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Risk Assessment: The Impact of Rapid Adoption of Drought-Tolerant Genetically Modified Maize Varieties on Food Security in Kenya

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Risk Assessment: The Impact of Rapid Adoption of Moderate Drought Tolerant Genetically Modified Maize Varieties on Food Security in Kenya

David Kipkosgei Tarus

ABSTRACT

The Rift Valley Region of Kenya experiences persistent drought, severely affecting the livelihoods of millions of smallholder farmers dependent on rainfall for maize cultivation. These recurrent droughts have led to considerable agricultural damage, resulting in reduced crop yields, food shortages, and increased prices. In response, farmers are increasingly interested in adopting new drought-tolerant maize varieties to mitigate yield losses. The Kenyan government, in collaboration with local and international research institutions and seed companies, has introduced maize varieties aimed at alleviating production constraints. Current efforts involve a multifaceted approach, including the development of both conventional and genetically modified (GM) varieties. There is a significant push to commercialize transgenic maize varieties that are both drought-tolerant and resistant to maize stem borers. The commercialization of these GM varieties is supported by a robust biosafety regulatory framework governing their safe use in Kenya.

This study assessed the potential adverse impacts associated with the commercial release and rapid adoption of drought-tolerant GM maize varieties by farmers in Trans Nzoia, Uasin Gishu, Elgeyo Marakwet, and Nandi Counties. Factors examined included the frequency and severity of drought, adoption rates of improved maize seed, farmers'

attitudes towards adopting GM maize varieties based on gender and education, sources of maize for household consumption during drought years, land ownership and designated maize cultivation areas, and the potential substitution of inherently drought-resistant crops like sorghum and millet with GM maize varieties. Data analysis was conducted using SPSS software version 28.0 and Windows 11 release.

The findings revealed that farmers across all counties are experiencing recurring droughts with varying frequency and severity. A significant proportion of farmers currently use enhanced hybrid maize seeds and show a strong positive attitude and readiness to adopt GM drought-tolerant maize varieties if available in the market. Additionally, the study found that the inclination to adopt GM seeds is higher in counties experiencing more frequent and severe droughts. This suggests a high likelihood of swift adoption and substitution of inherently drought-resistant crops with drought-tolerant GM maize if introduced.

The aim of this research was to conduct a comprehensive risk assessment of the potential impact of introducing moderately drought-tolerant maize varieties on food security. The hazard in this context is the occurrence of food shortages, while the exposure factor involves the extent of adoption of these varieties, potentially replacing both inherently drought-resistant crops and conventional maize varieties. Results indicated that over 90% of farmers expressed readiness to adopt GM drought-tolerant varieties, with an adoption rate of 88.8% for replacing inherently drought-tolerant crops. Sorghum and millet occupy only 7.8% of the total land, while maize covers 48.1%. Thus, the risk level is moderately high due to the high hazard level from widespread willingness to adopt the drought-tolerant varieties, although the exposure factor remains moderate given the proportion of land occupied by inherently drought-tolerant crops.

The study highlights the persistent challenge of drought in impairing maize production, with farmers progressively embracing improved maize seed varieties known for high yield capacity. This readiness to adopt new varieties transcends demographic boundaries such as gender, educational attainment, farm size, and geographical location. The motivation to adopt drought-tolerant GM maize varieties arises from the significant reduction in crop yields due to drought and other unexplored factors impacting production. Analysis indicates a notable inclination among farmers towards adopting GM varieties, potentially surpassing the use of traditionally drought-resilient crops like sorghum and millet. This preference for drought-tolerant GM maize suggests its perceived capacity to mitigate the adverse effects of drought on crop yields. However, widespread adoption of these varieties could lead to severe grain supply shortages in the event of a severe drought, exacerbating food insecurity. The trend of farmers procuring maize grain from markets during drought years underscores the vulnerability of market-dependent food access systems to disruptions in maize grain supply.

The successful transition to drought-tolerant GM maize depends on sustained severe drought scenarios coinciding with rapid adoption rates, potentially leading to the displacement of traditionally drought-resistant crops in favor of GM maize varieties. This shift could result in monoculture cultivation, increasing susceptibility to pests and diseases specific to the cultivated variety, soil degradation, and reduced biodiversity, posing long-term sustainability challenges for agricultural systems.

Policy interventions promoting diversified agricultural strategies are crucial to mitigate the risks associated with monoculture cultivation of drought-tolerant GM maize. Initiatives focusing on crop diversification, soil conservation, and sustainable agricultural practices could enhance resilience to environmental perturbations while safeguarding food security. While the adoption of drought-tolerant GM maize offers a promising solution to mitigate drought impacts on maize production, careful consideration of associated risks and complementary strategies is imperative to ensure long-term sustainability and resilience of agricultural systems.

The hypothesis posits that the rapid uptake of moderately drought-resistant maize varieties among Kenyan farmers could potentially lead to a food shortage scenario. Farmers' inclination to adopt these varieties, driven by the necessity for resilient crops to mitigate yield losses, highlights the urgency for adaptive agricultural practices in the face of climate variability. The transition towards drought-tolerant maize varieties suggests a strategic shift in cropping patterns, potentially displacing traditionally cultivated crops. This dynamic interplay underscores the complexity of agricultural adaptation strategies, necessitating nuanced evaluation and proactive mitigation measures to formulate sustainable agricultural policies enhancing food security in the face of climate variability.

