92	112	228	2117
Per capita use	16	16	16	9	9	5	36
Total Consumption	1026	1026	1026	114	114	215	2103
Imports	823	795	754	22	2	28	16
Exports	0	0	0	0	0	40	30
Self Sufficiency (%)	20%	23%	27%	81%	99%	106%	101%

Kenya* self-sufficiency target year is 2030. Rwanda, Tanzania and Uganda target to be self-sufficient by 2018

4.2 RiceFlow Results

Table 8 shows the results from the RiceFlow model for self-sufficiency scenario simulation for the four countries.

At the current efficiency, an elimination of 90% of long grain rice imports into Kenya would lead to extremely high[13] producer and consumer price increase along with significant consumption shrinkage of the same. Under self-sufficiency, an efficiency gain of up to 345% is required to maintain consumers' welfare at pre-SSF levels, that is, negligible price increase and negligible consumption decrease.

Similarly in Rwanda, elimination of 99% of long grain rice imports would lead to extremely high price increase and a significant decrease in consumption. To do this without hurting the consumers' welfare an efficiency gain of 93% is required.

In Tanzania, attaining self-sufficiency in long grain rice at the current efficiency results to very high producer and consumer price increases and significant consumption shrinkage. Subsequently an efficiency gain of 28% would be needed to maintain prices unchanged from the benchmark but affording self-sufficiency.

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[13] Key to rank the magnitude of change: <1% =>negligible; >1%-10% => slight; >10%-100% => significant; >100%-500%=> very high; >500% => extremely high

Table 8 RiceFlow Scenario Results

KENYA		**2030 Baseline**	**Scenario 1 (SSF at current efficiency)**			**RWANDA**	**2018 Baseline**	**Scenario 1 (SSF at current efficiency)**		
		Value ($ 1000)	Value ($ 1000)	% change in qtty	% change in Price		Value ($ 1000)	Value ($ 1000)	% change in qtty	% change in Price
Production	LGP	151618	826691648	345%	122380%	LGP	40305	1785380	93%	2194%
	LGB	161609	833747072	320%	122714%	LGB	41400	1787507	93%	2137%
	LGW	166244	834587264	314%	121113%	LGW	45776	1795959	93%	1933%
	FRW	84	110	30%	0%					
Consumption	LGW	1933953	812735424	-65%	121112%	LGW	149376	1932441	-36%	1933%
	MGW	323	421	30%	0%					
	FRW	61058	79560	30%	0%					
Efficiency gain required	**345%**					**Efficiency gain required**	**93%**			
Producer subsidy required ($1000)	**353,014,691**					**Producer subsidy required ($1000)**	**823,275**			

Table 8 (Cont.) RiceFlow Scenario Results

TANZANIA		**2018 Baseline**	**Scenario 1 (SSF at current efficeincy)**		
		Value ($ 1000)	Value ($ 1000)	% change in qtty	% change in price
Production	LGP	749756	3137388	28%	226%
	LGB	751070	3143800	29%	225%
	LGW	770253	3169405	29%	219%
	MGB	8	8	4%	0%
	MGW	8	8	4%	0%
Consumption	LGW	1873901	5029417	-16%	219%
	MGW	906	946	4%	0%
	FRW	15524	16210	4%	0%
Efficiency gain required	**28%**				
Producer subsidy required ($1000)	**478,678**				

UGANDA	**2018 Baseline**	**Scenario 1 (SSF at current efficiency)**		
	Value ($ 1000)	Value ($ 1000)	% change in qtty	% change in price
LGP	131166	3121493	73%	1273%
LGB	132076	3123327	76%	1270%
LGW	137107	3135251	67%	1272%
LGW	313199	2902034	-32%	763%
FRW	196	216	10%	0%
Efficiency gain required	**73%**			
Producer subsidy required ($1000)	**1,224,667**			

As for Uganda, elimination of 95% of long grain imports at current efficiency would lead to extremely high producer and consumer price increases and significant consumption decreases. Moreover, an efficiency gain of 73% is adequate to attain the same sufficiency level without consumption decrease and/or price increase.

Whereas subsidies to boost domestic production to self-sufficiency levels were mathematically solvable, the costs were extremely large.

