Small holder farmers' postharvest management behavior and influence on maize production cycle in Rwanda.

Dr. Emmanuel NZEYIMANA[*], Gbadebo Odularu [**]

[*] PhD in Development Studies, Jomo Kenyatta University of Agriculture and Technology, Kigali, Rwanda
[**] PhD, The President, No Hunger Food Bank, Nigeria; The President, African Finance and Economic Association, Washington DC, US. Research and Practice Specialist, Agri-food, Trade and Digitalization Programme, Socio-Economic Research Applications & Projects (SERAP LLC), 1720 Wisconsin Ave NW, Washington DC, 20007 - USA.

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Abstract- The agriculture sector in developing countries, particularly in Africa, is commonly characterized as subsistence farming. This involves fragmented land ownership, limited use of inputs, low levels of skills among smallholder farmers, reliance on rudimentary technologies, resistance to adopting new farming methods, and challenges in accessing finance and markets, level of production and postharvest management of the production. These interconnected factors influence the behavior of smallholder farmers along the entire value chain. These circumstances also shape the perceptions and reactions of key stakeholders in the agricultural ecosystem, including governments, ministries of agriculture, the private sector, and civil society organizations. Extensionists, working at various levels, respond to smallholder farmers at the farmgate level, within associations and cooperatives at the meso level, and at the macro level considering their contributions to the national economy in Rwanda. This study investigates maize smallholder farmers' behavior in managing the maize production and how their behaviors influence the counting of their contributions in the national economy, to gain insights into regional dynamics, we employed a comparative approach focusing on the East African Community (EAC). The investigation aims to shed light on the influences of the regional market. Given Rwanda's strategic position as a potential hub for regional socio-economic development and its active role in promoting the African Continental Free Trade Area (AfCFTA), our research aimed to offer a thorough understanding of the overarching context within which maize value chains operate. Furthermore, the study examines the behavior of smallholder farmers in the postharvest management of maize.

Index Terms- Maize Post-Harvest, Post-Harvest Management Practices, Smallholder farmers, Community food banking.

I. Introduction

Maize in Africa is typically consumed either as green maize young corn that is eaten shortly after harvest or after processing in the form or maize flour or meal. Common final products include porridge or cakes. The emphasis on such outputs elevates the position of maize flour in many African countries' export baskets. Depending on the year, Africa generally accounts for between 1.5-3.5% of global exports of maize; by comparison, the value of the continent's exports of maize flour represented 20.1% of worldwide exports in 2013, and the value of the continent's maize flour exports increased by close to 400% in the period from 2004 to 2013. Table 1 provides further detail on the global trade of maize. South Africa was the second largest global exporter of maize flour in 2013, while EAC countries Uganda, Tanzania and Rwanda all had a significant market share within Africa. Much of the maize flour emanates from more advanced processing nations to countries that do not have mills (IGC, 2016).
Table 1: Top 5 Global and African Exporters of Maize Flour, 2004-2013

Country	Export Value (US$, millions)					World or African Share (%)				
	2004	2006	2009	2011	2013	2004	2006	2009	2011	2013
WORLD	340	387	626	731	882					
US	94	106	153	141	131	27.9%	27.5%	24.5%	19.4%	14.9%
South Africa	—	—	64	58	128	—	—	10.3%	8.0%	14.6%
France	57	56	77	88	92	17.0%	14.5%	12.4%	12.1%	10.5%
Italy	46	49	59	68	60	13.7%	12.9%	9.5%	9.4%	6.8%
Turkey	—	—	—	—	47	—	—	—	—	5.4%
Brazil	—	—	35	48	—	—	—	5.7%	6.7%	—
El Salvador	—	22	—	—	—	—	5.8%	—	—	—
Mexico	15	18	—	—	—	4.5%	4.9%	—	—	—
Germany	12	—	—	—	—	3.6%	—	—	—	—
AFRICA	18	20	86	87	177	5.5%	5.3%	13.8%	12.0%	20.1%
South Africa	6	10	64	58	128	34.1%	50.5%	74.6%	66.5%	72.5%
Uganda	6	7	12	9	15	36.0%	38.5%	14.0%	10.4%	8.7%
Tanzania	—	—	—	2	13	—	—	—	3.3%	7.5%
Rwanda	—	—	—	—	6	—	—	—	—	3.8%
Namibia	—	—	—	—	6	—	—	—	—	3.6%
Botswana	—	0.3	0.5	7	—	—	1.8%	0.6%	9.0%	—
Algeria	—	—	3	2	—	—	—	4.3%	4.0%	—
Zambia	3	—	3	—	—	20.2%	—	3.9%	—	—
Lesotho	0.2	0.4	—	—	—	1.1%	2.4%	—	—	—
Kenya	—	0.4	—	—	—	—	2.2%	—	—	—
Cote d'Ivoire	1	—	—	—	—	5.5%	—	—	—	—

Source: IGC: Maize Chains in East Africa, F-38202-RWA-1

The trends in global maize trades underscore its crucial role in feeding the world's population. The shares of countries in global maize trades, whether in exports or imports, also reflect their significance in the global maize market. As shown in Table 1, the global north emerges as the dominant force, serving as the largest global exporter of maize. In contrast, African countries play a relatively minor role, with South Africa representing a significant contribution at 72% of the total maize exports from the continent.

Globally the post-harvest crop losses have an impact on global food security, one-third of food is lost during post- harvest actions along food supply chains globally (R.J. Hodges et al, 2011). State of Food and Agriculture (SOFA) of Food and Agriculture Organization of the United Nations (FAO, 2016), also reported that in 2016 about 14% of the food produced for human consumption in sub-Saharan Africa (SSA) was lost during the post-harvest stage of the food supply. According to the United Nations (UN, 2017) and Food Security Information Network (FSIN, 2021) indicate that food production needs to increase to match the global food demand associated with the rapid increase in world population. Meanwhile, managerial, and technical limitations such as lack of proper storage facilities and poor food handling practices are reported to be among the main causes of food losses in SSA (J.Aulakh et al, 2013).