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LIST OF ACRONYMS

AATF – African Agricultural Technology Foundation

CIMMYT – International Center for Maize and Wheat Improvement

DT – Drought Tolerant

EMC – Elgeiyo Marakwet County

FAO – Food and Agricultural Organization

GM – Genetically Modified

Ha - Hectare

HT – Herbicide Tolerant

IR – Insect Resistant

KALRO – Kenya Agricultural Research Organization

KEPHIS – Kenya Plant Health Inspectorate Services

KSC – Kenya Seed Company

NCPB – National Cereals and Produce Board

NGO – Non-Governmental Organization

NPT – National Performance Trial

T- Tonne

TNC – Trans-Nzoia County

USA – United States of America

VIRCA – Virus Resistant Cassava

WEMA – Water Efficient Maize for Africa

CHAPTER ONE

1.1.0 INTRODUCTION

1.1.1 Background

This study examined the potential impacts of successful introduction of genetically modified (GM) drought tolerant maize varieties in Kenya. As such, the exercise was basically a risk assessment of the outcomes in case of rapid adoption by farmers. To effectively evaluate the potential risks and possible occurrence of unwanted outcomes, the study focused on obtaining information from farmers by use of a structured questionnaire administered randomly in four counties namely, Trans-Nzoia, Uasin Gishu, Nandi and Elgeiyo Marakwet. The information sought included farmers' gender, education level, total size of land owned at least in the last three years, size of land under maize and millet/sorghum in the last three years, quantity of maize hybrid used in the last three years, farmers' knowledge and perception towards genetically modified crops, source of food whenever there is crop failure due to drought and number of drought years within the last ten years. The information obtained in the survey together with existing literature provides the basis for dismissing or accepting the postulated hypothesis for this study.

1.1.2 Problem Statement and Justification

In recent years, Kenya has faced frequent droughts, resulting in severe food shortages and famine across the country. Maize, the primary cereal crop cultivated by most households, is particularly vulnerable to drought due to heavy reliance on rainfed agriculture. Consequently, recurring droughts have exacerbated food shortages, leading to malnutrition and increased poverty among farmers. Maize cultivation is widespread across all agro-ecological zones in Kenya, serving both subsistence and commercial purposes. Given that farmers primarily grow maize for their own consumption, their opinions, preferences, and perceptions will significantly influence the adoption of genetically modified (GM) drought-tolerant (DT) maize varieties. This study aims to investigate two main aspects. Firstly, it will examine the role of the drought-tolerant trait in driving adoption rates among farmers of different scales. Secondly, it will explore farmers' willingness to adopt these varieties, focusing on their attitudes towards the technology, perceived economic and social benefits, and the potential impact on existing maize varieties and other crops. Based on the findings from the initial stage of the project, the study will then assess the immediate consequences on food security resulting from the rapid adoption of GM DT maize. This assessment will consider the extent to which replacing naturally drought-tolerant crops such as sorghum or millet with less drought-tolerant GM DT maize could further compromise food security in the region during periods of drought.

1.1.3 General Objective

To investigate the possibility of occurrence of food shortages in Kenya as a consequence of rapid adoption of genetically modified drought tolerant maize varieties by farmers.

1.1.4. Specific Objectives

1. To establish factors that influence adoption of drought tolerant GM maize, and the willingness to adopt, by administering questionnaires to 368 farmers in four counties in Kenya, namely, Trans-Nzoia, Uasin Gishu, Nandi and Elgeiyo Marakwet.
2. To find out the trends and frequency of occurrence of drought (insufficient rainfall) in the area under study and how this affects maize production in each of the four Counties.
3. To find out the extent to which farmers are willing to replace the innately drought tolerant crops such as sorghum and millet, with drought tolerant genetically modified maize varieties.

1.1.5. Hypothesis

Rapid adoption of genetically drought tolerant maize varieties by farmers will lead to abandonment or replacement of traditionally drought tolerant crops such as sorghum and millet and so create extreme food shortages in Kenya.

1.2.0 LITERATURE REVIEW

1.2.1 Maize production and its significance in Kenya

Maize (Zea mays) is a crucial staple crop in Africa, significantly contributing to the diets of many farming households across the continent. Its importance lies not only in its widespread cultivation but also in its nutritional value, providing essential nutrients such as phosphorus, carbohydrates, iron, calcium, thiamine, niacin, and fats (Brandes, 1992; Adeyemo, 1984).