It is important to note that the dramatic price increases under self-sufficiency in all countries is a consequence of (1) the maintained modeling assumption of highly inelastic land supply and (2) the Leontief production technology assumption that limits substitution away from the constraining factor of production. Furthermore, the model does not account for substitution with other crops both in production and consumption. This means land cultivated with say corn or sorghum cannot be shifted to produce rice in response to rising rice rental prices. Similarly, the specification of final consumption does not account for consumers switching their choices away from rice as rice prices increase.

4.3 Discussion

4.3.1 Kenya

Kenya is highly dependent on rice imports (up to 83%) to meet her domestic consumption needs. In retrospect the goal is to attain full rice self-sufficiency by 2030 in line with the country's 'Vision 2030' development Programme (Republic of Kenya 2008). With this in mind the Kenyan government drafted the NRDS to guide this ambition. However the NRDS has a severe shortcoming in that it largely underestimated domestic consumption growth and therefore setting the production target for 2030 to this gets the country to only 30% self-sufficiency whereas the objective was to attain 100% self-sufficiency. Expanding the area under rice production is one option that could be explored to increase rice production in the country as there is potentially 540,000 Ha irrigable land and an additional 1 Million Ha suitable for rain-fed rice production in Kenya (Republic of Kenya 2008). More so, an impressive area expansion (which had otherwise earlier stalled at 17000Ha since 2000) was observed between 2008 and 2016. In this regard, the components of the Kenya NRDS addressing rehabilitation of existing mal-functional irrigation schemes; opening up new irrigation schemes and promoting upland rain-fed rice production are very much sound. Towards these three components the GoK has allocated a total budget of $2M for rehabilitation of 5 existing schemes, $8M for establishment of 10 new schemes (5,800 Ha) and $50,000 for promotion of rain-fed rice production among farmers (Republic of Kenya 2014). However as Muhunyu (2012) states, it is also necessary that water in the irrigation schemes is managed efficiently to ensure reliable and fair distribution for all the farmers within a scheme.

Given the realities of climate change and diminishing productive land, advances to close yield gaps are critical. In fact, Lobell et al. (2009) argue that especially in irrigated systems of which most of the Kenya rice system is based, improving the yield potential is just as crucial or even more important as closing the yield gap. Although with the advancement in technology tremendous yield growths are possible, it is rare to surpass 80% of the yield potential (Lobell et al. 2009). Yields of up to 5.5t/Ha and 7t/Ha for aromatic and non-aromatic varieties grown in Kenya are possible (Muhunyu 2012). Currently at an average yield of 4 MT/Ha (paddy basis) there is not a huge gap that would be exploited as to be relied as a sole strategy to attain self-sufficiency just as retaliated in this analysis. As shown in this study a combination of both area expansion and yield improvement is more practical.

From the findings of this study, use of output price subsidies for the producers does not seem a plausible option for Kenya particularly with the goal of attaining rice self-sufficiency. It would be very costly and not sustainable. However input subsidies for certified seeds and fertilizers presents a window to boost rice productivity. Concerns over fertilizer market distortions; creation of dependence; and government budget burden have been fronted in arguments against provision of input subsidies (Makau et al 2016). However as Mason et al (2015) assessed, the National Accelerated Agricultural Inputs Access Program (NAAIAP) dabbed "smarter subsidy' or 'kilimo plus' recorded modest success in boosting maize production by an additional 556 kg of maize per acre (yield response rate of 3.61 kg of maize per 1 kg of the subsidized fertilizer). The subsidy was highly targeted to vulnerable smallholder farmers who otherwise could not buy fertilizer and certified seeds but owned at least one acre of land. More so, the subsidy came in the form of a voucher redeemable at accredited agro-dealers and was provided for only one season as to jump-start use of inputs with farmer education to plough back some savings from the first season to purchase inputs for the next season. These strategies off-sets the afore-mentioned concerns. In the most recent maize flour price crisis, the GoK responded by giving subsidies to maize importers (and millers) to lower the cost of a packet of maize meal to a pre-determined price with the requirement to indicate the recommended retail price on the package (Business Daily Africa, 2017). Although maize is the number one staple, with the recent upsurge of rice consumption and over-dependence on imports it is high time that the government considers incorporating rice within such programs which in fact can serve as a cushion in times of maize shocks.