As the modernization of agriculture is a top priority for governments worldwide, East African countries have as well prioritized maize as key crop to rely on for feeding their population and boosting their economies. Among the resource-poor smallholder farmers in the East-African sub-region, maize is a crucial food staple and cash crop that provides them with food, as well as income. It has also consistently been central to household food security for most Africans in general (A. Kathiresan, 2011). However, a significant quantity of the maize produced in SSA has continually been lost through poor postharvest operations along the food supply chain. For example, Gitonga et al. (2013) reported that between 4.3 and 11.2% of produced maize is lost due to inadequate storage technologies. Yet farmers store maize to hedge against seasonal food insecurity and attendant price volatility, and to cope with the damage that occurs during storage. Therefore, reducing maize losses through adoption of appropriate storage technologies could enhance food security as well as alleviate poverty, particularly in the rural areas of SSA (APHLIS, 2017).

Table 2: Maize Production in four countries of EAC, 2010-2021 (MT,000')

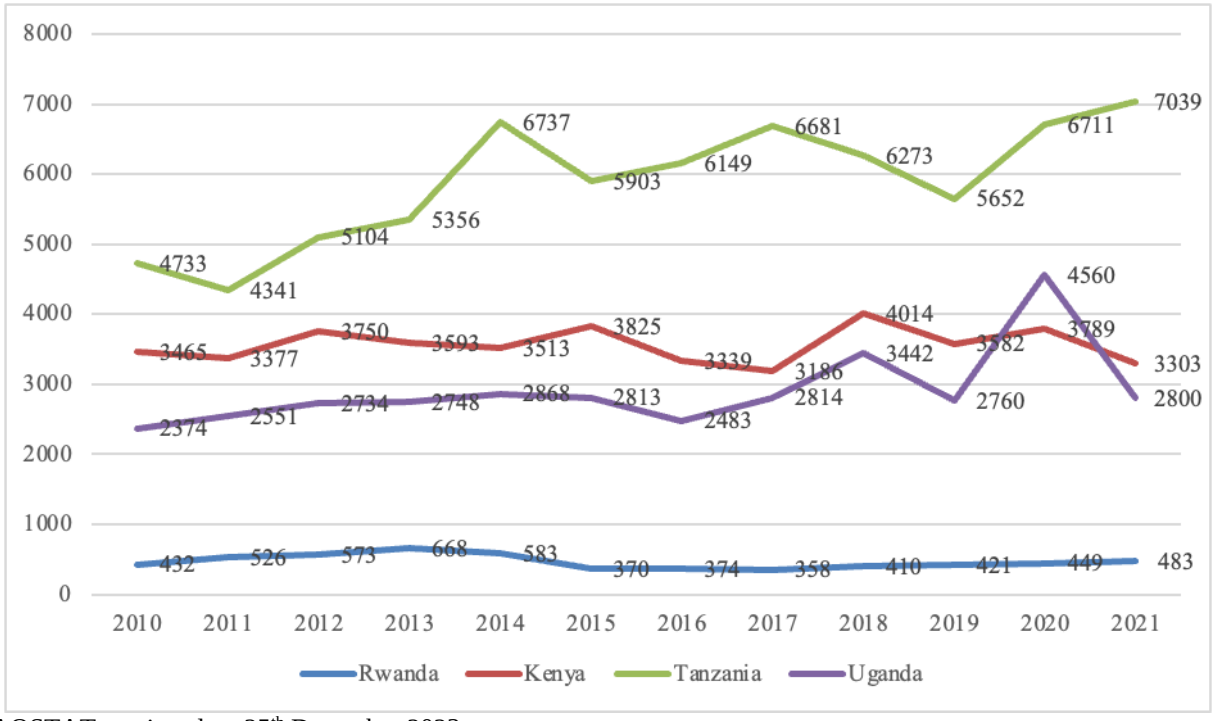
Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Rwanda	432	526	573	668	583	370	374	358	410	421	449	483
Kenya	3465	3377	3750	3593	3513	3825	3339	3186	4014	3582	3789	3303
Tanzania	4733	4341	5104	5356	6737	5903	6149	6681	6273	5652	6711	7039
Uganda	2374	2551	2734	2748	2868	2813	2483	2814	3442	2760	4560	2800

Source: FAOSTAT, retrieved on 25th Decemeber 2023

In the East African Community (EAC), the maize industries are intricately linked to regional socio-economic and demographic factors, which include the demographic landscape, land availability, the level of agricultural development, and overall economic conditions within the EAC. The EAC is home to an estimated 283.7 million citizens, with over 30% residing in urban areas. Encompassing a land area of 4.8 million square kilometers and boasting a combined Gross Domestic Product of US$ 305.3 billion for the four countries under consideration in this research, Tanzania stands as the largest both in size (945,087 km²) and population (63 million people). Kenya follows as the second-largest (580,367 km² and 56 million people), Uganda in third place (241,550 km² and 49 million people), and Rwanda in the fourth position (26,338 km² and 13 million people).

The maize context in the EAC diverges from global trends, influenced by maize's status as a staple food crop in East Africa, providing nearly half of the region's consumed calories and protein (Macauley, 2015). As discussed earlier, the production of maize in the four EAC countries considered in our study (refer to Table 2 and Figure 1) is likely influenced by governmental responsibilities in ensuring food security and is supported by factors such as land availability and government investments in maize farming.

Figure 1: Maize production in 4 EAC Countries from 2010-2021 (MT,000')