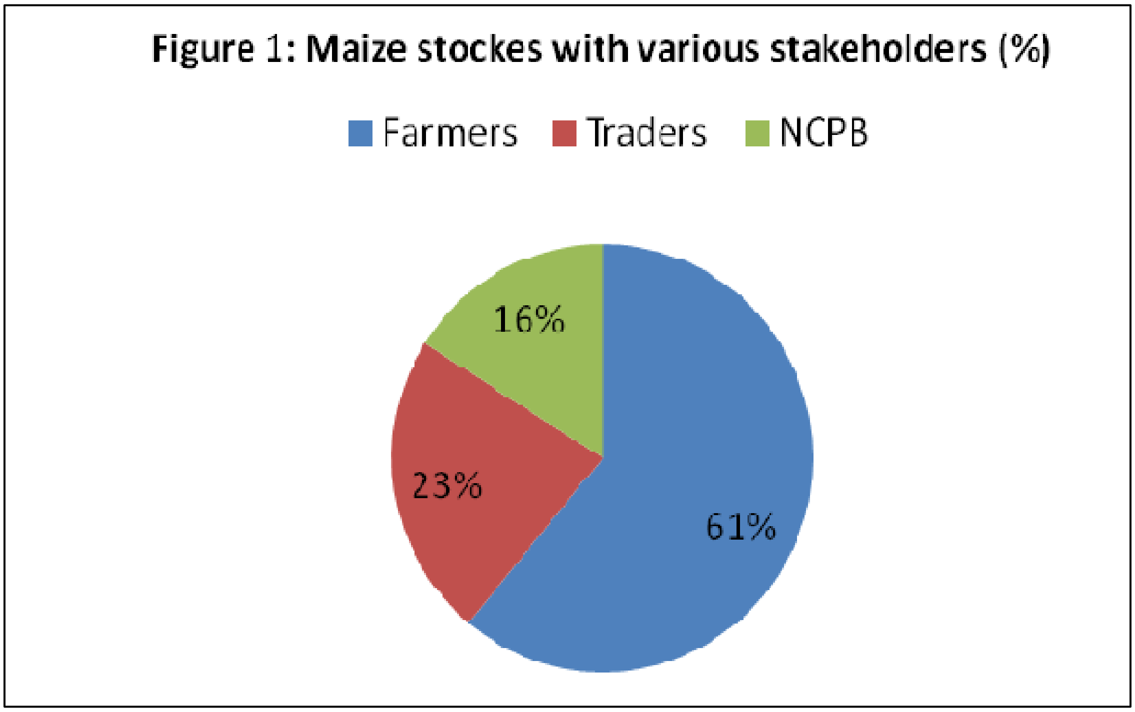
In Sub-Saharan Africa, maize plays a pivotal role in ensuring food security for a significant portion of the population. Food security, defined by the Food and Agriculture Organization (FAO) in 2008, includes the availability, accessibility, and nutritional content of food, as well as the general well-being of consumers (Mboya et al., 2011). In Eastern Africa, maize contributes up to 30% of daily caloric intake, with consumption rates reaching up to 100 kg per capita (Mboya et al., 2011). Particularly in Kenya, maize consumption is notably high, providing approximately 36% of total daily calories and 34% of total daily protein supply (FAO, 2018). Small-scale farmers dominate maize production in Kenya, accounting for over 85% of total production (Central Bank of Kenya, 2023).

Despite its significance, Kenya has experienced recurrent maize deficits over the past decade (KIPPRA, 2023). Efforts to address this challenge involve various stakeholders, including government agencies, private sector entities, non-governmental organizations (NGOs), and farmers themselves. These interventions aim to enhance maize productivity through improved seeds, efficient input utilization, better post-harvest handling practices, irrigation, and access to credit facilities for farmers (Ministry of Agriculture, 2009). However, the impact of these initiatives has been hindered by recurrent droughts, as 98% of maize production in Kenya relies on rainfed agriculture (Benjamin K., at al 2019).

A critical factor exacerbating maize shortages in Kenya is the lack of adequate storage facilities for harvested grain. Many farmers lack proper structures to store their produce, and those who do often face challenges with pest infestation, particularly from weevils, leading to significant post-harvest losses (Kirimi et al., 2011). Consequently, farmers are compelled to sell their maize immediately after harvest, exacerbating shortages and perpetuating food insecurity in their households (Government of Kenya, 1994).

Efforts to address the storage challenge and improve food security in Kenya require a multifaceted approach. This includes investment in storage infrastructure, promotion of better post-harvest management practices, and support for smallholder farmers to access technologies and resources that enhance productivity and resilience to climate variability. Collaboration among government agencies, research institutions, NGOs, and the private sector is essential to implement sustainable solutions that ensure maize availability and food security for all Kenyans. Figure 1 illustrates the distribution of maize holdings among various stakeholders, highlighting the need for coordinated efforts to address storage challenges and enhance food security in Kenya.

Figure 1: Maize stokes with various stakeholders



Source: Ministry of Agriculture, 2022.

The limited maize production among small-scale farmers in Kenya is influenced by various factors, including drought, soil depletion, diseases, pests, and low input utilization. Drought, in particular, is the main environmental stressor causing significant yield reductions in the country. To tackle this issue, scientific interventions have focused on breeding maize varieties with enhanced resilience to drought and other stresses. Research in Kenya is currently exploring genetically modified (GM) maize, targeting three primary traits: Drought Tolerance (DT), Insect Resistance (IR), and Herbicide Tolerance (HT). Progress has been made in developing maize varieties with both DT and IR traits, with several events getting approval for environmental release. This advancement is the result of collaborative efforts involving various organizations such as the Kenya Agricultural and Livestock Research Organization (KALRO), the International

Maize and Wheat Improvement Center (CIMMYT), the African Agricultural Technology Foundation (AATF), and Bayer.