4.3.2 Rwanda

Rwanda's rice self-sufficiency averaged well above 70% at the time the NRDS was drafted (2008) and there before but has since declined to below 60%. This can be attributed to an unmatched rice consumption growth (relative to production growth) as the Rwandan population as well as the income has been rapidly growing (Kathiresan 2013; Republic of Rwanda 2013). The Rwanda NRDS actually anticipated (maybe even overly anticipated) a rapid rice consumption growth projecting per capita consumption of 11.5kgs and 15.6 kgs for 2013 and 2018 respectively. Only 8.8 kgs per capita was estimated in 2013 (P S & D Online) and is projected to be at 9.1 kgs in 2018 (AGRM). So in this regard, the Rwanda NRDS production targets seem "over-ambitious' and unlikely to be attained. Moreover the recent years' trend 2008 when NRDS was drafted and after do not show any tremendous growth as to validate the ambitious targets for 2018.

On the positive side the Rwanda NRDS provided a well detailed breakdown of the activities, outcomes and budget of the NRDS (see table 3) and the revised version of 2013 is well inter-linked with other related policies: Rice Policy 2010-2020 (Kathiresan 2010); Fertilizer Policy 2014 (Republic of Rwanda 2014); Crop Intensification Program (Republic of Rwanda 2011); Government Program 2010-2017 (Kathiresan 2010). Furthermore the Rwanda NRDS well acknowledged and addressed a gap in the quality competitiveness of the locally grown rice. In particular following EICV survey (Kathiresan 2013), it was recommended that more long grain non-sticky rice varieties be developed and promoted as to match the preferences of especially the urban consumers. More so, a budget to the tune of $921,000 was allocated to improve the milling quality (reduce the percentage of broken rice). Establishment of processing and trading regulations followed shortly placing the authority to sell paddy rice on registered cooperatives and these could only sell to licensed processors (Republic of Rwanda 2012).

Marshlands, otherwise previously seen as marginal land now present a great opportunity to increase Rwanda rice production since this realization by the GoR in 2002. At that time, the government pronounced rice as a priority crop and has since embarked on reclaiming marshland areas and setting up irrigation for rice production (Republic of Rwanda 2013). As of 2012 up to 22,554 Ha marshlands had been brought to rice production through public-private partnerships (Republic of Rwanda 2013). The climatic conditions in the inland valleys (marshlands) of Rwanda where rice is mostly produced have been equated to that of some subtropics in Asia with potential yields of up to 8-10 T/Ha (Gasore 2015).

From the findings of this study, if Rwanda relied solely on an area expansion based strategy, an additional 13700 ha (from 2013, the latest p s & d estimate available) would be needed to attain rice self-sufficiency. Three options to expand rice production area exist: develop new marshlands; extend the tail-ends of existing ones through installation of storage structures such as dams; develop the hillside for upland rain-fed rice production. The GoR planned to reclaim up to 40,000ha marshland and 60,000Ha hillside for agricultural purposes. Out of this 19,162 ha marshland would be set for irrigated paddy production between 2010 and 2018 (Republic of Rwanda 2013). However, an increase of only 3,000 ha rice area was recorded between 2010 and 2013 (PS&D estimates). It is unfortunate that the latest rice production data available for Rwanda in the USDA –FAS database was for the year 2013. Otherwise it would have been more insightful if the predictions were made with more recent years' data taking into account progress made on the government plans.

Rwanda rice productivity is well above the world average and several traditional rice producing regions. Very rapid yield growth of about 13% (0.15 t/ha) every year have been noted in the country but as discussed by Lobell et al. (2009) there is risk of plateau at such productivity levels. One option to raise the average yield further is to scale up the less progressive farmers' yields. As Kathiresan (2013) and Gasore (2015) recommends, a shift from blanket fertilizer recommendations to more specific recommendations is vital as the marshlands fertility largely vary depending on composition and prior use (Republic of Rwanda 2013). According to on-farm trials conducted by the International Fertilizer Development Center in Rwanda, yields up to 8.6 MT/Ha on a paddy basis are possible (Kathiresan 2013).