Source: FAOSTAT, retrieved on 25th December 2023

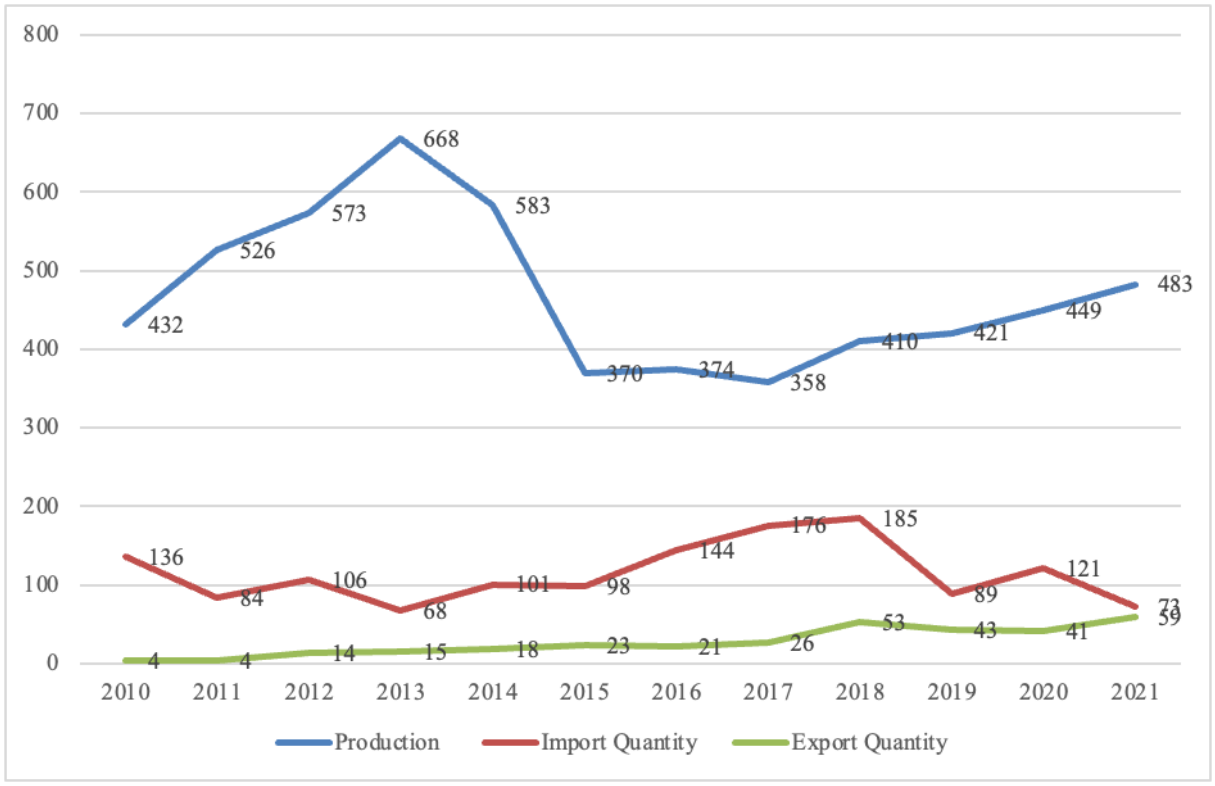
In Rwanda the maize industry is characterized by smallholder farmers and substantial volumes of informal trade. The country has roughly 300,000 households growing maize, and the average farm size is 0.6 hectares (Stone et al., 2011). Government data provides explicit estimates of the size of the informal export market between 57-69% of the export value of maize from 2012-15, and between 45-90% of the value of maize flour in the same period. However, stakeholders reported in interviews that the volume of informal trade is likely still underreported (IGC, 2016).

Maize was identified as a priority crop by the Government of Rwanda and through the Crop Intensification Program, the production of maize is currently holding the detailed attention of the Rwandan Ministry of Agriculture and Animal Resources. Maize is likely to contribute significantly to food security of Rwandans and to sustainable agricultural and rural development. According to MINAGRI (2009), several reasons have led the Ministry of Agriculture to target maize among its priority agricultural sectors: i) Its relative ease of conservation at the farm and its low spoilage compared with other crops, ii) Its high food value in energy and proteins (food crop) and significant source of income (cash crop); iii) The majority of the agro-bio-climatic zones of Rwanda present strong aptitudes for maize growing.

While maize has not traditionally been a primary crop in Rwanda, lagging behind plantains, potatoes, cassava, and sweet potatoes in daily consumption, it was incorporated into the government's 2007 Comprehensive Africa Agriculture Development Programme (CAADP) due to its potential to bolster food security. This initiative, encompassing endeavors to enhance the quality of and accessibility to crucial inputs, has played a significant role in fostering a substantial increase in maize yields and production volumes over the past decade.

Over the past decade (2010-2021), Rwanda consistently imported more maize than it exported. In 2010, the country imported 136,000 metric tons (MT) while exporting only 4,000 MT. Subsequently, there was a declining trend in maize imports and an increasing trend in exports, reaching a notable point in 2021. In that year, Rwanda imported 73,000 MT of maize and exported 59,000 MT, reflecting a shift in the balance between imports and exports.

Figure 2: Rwanda's Maize Production, Import and Exports, 2010-2021



Source: FAOSTAT, retrieved on 25th December 2023

The fourth Rwanda Strategic Plan for Agriculture Transformation (PSTA4) 2018-2024, projected to reduce the maize postharvest losses from 26% (baseline in 2018) to 13.3% by 2023/2024. The Crop Competitiveness Assessment 2016[1] found that yields for several crops are less than half of their potential, taking agro-climatic conditions into account. Furthermore, post-harvest losses were recorded as high as 30 per cent in some value chains. To alleviate pressure on land is to increase yields through a package of productivity-enhancing measures, involving research, extension, inputs systems and credit. In addition, opportunities exist to add nutritional and economic value by reducing post-harvest losses through investing in handling, storage, and processing. More pluralistic partnerships with universities, farmer organizations and the private sector can produce innovations in science, technology, extension, policy, and social learning to meet Rwanda's agricultural development goals.

In East and Southern Africa, the African Postharvest Losses Information System (APHLIS) estimates that losses are valued at US$1.6 billion annually, which is about 13.5 percent of the $11 billion total value of grain production in the two regions (WB, 2011). According to the data presented in Table 3, which compares the postharvest loss ratios for maize in our four East African Community (EAC) countries under investigation, it is evident that Tanzania has the highest maize postharvest ratio in the region. Over the last decade, Tanzania's average ratio stood at 12%. Rwanda follows in second place with an average ratio of 7%, Uganda takes the third position with an average ratio of 5%, and Kenya ranks fourth with an average ratio of 3%.

Table 3: Maize Production and Losses in 4 countries of EAC (Production: MT,000')

	Rwanda			Kenya			Tanzania			Uganda		
Year	Pdx	Loss	Loss ratio	Pdx	Loss	Loss ratio	Pdx	Loss	Loss ratio	Pdx	Loss	Loss ratio

[1] Rwanda Crop Competitiveness Assessment, MINAGRI, 2016

2010	432	20	5%	3465	164	5%	4733	582	12%	2374	112	5%
2011	526	25	5%	3377	159	5%	4341	533	12%	2551	120	5%
2012	573	27	5%	3750	177	5%	5104	634	12%	2734	129	5%
2013	668	32	5%	3593	170	5%	5356	665	12%	2748	130	5%
2014	583	28	5%	3513	78	2%	6737	831	12%	2868	135	5%
2015	370	33	9%	3825	83	2%	5903	728	12%	2813	132	5%
2016	374	35	9%	3339	72	2%	6149	758	12%	2483	115	5%
2017	358	35	10%	3186	146	5%	6681	824	12%	2814	129	5%
2018	410	39	10%	4014	93	2%	6273	774	12%	3442	157	5%
2019	421	32	8%	3582	51	1%	5652	704	12%	2760	123	4%
2020	449	37	8%	3789	88	2%	6711	829	12%	4560	204	4%
2021	483	37	8%	3303	74	2%	7039	866	12%	2800	129	5%
Average			**7%**			**3%**			12%			**5%**

Source: Calculated based on FAOSTAT data (December 2023).