The Biosafety law in Kenya establishes a regulatory framework for evaluating and approving GM crop products, including maize. Pending successful field trials meeting all safety and regulatory requirements, GM maize varieties could potentially receive commercial approval within the next year, by end of 2024.

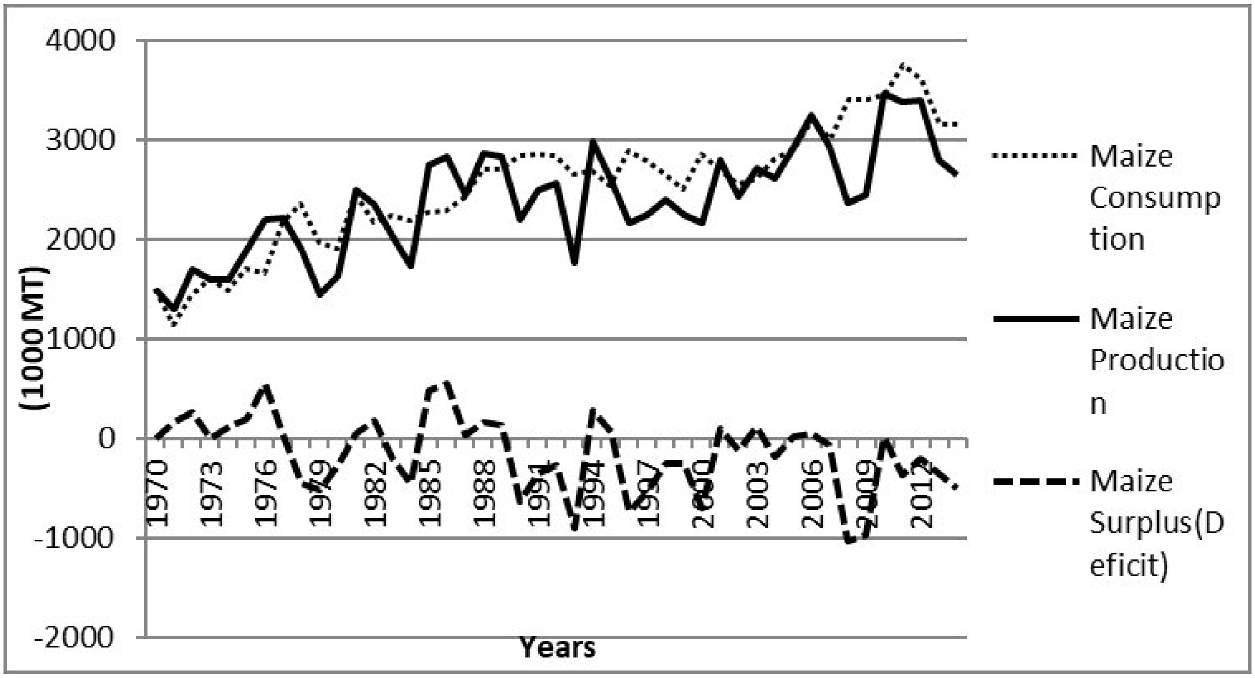
Maize plays a vital role as a staple food in Kenya, particularly white maize varieties, which are preferred for human consumption compared to yellow maize varieties commonly found in North American and European markets (Onyango, 1997). The authorized genetically modified (GM) maize events primarily comprise white varieties, in line with the preferences of Kenyan farmers and consumers alike. Figure 2 illustrates the trends in maize consumption in Kenya from 2001 to 2008, emphasizing the crop's central role in the country's food security and dietary habits. The figure indicates sustained high maize consumption over the years, highlighting the importance of initiatives aimed at improving maize production and resilience to environmental pressures.

The development and adoption of GM maize varieties with enhanced traits represent promising avenues to address the challenges faced by smallholder farmers in Kenya. By incorporating traits such as drought tolerance and insect resistance, these varieties hold potential to increase yields, bolster food security, and improve the livelihoods of farming communities. Nevertheless, it is imperative to conduct thorough risk assessments, enforce regulatory oversight, and facilitate transparent communication to address concerns pertaining to biosafety and environmental impact associated with the introduction of GM maize.

In addition, endeavours to promote sustainable agricultural practices, encompassing soil conservation, integrated pest management, and efficient water utilization, are pivotal for enhancing maize production and resilience amidst climate change and other environmental adversities. Collaboration among researchers, policymakers, farmers, extension services and other stakeholders is essential to facilitate the adoption of innovative technologies and practices that can contribute to the long-term sustainability and resilience of maize farming systems in Kenya.

Addressing the challenges of insufficient maize production among smallholder farmers in Kenya necessitates a multifaceted approach that integrates scientific research, technological innovation, policy support, and stakeholder engagement. By harnessing the potential of genetically modified maize varieties and promoting sustainable agricultural practices, Kenya stands to fortify its food security, enhance farmer livelihoods, and contribute to broader development objectives.

Figure 2: Maize Production and Consumption Trends in Kenya (1970-2014)



Source*:* Republic of Kenya. Economic survey (various issues).