The Government of Rwanda has maintained a strong hand in the regulation of inputs access/use as well as output marketing, a commitment it deems vital to safeguard food and livelihood security of the poor smallholder farmers (Republic of Rwanda 2014). Fertilizer/input policies in the country have undergone several back and forth revisions between state led fertilizer importation and distribution (1985); private sector importation and distribution (2000); back to government importation (2006); and back again to the private sector (2013) (Nkurunsiza 2015). The 2014 fertilizer policy seeks to foster sustainable partnership between the state and the private sector for bulk procurement (by GoR) and a private led distribution system (Republic of Rwanda 2014). Provision of input subsidies has taken a similar fashion beginning from the EU 50% fertilizer subsidy program in 1995; reduction to 20% in 1998 and eventual ban in 1999 (Nkurunsiza 2015). The government however deems input subsidies important for profitability of its farmers especially considering it is a landlocked country with significant transport costs (up to 40% of import cost, World Bank 2016 estimate) and as such maintains provision of subsidies at least equivalent to transport costs from the nearest sea port until the rail road reaches Kigali (Republic of Rwanda 2011). Cognizant of the risk of reversed progress upon halting of subsidy programs as experienced in other countries like Malawi, the government plans a gradual exit strategy guided by adoption levels and degree of soil amelioration. In addition, the GoR has diversified the range of subsidies to include machinery acquisition and targets farmers who have otherwise not adopted improved inputs (Republic of Rwanda 2011). Noteworthy, as a result fertilizer use has increased from 4kg/ha in 2006 to 30kg/Ha in 2013. The target is to attain 45kg/ha by 2018.

As concerns the rice farm gate price, these are commonly agreed by the farmer cooperatives, the processors and the ministries of agriculture and commerce every season based on the costs of production allowing a certain margin for the farmers (Kathiresan 2013).

In general rice development in Rwanda is well positioned within the national development priorities. The role of agriculture is emphasized in the government plan to attain middle income status by 2020 and rice is identified as a priority crop in the National Agriculture Policy.

4.3.3 Tanzania

Tanzania is nearly self-sufficient in rice averaging above 92% in the last ten years. Some sources actually indicate Tanzania is a net rice exporter (Stryker & Amin 2012; Barreiro-Hurle 2012). In this regard, a goal of self-sufficiency (production equals consumption) seems not as relevant for the country. Although the over-arching vision of the Tanzania rice sub-sector development is to transform the rice sector into a commercially viable one, much emphasis of the NRDS was laid on the area expansion and yield improvement strategies for doubling production with other components highlighted at the surface. Tanzania NRDS had one major limitation in that the production targets as noted in the results section were very low following an under-estimate of the area in 2008 (685,000 ha compared to 896,000 ha and 887,000 ha FAO and USDA estimates). Stryker (2012) noted similar concerns that Tanzania production data is heavily flawed due unclear methods and instruments of collection. Consequently the projected/targeted production for 2018 in the NRDS (935,000 Ha) is actually lower than the estimated average production in 2014-2016

(1.7 Million MT). A mid-term update (2013) of the NRDS as required by CARD was not available for Tanzania.

The area expansion and yield improvement simulations in this study indicate relatively less dramatic increases required to attain self-sufficiency (see figure 3d). However most of Tanzania rice production is based on low input rain-fed system, up to 74% of the total national rice area (Wilson & Lewis 2015), and therefore low productivity averaging between 1 and 1.5t/ha since 2000 (P S & D Online). Rice yields in Tanzania are lower than in the neighboring countries such as Kenya and Rwanda which have mostly irrigation based rice production systems. In a survey at the Wami-Ruvu basin, farmers cited irrigation as the one major required adaptation measure to the ever changing climate (Mugula 2013). An average yield of 4 t/ha has been attained by the more advanced producers with access to irrigation in Tanzania. Commercial companies such as Kilombero Plantations, Mtenda Kyela, Kapunga and Mbarali are gradually uplifting the face of productivity through their out-grower schemes which provide the necessary inputs and training (Wilson & Lewis 2015; United Republic of Tanzania 2008)

As already mentioned, setting production targets as to match domestic consumption may be seen as limiting the potential that Tanzania has for rice exports in the neighboring regions and beyond. Tanzania has membership in several communities: East Africa Community (EAC); Southern Africa Development Community (SADC); Common Market for Eastern and Southern Africa (COMESA). This grants duty free access to markets in the other member states of the communities (Barreiro-Hurle 2012). Furthermore, Tanzania rice is liked by consumers in these regions for its strong aroma (United Republic of Tanzania 2008).