Furthermore, over the past decade, a consistent trend in maize production and postharvest losses is evident in the four countries, as illustrated in the table above. This trend suggests a lack of significant changes in the efforts, initiatives, and investments dedicated to reducing maize postharvest losses in the region. By analogy, it can be inferred that there was minimal advancement in addressing this issue, with all relevant factors remaining relatively constant during this period.

Considering that a typical 10-year span usually encompasses at least two agricultural policies (each lasting 5 years), the observed pattern emphasizes the urgency for leadership in the four countries to reevaluate the maize postharvest loss problem. This calls for a fresh perspective and heightened attention in the planning process, acknowledging the need for a more effective strategy to mitigate postharvest losses in the maize sector.

II. The Problem

The Government of Rwanda has prioritized maize production in the country's marshlands and hillsides in regions as recommended by the Crop Intensification Program (CIP). Over the last 2 decades, huge investments were made in agricultural infrastructures, including swamp reclamation and irrigation systems. Maize is cultivated in all regions of the country; however, it is the main crop in East and Northern parts of Rwanda, where it is a cash crop on a large scale. Maize production and productivity have increased in the last decade in these regions. The development of maize production has boosted the need for postharvest handling materials and infrastructures for proper postharvest management, aiming to meet market conditions for quality among the key market price determinants. The government of Rwanda's investments in the maize value chains aimed at reducing poverty through increased income for the smallholder farmers. However, this objective faced various challenges, primarily due to poor post-harvest practices that led to the poor quality of maize, and smallholder farmers can earn very little from their maize. According to NISR (2023), only 32.2% of the national maize production is taken to the market. Postharvest practices and the behavior of smallholder farmers remain key challenges that lead to persistent high maize losses. This affects the quality and quantity of the maize sold in the market, reducing the income of smallholder farmers. As a result, locally produced maize has become less competitive than maize imported from the region.

III. Materials and Sources of Data

We primarily relied on secondary data from key sources such as the National Institute of Statistics of Rwanda (NISR), FAOSTAT, and the Ministry of Agriculture and Animal Resources (MINAGRI) to delve into the Maize Value Chains and postharvest losses in Rwanda over the past decade. The Seasonal Agricultural Statistics (SAS) provided by NIRS were pivotal in our research, offering insights into maize production and its utilization by farmers. To enhance our understanding and validate the information from NISR and MINAGRI, we conducted data triangulation, cross-referencing with additional sources like FAO (FAOSTAT) and World Bank.

Furthermore, we integrated a case study from previous research conducted on a maize production cooperative in the Bugesera region. This case study served to illustrate the dynamics of maize value chains, encompassing production and the utilization of produce from the household (farmgate) level to the macro level.

In our investigation, we adopted a comparative approach at the regional level, specifically within the East African Community (EAC). This comparative analysis aimed to elucidate regional dynamics and discern the influences of the regional market. Given Rwanda's strategic position as a potential hub for regional socio-economic development and its role in promoting the African Continental

Free Trade Area (AfCFTA) [2], our research sought to provide a comprehensive understanding of the broader context in which maize value chains operate.

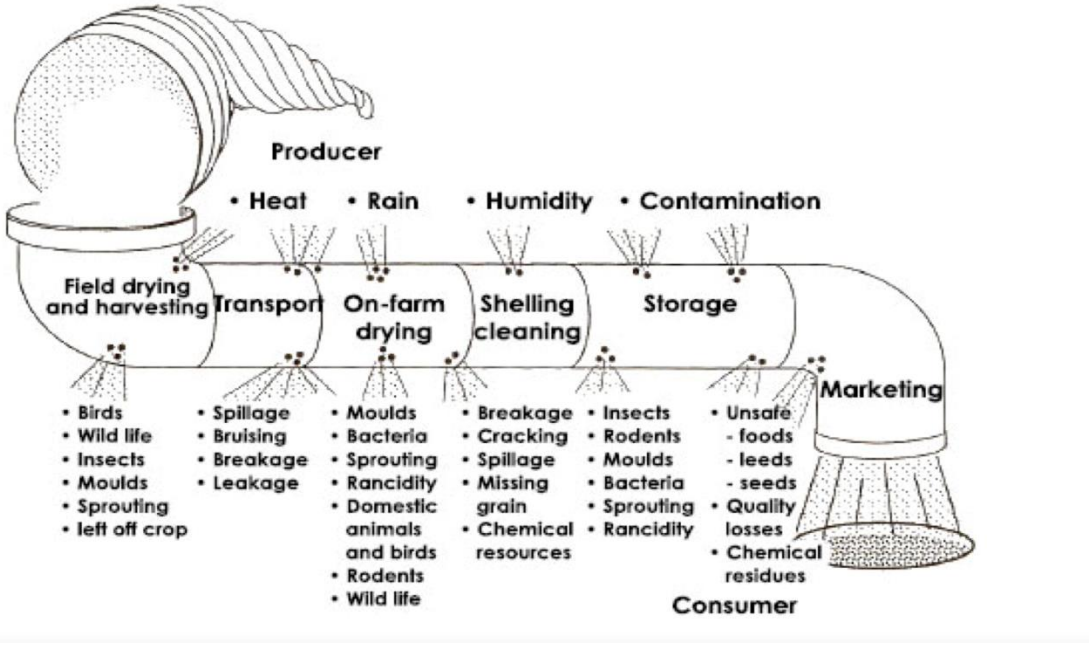
IV. Results and Discussions

3.1 Postharvest losses

Postharvest losses can be further categorized into physical, quality, and economic losses. Physical losses refer to reduction in the volume or weight of the grain due to such factors as shrinkage, attack by rodents, and insect infestation. Quality losses refer to deterioration in the condition of the grain which impacts negatively on attributes such as appearance, taste and texture, nutritional value, and product safety. An important safety-related quality loss is contamination by mycotoxins. Economic losses are closely linked to quality and refer to reductions in unit sales price and the inability of grain to access higher value markets (WB, 2011).