Over the past three decades, maize production in Kenya has decreased relative to consumption, prompting concerns. Various factors have contributed to this trend. Analysis of data dating back to 1970 reveals a consistent unpredictability in production due to drought and unfavorable weather conditions. This corresponds with earlier research suggesting that drought significantly impacts agricultural productivity in Kenya (George K., et al., 2020).

The decline in maize production is primarily driven by the diminishing availability of suitable farmland. This decline can be attributed to land fragmentation, resulting from population growth. As populations expand, the average size of land holdings decreases, limiting farmers' ability to cultivate maize effectively. Consequently, the adoption of advanced agricultural methods like high-yield seeds and mechanized farming is hindered, as these techniques require sufficient land area to be economically viable (Munyua et al., 2015).

Counterfeit agricultural inputs, including seeds and fertilizers, are prevalent in Kenya and exacerbate the challenges faced by maize farmers. These low-quality inputs lead to reduced crop yields and pose threats to soil health and environmental stability. The problem of counterfeit inputs is most acute in regions with high agricultural potential, where farmers could otherwise achieve greater productivity under favorable conditions (Smale & Olwande, 2011). This issue presents a significant barrier to the agricultural sector in Kenya, where maize farming is essential for food security and economic stability. Addressing the prevalence of counterfeit inputs is crucial for enhancing the resilience and sustainability of maize farming in the country. Efforts to tackle this issue should include improved regulation, enhanced monitoring systems, and increased awareness among farmers about the risks associated with counterfeit agricultural inputs. By addressing this challenge, policymakers and stakeholders can support the livelihoods of maize farmers and contribute to the overall development of Kenya's agricultural sector.

In Kenya, maize production is hindered by the reliance on rain-fed agriculture, which exacerbates the impacts of climate change. The increased frequency and severity of droughts, attributed to global warming, pose a threat to agricultural productivity. Unpredictable rainfall patterns further complicate the effective planning of planting and harvesting schedules.

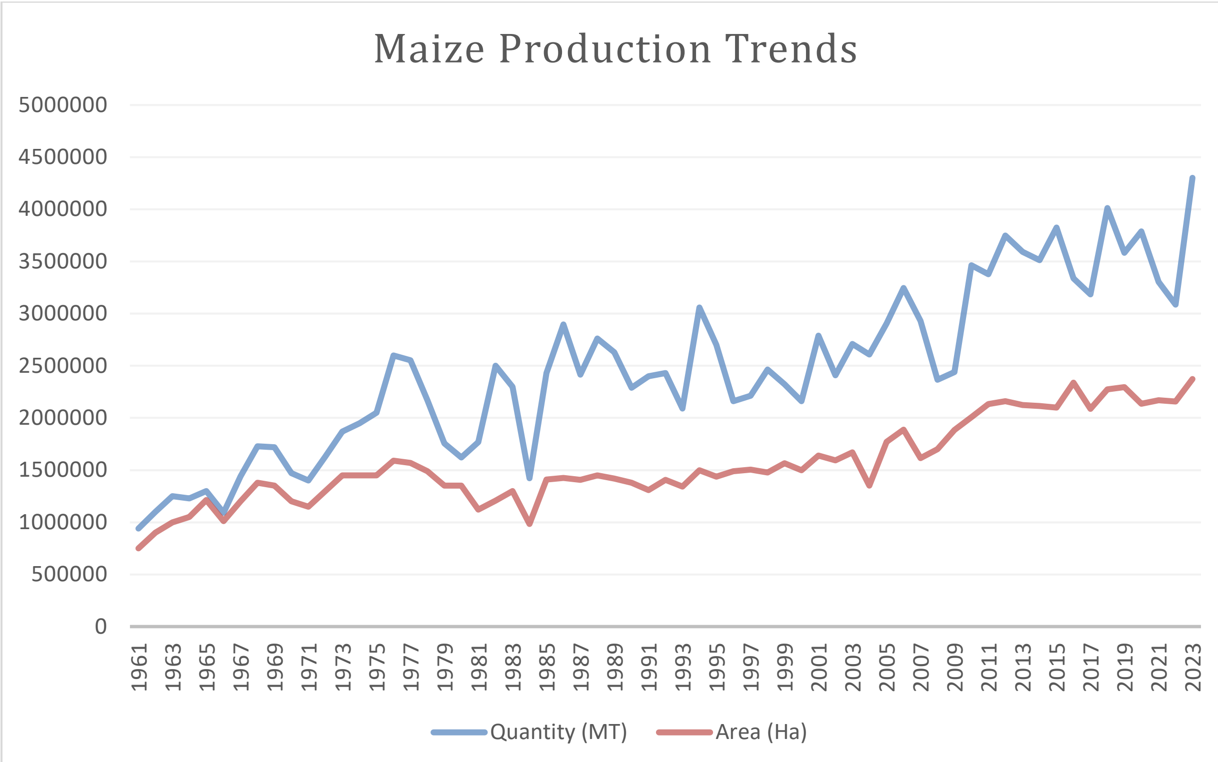
To address the decline in maize production, a comprehensive strategy is necessary. This strategy should address immediate challenges as well as systemic issues. Investment in sustainable land management practices, such as agroforestry and soil conservation, can mitigate land fragmentation and degradation. Similarly, combating the spread of counterfeit agricultural inputs through stricter regulations and enforcement mechanisms is vital to protect farmers' livelihoods and ensure the sustainability of maize production. Furthermore, initiatives aimed at promoting climate-resilient agricultural practices, such as the adoption of drought-tolerant maize varieties and water-efficient irrigation techniques, can help mitigate the impacts of climate change (Kandji, 2006). Investing in agricultural research and extension services to disseminate knowledge about best practices and technological innovations is crucial for enhancing the adaptive capacity of smallholder farmers in Kenya.