Tanzania has a history of closed economy dating as back as 1950 when the legislative gave the executive branch authority to ban exports whenever deemed necessary to safeguard food security of the citizens (Amin & Stryker 2013). Great progress has been made fostering trade liberalization especially eliminating tariff based barriers, but non-tariff barriers (NTB) to trade still exist. One such NTB is the requirement for import and export permits. Maize and rice are two commodities mostly affected by these regulations. Bureaucracies in the issuance of permits is a great disincentive to cross-border trade, with traders resulting to second markets for permits which of course come with rent creation and eventually penalize farmers and/or consumers but mostly the former (Amin & Stryker 2013).

4.3.4 Uganda

Rice is a rather recently discovered crop in Uganda. In 2001 and 2002 upland rice varieties, NERICA developed by the Africa Rice Centre, were introduced in the county and adoption by farmers has been remarkable. This owes to the high profitability seen by farmers compared to other upland crops: maize and sweet-potato, which have since been replaced by upland rice (Haneishi 2014). The NERICA 4 is especially very popular with up to 70% of the rice area in the country planted with it (Mohapatra 2013). Subsequently the Government of Uganda acknowledged the important role that upland rice could play in food security and poverty alleviation and thus launched the Upland Rice Project in 2004.

Rice production in Uganda increased by 64% between 2000 and 2007 (see fig 3c). Motivated by this growth the NRDS for the country set to achieve an unprecedented 509,600 tons milled rice production the year 2018, 300% growth in ten years. Two years to the end of the NRDS time frame, only 150, 000 tons milled production has been recorded (P S & D Online). The issue of low productivity as in Tanzania is noticeable in Uganda as well. Relatively low yields between 1 and 1.6 t/ha (P S & D estimates) are typical of Uganda rice which is predominantly based on rain-fed production. Yields up to 3.7 t/ha have been registered in Doho which is based on an irrigated although low input use production system (Kikuchi et al. 2016). The cost competitiveness of Uganda can be significantly improved through adoption of "small and micro scale" irrigation projects. According to Kikuchi et al (2016) large scale irrigation investments' may be too huge to be off-set by yields as high as 5.5 tons/ha and therefore not recommendable as a strategy to improve Uganda's rice price competitiveness. There is potentially 500,000 ha suitable for lowland rice production in Uganda on which such small to micro scale irrigation could be installed (Mohapatra 2013).

Rice in Uganda is more over a commercial crop and as Mohaptara (2013) noted, production is responsive to the market conditions considering greater flexibility is possible in a rain-fed system as compared to an irrigation based production system with investments not as quickly adaptable for production of other crops. In fact up to 50% of the rice produced in Uganda is exported to the neighboring countries mainly Rwanda (Comtrade 2016). In this regard the CARD template on which the NRDS were drafted fails in that production target was based solely on the consumption projection, self-sufficiency over-emphasis. Considering the potential for exports, strategies emphasizing on market linkages and gaining regional competitiveness are more plausible in the case of Uganda. In 2005 the GoU successfully convinced other members of the EAC to adopt the 75% CET in an effort to protect domestic production. Although Uganda has religiously applied the tariff, problems with implementation and requests for adjustments from the other member countries have rendered the policy not very effective at the regional level (Kilimo Trust 2014).

4.3.5 Self-sufficiency and Food Security

Self-sufficiency policies may be justified as protecting a country from fluctuations in the international markets. In particular following the 2008 crisis when food prices sky-rocketed and with some countries restricting exports, a country's ambition to attain self-sufficiency for at least in its staple foods is understandable. However as many studies (Wilson & Lewis 2015; Amin & Stryker 2013; Davis et al. 2016; Vanzetti et al. 2010) have suggested de-linking domestic markets from international markets would still leave the former vulnerable to fluctuations in the local supply as caused by calamities such as drought or diseases occurring in the nation/region and not in other parts of the world. In this regard some degree of dependency on international markets may be seen as spreading risk.

As shown in this study attaining self-sufficiency can be very costly resulting in very high prices paid by consumers. This is especially the case when the costs of production (farm gate prices) are higher locally relative to other producing countries. Such is the case in the East African Countries relative to Asian countries such as Pakistan, India, and Vietnam where most of the rice imports into EAC come from (Kilimo Trust 2014). Consumers especially poor households tend to lower their consumption when the prices get too high (Hasan 2016). High prices directly impact on the economic access aspect of food and nutrition security. The price elasticities estimated for Kenya, Rwanda, Tanzania and Uganda (Appendix Table 1) indicate rice consumers in these countries are very sensitive to prices.