Roughly one-third of the edible parts of food produced for human consumption, gets lost or wasted globally, which is about 1.3 billion ton per year. Food is wasted throughout the Food Supply Chain (FSC), from initial agricultural production down to final household consumption. In medium- and high-income countries food is to a great extent wasted, meaning that it is thrown away even if it is still suitable for human consumption. Significant food loss and waste do, however, also occur early in the food supply chain. In low-income countries food is mainly lost during the early and middle stages of the food supply chain; much less food is wasted at the consumer level (E. Nzeyimana, 2020).

Figure 3: The Postharvest pipeline for Maize



Source: MINAGRI, 2011

In Rwanda the national average post-harvest losses, according to the APHLIS system, were 21.1% in Season A and 17.5% in Season B. The increased losses in Season A are driven by higher incidence of rain at harvest as well as breaking the "4 month" storage threshold, at which point modeled APHLIS storage losses increase from 0% to 2.6%. The total APHLIS- calculated losses for the year 2012 are 19.8% (CARANA, 2013).

Smallholder maize farmers get busy with their maize produces from the harvest time, during the post-harvest till they sell their maize to the market; this process involves different crucial maize quality and quantity determinant steps: the harvesting, drying, shelling, shelling, winnowing, sorting, aggregation and transport, storage and speculation, marketing, and processing, these steps require technologies, skills and financial capacities at the level of smallholder maize farmer, any default and non-compliance to standards into the process result into deterioration of the maize quality at the end (E. Nzeyimana, 2020).

[2] ECA (2022): Experts say that Rwanda's AfCFTA strategy places the country on a firm footing.

3.2 Maize utilization

The table 4 below highlights variations in maize farmers' production management practices. Notably, African farmers allocate over half of their production for food consumption, with a utilization rate of 54.3%. In regions characterized by advanced agricultural technology and high yields, such as the USA, Asia, and Europe, the percentage of production used for food is considerably lower. Specifically, the USA allocates 7.5%, Asia allocates 11.6%, and Europe allocates 5.6% for food purposes. The difference is explained by the level of production, technology involved in maize production and the behavior of farmers.

Table 4: Maize utilization globally

Region	Average use (% of domestic supply)					
	Food	Feed	Seed	Post-harvest losses	Processing	Other uses (non-food)
Africa	54.3	30.3	1.1	8.3	1.6	3.5
Eastern & Southern	65.8	19.8	1.2	6.7	1.4	5.2
West & Central	53.3	27.1	1.7	11.7	2.6	0.4
Northern	34.6	53.2	0.2	7.4	0.7	3.8
Asia	11.6	64.2	1.0	4.9	2.7	15.6
South	35.6	50.9	2.6	8.7	0.8	2.1
East Asia	5.3	69.9	0.9	4.8	3.6	15.6
South-East Asia	20.1	47.0	0.4	3.6	0.5	28.3
West & Central	21.7	66.7	0.6	2.5	1.7	6.6
Americas	7.5	50.5	0.5	6.9	5.9	28.7
Northern	1.4	44.6	0.3	5.6	7.5	40.6
Central & South	21.1	63.6	1.0	9.6	2.5	2.2
Europe	5.6	75.7	0.9	2.6	9.0	6.4
Oceania	18.5	66.8	0.2	1.5	3.1	10.0
L/LM-IC [a]	43.1	41.0	1.7	7.9	1.6	4.9
UM/H-IC [b]	7.6	59.0	0.6	5.5	5.2	22.1
World	12.8	56.3	0.7	5.8	4.7	19.6

Source: Olaf Erenstein et al, 2022

Improving land consolidation is crucial for enhancing agricultural productivity and ensuring effective utilization of resources. Fragmented land leads to mismanagement by smallholder farmers, resulting in the diversification of production into various non-monetizable uses. This practice prevents farmers from realizing the full monetary value of their produce.

For instance, in Africa, 54% of maize production designated for food consumption by smallholder farmers does not generate any cash income for them. Additionally, in Rwanda, 66.7% of maize production remains untapped in the market, further depriving farmers of potential monetary gains. Addressing the fragmentation of land and promoting efficient market access for smallholder farmers are essential steps to enable them to derive economic benefits from their agricultural endeavors.

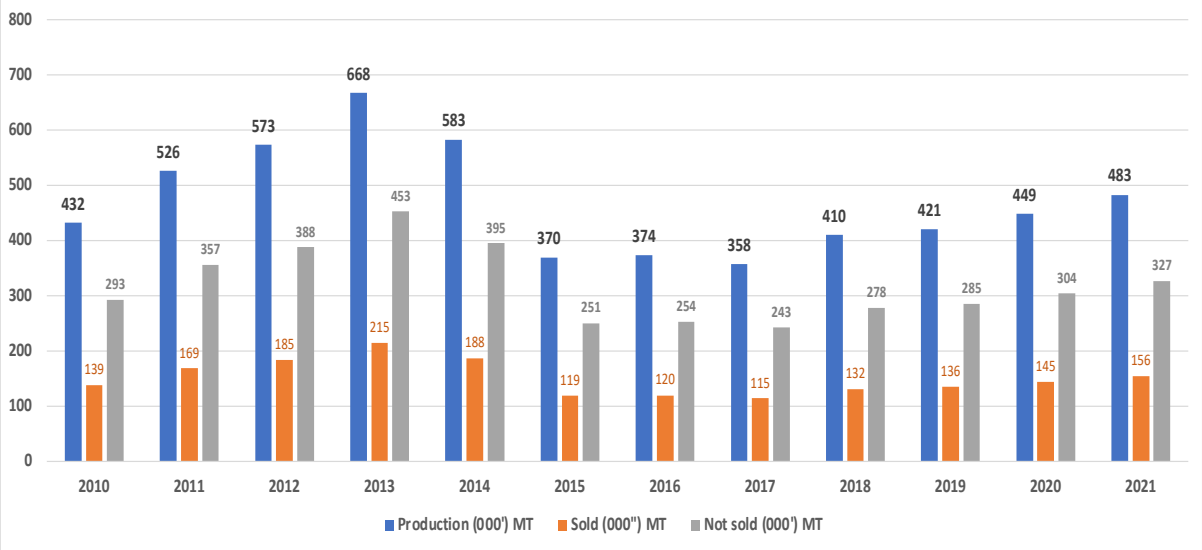
Table 5: Maize utilization by small holder farmers in Rwanda

Maize	Sold	Food	Wages	Farm rent	Offered (gift)	Seeds	Feed	Stored	Post harvesting losses	Other usage
NISR*	32.2	55.0	1.2	1.9	5.6	1.0	0.5	1.8	0.2	0.5
Case Study**	33.3	66.7								

*: NISR, 2023 Season A the Use of production by farmers (in percentage)
**: Case Study “UMUCYO Cooperative”, Bugesera District.