The decline in maize productivity in Kenya is a multifaceted issue influenced by a combination of factors, including drought, land fragmentation, counterfeit agricultural inputs, and climate change. Addressing these challenges requires coordinated efforts from government agencies, research institutions, and development partners to implement sustainable solutions that enhance the resilience and productivity of maize farming systems in the country.

1.2.2 Maize production trends in Kenya

Data from the Food and Agriculture Organization (FAO) of the United Nations reveals notable fluctuations in maize yields in Kenya over several decades. From 1961 to 2023, the production increased with increased in acreage with the national average maize yields displayed periodic changes influenced primarily by weather conditions and input utilization in production systems (refer to Figure 3). These fluctuations underscore the variable nature of maize production in the country during this period. Throughout these years, Kenya's maize yields fluctuated, reflecting the interaction between natural factors and agricultural practices. Weather conditions, particularly rainfall patterns, temperature variations, and extreme weather events, significantly influenced maize productivity. Additionally, the management and application of inputs in agricultural production, such as fertilizers, pesticides, and irrigation systems, further contributed to observed yield fluctuations. Understanding and effectively managing these factors are crucial for enhancing maize production stability and ensuring food security in Kenya.

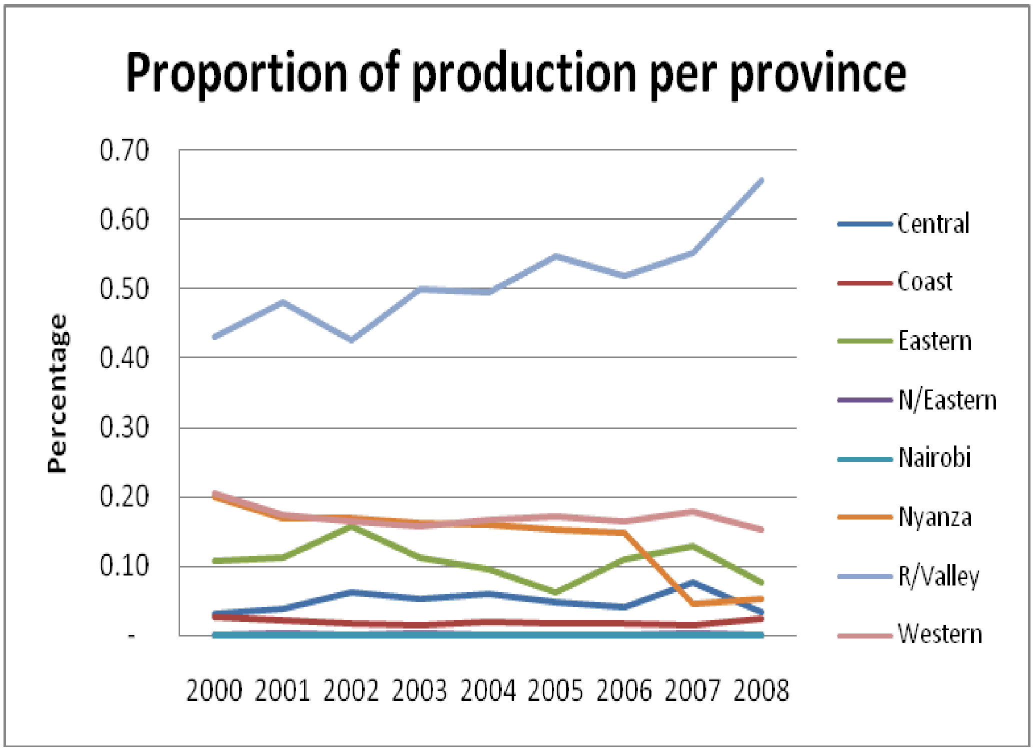
Figure 3: Kenya's maize production and cultivation trend from 1961 to 2023.



Source: FAOSTAT data (https://www.fao.org/faostat/en/#data/QCL)

Statistical analysis reveals that the Rift Valley region in Kenya, encompassing the four surveyed counties, serves as a significant maize supplier to the national market. The data emphasizes the notable role of this geographical area in the country's overall maize production. Specifically, within the Rift Valley, the four identified counties are key contributors to meeting the national maize demand. This region is prominently recognized as a primary maize source, ensuring a consistent supply of the commodity to the broader market, accounting for over 65% of national production (see Figure 4). The agricultural output from these counties not only meets local consumption needs but also serves as a substantial contributor to the national market. These findings underscore the crucial importance of the Rift Valley region in the maize supply chain, confirming its substantial contribution to Kenya's agricultural economy.