Welfare analysis was beyond the scope of this study and more over the RiceFlow model assumed a zero profit condition along the value chain implying that the high prices paid by consumers would be transferred to the farmers. This is not necessarily true especially in a market system characterized by traders who serve as middlemen between the farmers and the markets (Amin & Stryker 2013).

CHAPTER 5: CONCLUSION

5.1 Summary of Findings

Following the 2008 food crisis, the Coalition for Africa Rice Development (CARD) was launched jointly by the Japan International Cooperation Agency (JICA) and the Alliance for Green Revolution in Africa (AGRA). The aim of the initiative was to double rice production in Africa between the years 2008 and 2018 with the ultimate goal of eliminating dependence on rice imports in these nations. There are 23 CARD members who with the help of the initiative drafted the strategies to attain this goal dubbed as National Rice Development Strategies (NRDS). This study assessed the feasibility and impacts of four East African countries' NRDS targets and the implicit self-sufficiency goal within the global rice economy. This was done using the Arkansas Global Rice Model (AGRM) and the RiceFlow model.

Several shortcomings in the four countries' NRDS documents were identified: consumption growth under-estimation (Kenya); poor production data on which the estimates were based (Tanzania); and over-ambitious targets (Rwanda and Tanzania). Furthermore the template adopted for drafting the NRDS was rather rigid in the sense that the production targets were based solely on projected domestic consumption. Emphasis on self-sufficiency may be seen limiting some country's productivity and potential for exports as in the case of Tanzania. With the exception of the Rwanda NRDS, more emphasis was laid on supply-lifting strategies and less on value-addition and/or demand-lifting strategies. As discussed by Demont 2013 and Wailes et al. 2015, production increases without accompanying value addition and/or domestic demand lifting may harm a country's rice economy more than it benefits it as local markets are flooded with an otherwise less preferred/demanded local rice like in the case of Rwanda (Republic of Rwanda 2013; Kathiresan 2013)

The findings of this study showed that none of the four countries is projected to attain 100% self-sufficiency in the target period documented in the NRDS if the business-as-usual trends of production and consumption are maintained. In fact a slight decrease of the current self-sufficiency ratio is more likely as consumption growth outstrips production growth. Of the four, Kenya is the most import dependent with up to 84% of its domestic rice consumption imported.

In terms of area, yield, or subsidy required for attaining self-sufficiency in the four countries, these were very high and unlikely to be achieved except for Tanzania which is very near to sufficiency. Furthermore if rice imports are eliminated the consumers would bear the burden of very high prices which will undermine food security in the region. These findings are consistent with several other studies: Hasan 2016; Vanzetti et al. 2010; Davis et al. 2016). It thus follows it would be extremely challenging and probably needless for these countries to strive to attain self-sufficiency without dramatic changes in resource allocation, productivity and consumption trends. It is thus vital that the efficiency of use of resources such as water, land and other inputs is improved for sustainable self-sufficiency.

5.2 Limitations of the Study and Future Research

The main challenges of this study lie in the unavailability of sufficient data. Time series data on input prices and the respective usage in rice production was in-existent for the four countries thereby constraining the econometric yield equations to trend as the main explanatory variable. Disaggregated data on local versus imported rice prices as well as disaggregated production costs arising from the different systems which would otherwise enable relaxation of some of the modelling assumptions were lacking.

Moreover, strategies beyond production such as milling efficiency improvement; post-harvest storage improvement; demand lifting strategies such as local rice brand creation and awareness enhancement were not analyzed. Future studies analyzing impact on producer and consumer welfare at the national and regional (East Africa) could substantially add value to this study.