The majority of maize production, accounting for 67%, does not make it to the formal market. This includes maize consumed as home food, processed maize sold as flour through informal channels (which ideally should go through recognized processing units), maize shared among friends, and losses resulting from inadequate postharvest handling practices. Assigning an economic value to this portion of maize (67%) becomes challenging as it essentially disappears at the household level.

Figure 5: National Maize Production Sold Vs Not Sold



Source: Calculated from FAOSTAT (2023)

The case study reveals that 78% of smallholder farmers engage in maize cultivation on fragmented lands, specifically those with a size of 0.1 Ha or less. The remaining 22% of farmers work on lands ranging from 0.1 to 0.25 Ha. The study further establishes that all surveyed farmers fall under the classification of smallholder farmers, in line with the World Bank's Rural Strategy, which characterizes them by a limited asset base and operations on less than 2 hectares of cropland.

Notably, the research highlights that the majority of farmlands in Rwanda are comprised of fragmented plots. The average size of a farm holding in Rwanda is 0.76 Ha, and, on average, these holdings are distributed across four different land blocks. A significant proportion, approximately 80%, of farms have a surface area of less than 1 Ha each (E. Nzeyimana, 2020).

Wages: Human labor, constitute a substantial and crucial expense in maize production, as per NISR, it takes equivalent of 1.9% of the value of the total production. Various agricultural tasks, including land preparation, weeding, fertilizer and insecticide application, harvesting, and transportation, necessitated human labor. Two primary categories of human labor are utilized: family labor, encompassing the farmer, adult family members, and children[3], as well as permanently hired labor. To assess the costs associated with unpaid family labor, the study employed the opportunity cost concept, assuming the market wage rate as the equivalent cost. In this context, permanently hired labor was categorized as family labor. The computation of hired labor costs involved actual wages paid, and in cases where meals were provided to laborers, the monetary value of such provisions was included in the overall labor cost.

Land Use Cost/Farm rent: The land price varied based on the location and soil topography of individual plots, the cost of the land cost relies on the cash rental value associated with each plot. Our case study research revealed that 78% of smallholder farmers cultivate maize on fragmented lands, each less than or equal to 0.1 hectares. In contrast, 22% of farmers have land sized between 0.1 and 0.25 hectares. Only 34% of farmers own the land they cultivate, while the remaining 76% rent the land. The research also confirmed that all surveyed farmers fall into the category of smallholder farmers, as defined by the World Bank's Rural Strategy, which characterizes smallholders as those with a low asset base operating less than 2 hectares of cropland (E. Nzeyimana 2020).

The results of our case study closely align/high Correlation with the national findings from the seasonal agricultural survey (2023 Season A) conducted by the National Institute of Statistics of Rwanda (NISR, 2023). According to the survey, maize smallholder farmers in the country sell only 32.2% of their maize production to the market. The remaining 67.8% is allocated for various purposes such as food consumption, wages, farm rent, gifts, seeds, livestock feed, storage, post-harvesting losses, and other uses.

This situation highlights the need for urgent attention in terms of mobilization, sensitization, and capacity building for smallholder farmers. There is a necessity for a shift in mindset among these farmers towards embracing entrepreneurship and agribusiness. Encouraging collaboration and demonstrating the advantages of collective action in facing markets together can significantly enhance their bargaining power. Continued efforts in raising awareness and providing support are crucial for addressing these challenges in the maize value chain (E. Nzeyimana, 2020).

[3] Agriculture in Africa is predominantly practiced at the subsistence level. Smallholder farmers make up about 80 percent of all farms in sub-Saharan Africa and employ nearly 175 million people (FAO and OECD, 2016). There is a functional and economic dependency upon child labor in the agricultural sector, especially among poor households. The presence of children in agriculture is a key contributor to the sustenance of family livelihoods, and farming operations are often labor- intensive. In addition, adult labor force is not always available or affordable, making it challenging for small-scale farmers to attain the level of production needed for their survival without children's involvement (FAO, 2020).

3.3 Understanding profitability in maize production

3.3.1 Factors considered in the computation of costs of production

Farmers cultivating maize are required to cover the expenses associated with various inputs utilized in the cultivation process. These input materials are assessed at the prevailing market rates or occasionally based on the government-set prices in the regions during the survey period, or the rates at which farmers made their purchases. Essential items like mechanized land preparation (Mostly is eastern part of Rwanda), seeds, fertilizer and pesticides were occasionally procured by farmers 'cooperative. Conversely, certain inputs, such as family labor, don't involve direct cash payments, making the computation of their production costs particularly challenging. To address this issue, the opportunity cost principle is applied, considering the following cost components when estimating the overall production cost:

- Human labor;
- Land preparation/mechanical power cost;
- Seed;
- Manure;
- Fertilizer;
- Irrigation;
- Pesticides cost;
- Interest in operating capital;
- Land use.

3.3.2 Estimation of Costs (case study)

Expenses arise during the organization and execution of the production process, constituting the costs incurred. In the course of production, farmers encounter two types of costs: variable and fixed. Variable costs associated with maize production encompass expenses such as seed, hired labor, animal and power tiller costs for land preparation, fertilizer, manure, irrigation, and pesticides.

From the case study, the costs for maize production are shown in table 6: Pre-harvest activities cost 720,000 RWF/Ha (First Plowing, Second Plowing, Sowing, First weeding, Second weeding, Third weeding, Pesticide spraying, Detasseling, Guarding (2 months), Harvesting), Inputs cost 545,950 RWF/Ha (Manure (Trucks), Seeds (Kg), Fertilizer DAP(Kg), Fertilizer UREA(Kg), Pesticides), Post-harvest activities cost 447,000 RWF/Ha (Drying, Threshing, Sorting, Guarding, Loading, Off-loading, Transport).