Figure 4: Contribution of regions to national production: 2000-2008



Source: Ministry of Agriculture, 2009

1.2.3 Maize production trends in Kenya

Kenya's public maize breeding program, in conjunction with private seed companies, has actively worked on creating hybrids, many of which display varietal traits (Owuor, 2010). Initially, in 1992, only 12 hybrids were grown, all developed and released by KALRO. However, between 2001 and 2006, the number of released varieties surged to over 90 (Nyoro et al., 2006), with contributions from various institutions, both public and private, including KALRO, KSC, Pannar, Pioneer, Lagrotech, Western Seed, Bayer, Agri-Seed, SEEDCO, and others. Data from the Kenya Plant Health Inspectorate Service (KEPHIS) show a significant increase in maize hybrids registered and grown by Kenyan farmers, from 33 in 2003 to 398 in 2022 across all agro-ecological zones (MoA&LD, 2023).

Several comprehensive studies on maize seed adoption by farmers in specific regions of Kenya (Ouma et al., 2002; Salasya et al., 2002; Wekesa et al., 2002) suggest that diverse and sustainable net returns from maize hybrid seeds contribute to successful adoption rates among farmers, who often imitate each other. These studies indicate that maize hybrids not only increase average yields but also decrease yield variability among growers of hybrids, thus protecting small-scale farmers from risks associated with traditional low-yielding varieties (De Groote et al., 2005; De Groote et al., 2006).

Recent analysis by Smale, Olwande, and De Groote (2024) suggests that maize hybrid seed adoption rates have exceeded 80% in high-potential areas of Kenya. This increase is partly due to existing seed-to-grain price ratios and a liberalized seed market. However, despite the growing number of maize seed companies and increased competition, Swanckaert (2024) argues that new entrants have had minimal impact on adoption rates and maize productivity overall.

A survey by Ayieko and Tschirley (2006) revealed that about two-thirds of maize seed grown by farmers in Kenya is purchased from formal sources such as accredited agro-dealers, seed company stores, and the NCPB. Furthermore, after the liberalization of the seed market in Kenya, private sector participation has flourished, resulting in improved seed supply across the country (Wangia et al., 2004). A study in the Trans-Nzoia District by Nambiro et al. (2004) suggested that seed industry liberalization encouraged numerous players to enter the market, leading to increased adoption rates. However, this has also led to the dominance of a single variety, the maize hybrid H614D from KSC, which has holds a staggering 43% market share (Abate et al.2017).

Published articles indicates a significant connection between current research efforts and the adoption of improved maize varieties in Kenya, directly impacting farmers' welfare. Studies, such as the one conducted by Mwabu et al. (2007) and (Bozzola, M. et al. (2021), using a bivariate probit model, found a strong relationship between the uptake of maize hybrid seeds and food availability among smallholder farmers in rural districts of Laikipia and Suba in Kenya. This suggests that farmers who adopt faster benefit from higher yields, ensuring sufficient food for their families and surplus for income.

Kenya's maize breeding program, in collaboration with private seed companies, has greatly increased the availability of maize hybrids, leading to increased adoption rates among farmers. While liberalization of the seed market has facilitated access to improved seeds, it has also led to the dominance of certain varieties. However, ongoing research efforts continue to demonstrate the positive impact of hybrid seed adoption on farmers' welfare, emphasizing the importance of further investment in agricultural innovation and extension services to ensure sustainable food security and economic development in Kenya.

1.2.4 General world perception towards genetically modified Crops

Transgenic crops face resistance in certain regions, notably Africa, Europe, and Japan, despite their widespread acceptance in many developed countries. In the United States, farmers readily adopt genetically modified (GM) crops but encounter marketing challenges due to consumer perceptions (Chern et al., 2002). Global uncertainties regarding transgenic crops arise from concerns raised by consumer groups, non-governmental organizations (NGOs), and environmentalists, encompassing ethical, religious, environmental, and health considerations (Kameri-Mbote et al., 2009). These concerns are compounded by limited consumer choice resulting from insufficient labeling, with a noticeable reluctance among European Union (EU) consumers toward GM products (Verdurme and Viaene, 2002).

Conversely, although Chinese consumers may have limited knowledge of transgenic technologies, they generally hold favorable attitudes toward GM foods and are willing to pay premium prices for products such as rice and soybeans (Li et al., 2002). In the USA, consumers are inclined to accept GM foods when offered significant price discounts (Kaneko and Chern, 2003). Unlike in developed nations, consumers in developing countries exhibit less aversion to GM foods, possibly due to prevalent food shortages (Curtis et al., 2004). The acceptance or rejection of GM foods by consumers is closely associated with their levels of knowledge, with better-informed consumers making more independent decisions (Loader and Henson, 1998). Ultimately, the success of transgenic products hinges on market acceptance and perception (Springer et al., 2002).

However, in Africa, where population growth outpaces food production, outright rejection of GM foods may not be prudent given recurring food shortages. African policymakers are torn between embracing biotechnology to alleviate hunger or maintaining the status quo (De Groote et al., 2004). Most developing countries, particularly in Africa, are yet to declare their stance on GM crops, likely reflecting the positions of developed nations (De Groote et al., 2004).

To empower African farmers and consumers to make informed choices about GM foods, prioritizing information sharing and farmer education on product use and safety is crucial (Pinstrup-Andersen and Schioler, 2002). Objective analysis from scientists is integral to farmers' and consumers' decision-making processes, helping to address controversies surrounding GM crop adoption (De Groote et al., 2003).