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APPENDICES

Appendix Table 1: Summary of Kenya, Rwanda, Tanzania and Uganda Sub-Models

Kenya Sub-Model	**Coefficient**	**P-Value**	**Adjusted R Square**	**Standard Error**	***F***
Area Harvested					
Intercept	3.0341	0.1072	0.6716	0.1735	11.7389
$Ln\ (Area_{t-1})$	0.6824	0.0017			
$Ln\left(\frac{RicePr_{t-1}}{MaizePr_{t-1}}\right)$	0.2898	0.0084			
$Dummy_{1994}$	1.1447	0.0004			
$Dummy_{2008}$	-0.4319	0.0301			
Yield					
Intercept	0.4907	0.0426	0.7276	0.1431	31.7241
$LnTrend$	0.2555	0.0040			
$Dummy_{2007-2009}$	-0.7480	0.0000			
Per Capita Consumption					
Intercept	-17.6234	0.0057	0.7954	0.1207	26.2618
$Ln\ Real\ GDP\ per\ capita$	2.1904	0.0002			
$LnRiceRetailPr$	-0.9307	0.0850			
Rice Producer Price Linkage					
Intercept	-0.8062	0.4117	0.7469	0.2662	51.1777
$Ln\ IntlRicePr$	1.1748	0.0000			
Maize Producer Price Linkage					
Intercept	2.0084	0.0705	0.2768	0.4038	9.4197
$Ln\ IntlMaizePr$	0.6564	0.0058			
Rice Retail Price Linkage					
Intercept	1.0879	0.0004	0.8304	0.1981	113.6249087
$IntlRicePr$	0.8853	0.0000			

Appendix Table 1 (Cont.) Summary of Kenya, Rwanda, Tanzania and Uganda Sub-Models

Rwanda Sub-Model	**Coefficient**	**P-Value**	**Adjusted R Square**	**Standard Error**	***F***
Area Harvested					
Intercept	-1.3173	0.4682	0.9108	0.1186	62.2682
$LnArea_{t-1}$	0.7749	0.0000			
$RealProducerPr_{t-1}$	0.2834	0.0518			
Yield					
Intercept	-4.6247	0.0602	0.9473	0.0512	78.8866
$LnRealProducerPr_{t-1}$	0.2056	0.3033			
$LnTrend$	1.1052	0.0000			
$Dummy_{2009}$	0.3739	0.0706			
Per Capita Consumption					
Intercept	-3.7037	0.0558	0.8973	0.1494	57.7876
$Ln\ GDP\ Per\ Capita$	1.3348	0.0014			
$Ln\left(\frac{RiceRetailPr}{MaizeRetailPr}\right)$	-0.7568	0.0120			
Rice Producer Price Linkage					
Intercept	3.1532	0.0000	0.8346	0.1205	46.3974
$Ln\ IntlRicePr$	0.6042	0.0000			
$Dummy_{2008}$	-1.1289	0.0000			
Rice Retail Price Linkage					
Intercept	2.8851	0.0003	0.7489	0.1553	42.7503
$Ln\ IntlRicePr$	0.6517	0.0000			
Maize Retail Price Linkage					
Intercept	0.6976	0.4472	0.6698	0.3017	29.4043
$Ln\ IntlMaizePr$	0.9593	0.0001			

Appendix Table 1 (Cont.) Summary of Kenya, Rwanda, Tanzania and Uganda Sub-Models

Uganda Sub-Model	**Coefficient**	**P-Value**	**Adjusted R Square**	**Standard Error**	***F***
Area Harvested					
Intercept	-1.6889	0.5388	0.7316	0.0720	12.8128
$Ln\ Area_{t-1}$	0.5666	0.0023			
$Ln\ RiceRetailPr_{t-1}$	0.9709	0.0395			
$Ln\ ShiftTrend_{2009}$	-0.3212	0.0114			
Yield					
Intercept	0.3825	0.0000	0.9637	0.0501	399.5106
$Ln\ ShiftTrend_{2009}$	0.5046	0.0000			
Per Capita Consumption					
Intercept	-2.0593	0.0009	0.8222	0.0397	33.3595
$Ln\ GDP\ Per\ Capita$	0.6383	0.0000			
$Ln\left(\frac{RiceRetailPr}{MaizeRetailPr}\right)$	-0.5467	0.0080			
Rice Retail Price Linkage					
Intercept	2.5459	0.0024	0.7294	0.1797	38.7331
$Ln\ IntlRicePr$	0.7177	0.0000			

Appendix Table 1 (Cont.) Summary of Kenya, Rwanda, Tanzania and Uganda Sub-Models