Table 6. Per hectare costs for maize cultivation (Optimum Agronomic Condition)

Costs	Unit	Quantity	Unit Cost	Total cost (RWF)
A. Variable Cost				
I. Inputs (Variable Cost)				
Manure (Trucks)	Truck	2	100,000	200,000
Seeds (Kg)	Kg	25	1,350	33,750
Fertilizer DAP(Kg)	Kg	200	834	166,800
Fertilizer UREA(Kg)	Kg	100	754	75,400
Pesticide	Ltrs	2	15,000	30,000
Bags (pces)	Number	100	400	40,000
ST/1				**545,950**
II. Pre-harvest activities				
First Plowing	Casuals	100	1,500	150,000
Second Plowing	Casuals	50	1,500	75,000
Sowing	Casuals	50	1,500	75,000
First weeding	Casuals	50	1,500	75,000
Second weeding	Casuals	30	1,500	45,000
Third weeding	Casuals	30	1,500	-
Pesticide spraying	Casuals	20	1,500	30,000
Detasseling	Casuals	30	1,500	-
Guarding (2 months)	Guards	2	60,000	120,000
Harvesting	Casuals	100	1,500	150,000
ST/2				**720,000**
III. Post-harvest activities				
Drying	Casuals	30	1,500	45,000

Threshing	Casuals	50	1,500	75,000
Sorting	Casuals	30	1,500	45,000
Guarding	Casuals	1	30,000	30,000
Loading	Kg		3	21,000
Off-loading	Kg		3	21,000
Transport	Kg		30	210,000
ST/3				**447,000**
Total Variable Costs				**1,712,950**
A. Fixed Cost				
Land lease fee	Per Ha/year	1	375,000	375,000
Total Fixed Costs				**375,000**
Total Cost (A+B)				**2,087,950**

Source: Case study, Umucyo Cooperative

The Total Variable Costs as per the above table for 1 ha it is 1,712,950 RWF and the Total Fixed Costs is 375,000 RWF which will give us the Total Cost for 1 Ha of maize to be 2,087,950 RWF.

Table 7. Per hectare cost-return analysis

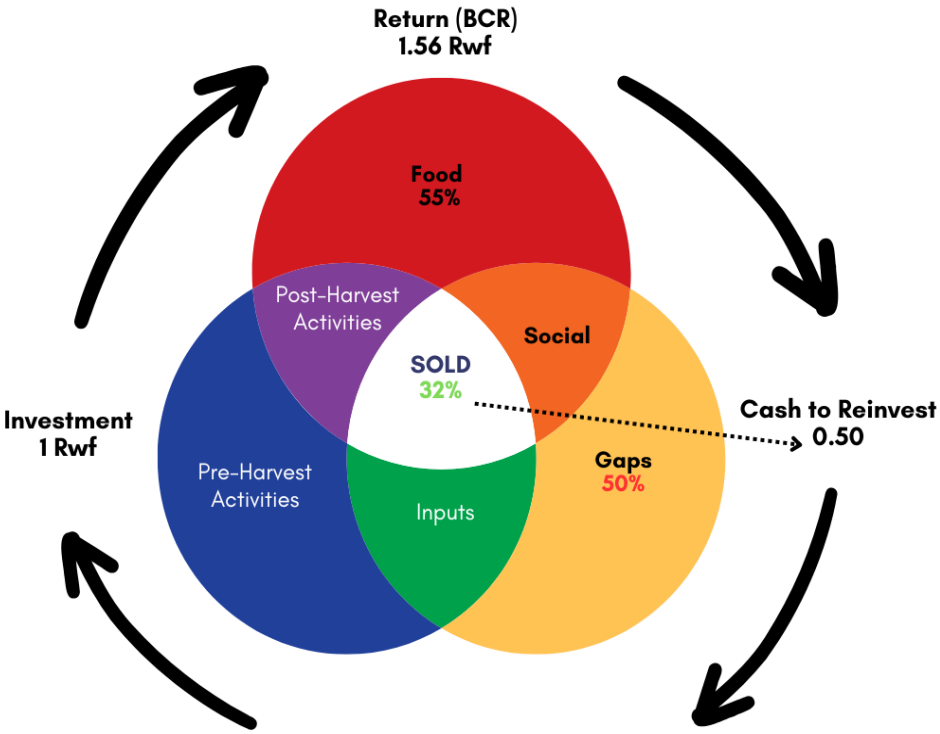
Items	Quantity	Unit Cost (RWF)	Total Cost (RWF)
Total Production (Kg/ha)	6,500		
Price of Maize (RWF/Kg)		500	
Gross Return (RWF/ha)			3,250,000
Total Variable Cost (RWF/ha)			1,712,950
Gross Margin (RWF/ha)			1,537,050
Total Cost (RWF/ha)			2,087,950
Net Return (RWF/ha)			1,162,050
BCR (Total cost basis)			**1.56**
BCR (Variable cost basis)			**1.90**

Source: Case study, Umucyo Cooperative

3.3.3 Benefit–Cost Ratio (Undiscounted)

The Benefit–Cost Ratio (BCR) is a relative measure used to compare benefits per unit of cost. With a BCR of 1.56, it signifies that for every 1 Franc invested in maize production, a return of 1.56 Francs is generated, indicating the profitability of the maize production sector. However, according to statistics by the NISR (2023) which says that maize smallholder farmers sell only 32.2% of their production and there is no monetary equivalence attributed to a big portion of the maize production 67.8%, how can we interpret this situation?

Figure 4: Maize Utilization & Production Cycle



Source: Illustration by the author from NISR data, SAS, Season A, 2023

V. Discussion

Maize production in Rwanda remains profitable, as evidenced by our cost-benefit analysis. The analysis revealed a favorable Benefit-Cost Ratio (BCR) of 1.56, meaning that for every 1 franc invested in maize production, 1.56 francs are generated in return. However, it is important to note that farmers are currently able to sell only 32.2% of their maize produce, receiving cash equivalent to this percentage of their total production. This results in a practical cash value of 0.50 units out of the 1.56 units generated by a 1-unit investment in maize production. This limited cash return may serve as the basis for their decision to invest in maize production in the upcoming season.