Tanzania Sub-Model

	Coefficient	P-Value	Adjusted R Square	Standard Error	*F*
Area Harvested					
Intercept	5.6337	0.0016	0.8518	0.1366	64.2236
$LnArea_{t-1}$	0.3319	0.0693			
$Ln(IntlRicePr + Tariff)_{t-1}$	0.2519	0.0019			
Yield					
Intercept	-0.5372	0.0571	0.4057	0.1687	17.3859
$LnTrend$	0.3725	0.0004			
Per Capita Consumption					
Intercept	-0.4591	0.3747	0.7451	0.1223	34.6172
$Ln\ GDP\ Per\ Capita$	1.5886	0.0000			
$Ln\ (IntlRicePr + Tariff)_{t-1}$	-0.2600	0.0025			

Appendix Table 2: AGRM Baseline Projections Results

Kenya Rice Supply and Utilization

Kenya	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	(Thousand Hectares)													
Area Harvested	44	47	49	50	52	52	53	54	54	55	55	55	55	56
	(Metric Tons per Hectare)													
Yield Milled	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	(Thousand Metric Tons)													
Milled Production	115	124	132	137	142	146	150	153	156	159	162	164	166	169
Beginning Stocks	91	93	98	108	109	117	118	124	126	132	134	141	143	144
Domestic Supply	206	217	230	245	251	263	268	277	282	291	296	304	310	313
Consumption	588	622	679	701	746	770	809	831	871	896	938	965	986	1025
Ending Stocks	93	98	108	109	117	118	124	126	132	134	141	143	144	150
Domestic Use	681	720	787	810	863	888	933	957	1003	1030	1079	1109	1130	1176
Net Trade	-476	-503	-558	-565	-612	-626	-665	-679	-721	-739	-783	-804	-821	-863

Appendix Table 2 (Cont.) AGRM Baseline Projections Results

Rwanda Rice Supply and Utilization

Rwanda	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
	(Thousand Hectares)										
Area Harvested	16	17	18	18	18	19	19	20	20	21	21
	(Metric Tons per Hectare)										
Yield Milled	4	4	4	4	4	4	4	4	4	5	5
	(Thousand Metric Tons)										
Milled Production	61	65	69	72	76	79	83	87	91	95	99
Beginning Stocks	1	1	1	1	1	2	2	2	2	2	2
Domestic Supply	62	66	71	73	77	81	85	89	93	97	101
Consumption	107	114	121	130	136	144	153	161	171	180	190
Ending Stocks	1	1	1	1	2	2	2	2	2	2	3
Domestic Use	108	115	123	131	137	146	155	163	174	182	192
Net Trade	-46	-48	-52	-58	-60	-65	-70	-74	-81	-85	-91

Appendix Table 2 (Cont.) AGRM Baseline Projections Results

Tanzania Rice Supply and Utilization

Tanzania	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
						(Thousand Hectares)					
Area Harvested	1085	1123	1152	1160	1177	1197	1219	1232	1250	1262	1275
						(Metric Tons per Hectare)					
Yield Milled	2	2	2	2	2	2	2	2	2	2	2
						(Thousand Metric Tons)					
Milled Production	1798	1894	1977	2027	2091	2166	2244	2308	2383	2447	2517
Beginning Stocks	1	3	3	5	5	6	6	7	7	8	8
Domestic Supply	1799	1896	1981	2031	2097	2171	2250	2315	2390	2455	2525
Consumption	2013	2100	2218	2302	2381	2457	2544	2616	2696	2765	2847
Ending Stocks	3	3	5	5	6	6	7	7	8	8	9
Domestic Use	2016	2103	2223	2307	2386	2463	2551	2623	2704	2774	2856
Net Trade	-217	-206	-242	-276	-290	-292	-301	-308	-314	-318	-331

Appendix Table 2 (Cont.) AGRM Baseline Projections Results

Uganda Rice Supply and Utilization

Uganda	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
(Thousand Hectares)											
Area Harvested	98	102	107	109	111	113	116	119	122	124	127
(Metric Tons per Hectare)											
Yield Milled	2	2	2	2	2	2	2	2	2	2	2
(Thousand Metric Tons)											
Milled Production	157	164	174	178	183	189	196	202	209	214	221
Beginning Stocks	1	1	1	1	2	2	2	2	3	3	3
Domestic Supply	157	165	175	179	185	190	198	204	211	217	224
Consumption	241	259	276	287	300	314	330	346	364	379	398
Ending Stocks	1	1	1	2	2	2	2	3	3	3	4
Domestic Use	242	260	278	289	301	316	333	349	367	382	401
Net Trade	-85	-95	-103	-110	-117	-125	-135	-144	-155	-165	-177