If the cashed portion of maize production covers only 50% of the upcoming production costs, the farmer will inevitably face a 50% shortfall. This creates a challenge for sustaining consistent investments in the next farming season, maintaining the same land size, and applying equivalent inputs. This predicament raises concerns about how small-scale farmers can remain active and reliable in the maize production sector.

The issue is elucidated by an unyielding vicious cycle, wherein smallholder farmers rely on external support for inputs such as seeds, fertilizers, and pesticides each season. This assistance often comes in the form of loans from cooperatives or agro dealers, with repayment scheduled at harvest. Alternatively, farmers may access subsidized inputs through government-supported schemes. The dependency on these external resources becomes crucial for sustaining agricultural operations and poses a significant challenge to the financial stability of small farmers.

The non-monetized portion of maize production accounts for 67.8% of the total output that goes unaccounted for. When assessed in terms of production versus investment, measured in units of francs, this corresponds to 67.8% of the 1.56 francs (BCR) generated by a 1-franc investment. Essentially, this implies that 1.07 units are not considered when evaluating the returns on a 1-unit franc investment in maize production. In simpler terms, 1.07 units out of the 1.56 units generated by a 1-unit franc investment in maize production can be viewed as maize losses or concealed losses at the farmgate.

In 2011, Stone et al indicated that the maize industry in Rwanda was characterized by smallholder farmers and substantial volumes of informal trade. That the country had roughly 300,000 households growing maize, and the average farm size is 0.6 hectares. In the same line of analysis, the International Growth Center said that the Government data provided explicit estimates of the size of the informal export market—between 57-69% of the export value of maize from 2012-15, and between 45-90% of the value of maize flour in the same period. However, stakeholders reported the volume of informal trade was still underreported (IGC, 2016).

VI. Conclusion and Policy Recommendations

Maize remains a vital crop for both food production and income generation among smallholder farmers in Rwanda. The existing challenges related to the costs of maize production, including the use of fragmented small lands and associated management practices

that facilitate underreporting of production, are likely to persist. According to the World Bank, land fragmentation has continued unabated in most African countries, and the corresponding decrease in farm size has been accompanied by declining soil fertility (WB,2011). These factors are currently accepted established problematic realities to be dealt with decisively by policy makers, particularly because they favor the informal maize trade at the farmgate and dealing with them will require strong, particular and specific policies.

Despite government efforts and investments in maize production, there is a pressing need for systematic and radical changes to disrupt the existing status quo in post-harvest production management and statistical reporting. The officially declared small portion of 32.8% of maize production that is sold contrasts significantly with the substantial 67.8% of maize production, out of which 55% is used for food consumption. As discussed earlier in this paper, developed regions such as the USA, Asia, and Europe, characterized by advanced agricultural technology and high yields, allocate a considerably lower percentage of maize production for food. Specifically, the USA allocates 7.5%, Asia allocates 11.6%, and Europe allocates 5.6% for food purposes, reflecting the impact of technology in maize production and farmer behavior, among other factors.

Here are key recommended actions to bring about the envisioned radical changes in maize production and post-harvest management:

- **Facilitating Land Consolidation for Enhanced Maize Production:** Monitor the implementation and do the review, if necessary, of programs such Crop Intensification Programs (CIP) that promote the consolidation of small land holdings to mitigate fragmentation challenges. The continued land consolidation will facilitate the adoption of modern and efficient farming techniques, including the reclamation of new land dedicated to maize farming. Emphasize the adoption of high-yielding maize seed varieties and promote the judicious application of fertilizers and manure to optimize maize production and productivity.

- **Community Action Partnership Food Baking Policies and Programmes with focus on Maize Supply Chain:** There is a need to develop a community action partnership driven maize food banking that acts as a clearing house for maize, where millions of harvested maize are received from all maize supply chain actors, the community action partnership driven maize food banking require a collaboration with the Ministry of Agriculture and agribusiness agencies who also process maize into cereals and canned fresh maize. In addition, the maize food banking should be established to collaborate with other network of maize retailers such that any salvaged maize meals are shared with a number of registered NGOs who will assist in allocating cooked maize meals to school feeding meals and other most vulnerable populations.

- **Skills development for small holder farmers:** Conduct training programs to educate farmers about efficient maize production and post-harvest management practices, emphasizing sustainable and high-yield farming methods and adoption of advanced agricultural technologies among farmers to increase productivity, streamline processes, and minimize post-harvest losses and reduce cost of production for maize.

- **Strengthen Post-Harvest Infrastructure:** Invest not only in the development of robust post-harvest infrastructure, including storage facilities and transportation networks, but also in small machineries and technologies that can be used at household level by small holder farmers to minimize losses and ensure the efficient management of maize produce.

- **Enhancing Maize Production Commercialization:** Currently, a significant number of smallholder farmers engage primarily in subsistence farming, resulting in approximately 55% of their production being utilized for personal consumption, while only 32.8% is allocated for sale. To address this issue, there is a need for a comprehensive capacity-building initiative aimed at fostering a shift in mindset among smallholder farmers. The program should encourage them to transition from subsistence farming to a more entrepreneurial and commercially oriented approach to maize production.

Promoting Research and Innovation in Maize Cultivation: Given the significant potential of maize, it is imperative to allocate resources to research and innovation. This involves exploring new varieties, resilient farming techniques, and technologies that can enhance yields and sustainability. Institutions of higher learning and research should prioritize maize-related studies and advancements, contributing to the overall improvement of the crop's productivity and resilience

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AUTHORS

First Author – Dr. Emmanuel NZEYIMANA, PhD in Development Studies, Jomo Kenyatta University of Agriculture and Technology, Kigali, Rwanda, Phone: +250 788384114. , E-Mail: emmavld@yahoo.fr and emmavlady@gmail.com,
Second Author – Gbadebo Odularu, PhD, The President, No Hunger Food Bank, Nigeria; The President, African Finance and Economic Association, Washington DC, US. Research and Practice Specialist, Agri-food, Trade and Digitalization Programme, Socio-Economic Research Applications & Projects (SERAP LLC), 1720 Wisconsin Ave NW, Washington DC, 20007 - USA., Phone: 1 202 860 3014; E: gbadebo.odularu@nohungerfoodbank.org; gbadebo@serapllc.com