1.2.5 Commercialization of Genetically Modified crops

Scientific data collected over a 26-year period following the introduction of the first genetically modified (GM) crop show that by 2023, the global area devoted to GM crops had expanded to 206.26 million hectares, up from 17 million hectares in 1996 (AgbioInvestor (2024). Notably, a substantial portion of this cultivated land is located in the United States, Brazil, Argentina, India, China, Honduras, Mexico, Chile, Pakistan, Australia, Myanmar, Bangladesh, Philippines, Indonesia, Spain, Portugal, Nigeria, Paraguay, Bolivia, Uruguay, Colombia, and Canada AgbioInvestor (2023).

In Africa, the adoption of commercial genetically modified (GM) crops has gained momentum in five countries: South Africa, Sudan, Ethiopia, Kenya, and Nigeria. Among these nations, South Africa stands out as a leader, ranking 7th globally in GM crop cultivation. The country has enthusiastically embraced GM soybean, Bt maize, and cotton varieties. Notably, around 85% of South Africa's maize production utilizes biotechnology, marking a significant shift in agricultural practices (USDA-FAS, 2023). This embrace of GM crops reflects a strategic approach to enhancing agricultural productivity and addressing food security challenges in the region. By leveraging biotechnology, these nations aim to boost yields, mitigate crop losses due to pests and diseases, and reduce the environmental footprint of agriculture. However, the adoption of GM crops also sparks debates regarding potential ecological and socio-economic impacts, underscoring the importance of balanced policymaking and robust regulatory frameworks to ensure safe and responsible deployment. As these countries navigate the complexities of agricultural innovation, their experiences serve as valuable lessons for other regions considering similar biotechnological advancements.

In Kenya, agricultural innovation has ushered in a new era with the introduction of various genetically modified crops. Among these are Bt maize, engineered to resist pests, and drought-tolerant maize, offering resilience in the face of unpredictable weather patterns. Enhanced nutrition cassava, known as Bio-cassava plus, promises improved nutritional content, while Bt cotton provides farmers with insect-resistant varieties, boosting yields. Virus-resistant cassava (VIRCA) and transgenic virus-resistant sweet potato offer protection against debilitating diseases, ensuring more stable harvests. Additionally, late blight resistant potato and bacterial wilt resistant banana address specific challenges faced by farmers, enhancing crop durability and yield reliability. Notably, GMO cotton has already been commercialized, demonstrating tangible benefits for farmers. However, the commercialization of GMO maize is pending due to a legal dispute seeking its prohibition, despite its potential to revolutionize farming practices. This information underscores the evolving landscape of genetically modified crops in Kenya, as highlighted in a study by Kunyanga N., et al. in 2023.

In recent years, efforts to improve maize cultivation in Kenya have surged, driven by collaborative endeavors between the government, public and private seed companies, and local as well as international research institutions (Owuor, 2010). This concerted push has resulted in the introduction of numerous enhanced maize varieties to benefit farmers across the country. Notably, the WEMA project stands out as a prominent initiative in this domain. A partnership between the Kenya Agricultural Research Institute, African Agricultural Technology Foundation, Bayer, and CYMMIT, the project introduced both conventional and genetically modified drought-tolerant maize varieties into Kenya's agricultural landscape.

The WEMA project as registered 59 royalty free hybrid maize varieties which are accessible by farmers in Kenya (MoA&LD, 2023). In 2023, the National Biosafety Authority in Kenya granted environmental release of four events of GMO maize, for commercial cultivation by farmers. The development of genetically modified maize varieties within the country is thus steadily advancing, supported by existing biosafety regulations. However, as these varieties edge closer to potential adoption by farmers, concerns loom among stakeholders regarding the readiness of the Kenyan government and relevant implementing agencies. These concerns center on the capacity of regulatory frameworks to adequately address and mitigate any potential adverse effects on human health, the environment, and the broader ecosystem. Both short-term and long-term ramifications are under scrutiny, reflecting the need for comprehensive risk assessment and management strategies. Despite the promise of enhanced maize varieties to bolster agricultural productivity and resilience in the face of challenges like drought, the imperative to safeguard against unintended consequences remains paramount. As such, ongoing dialogue and collaboration among stakeholders are essential to ensure a balanced approach that prioritizes both innovation and sustainability in Kenya's agricultural sector.

CHAPTER TWO

2.0 PRINCIPLES OF RISK ASSESSMENT

2.1 Risk Assessment of Genetically Modified Crops

Risk refers to carefully considering both how much harm could happen from something bad and how likely it is to happen. This involves a balance between the potential danger and the chance of it happening. It's like figuring out the chances of getting hurt from something going wrong:

Risk = hazard (H) x Exposure (E)

In this context, hazard refers to the concern about how bad the unwanted outcome might be. Exposure, on the other hand, is how likely it is for the hazard to happen. It's like the chance of the problem occurring. This can be measured if we clearly know what the hazard is. In this study, the hazard was the possibility of food shortages because the genetically modified (GM) maize, designed to withstand drought moderately, didn't work well during severe droughts.

GM crop Risk assessment is a careful evaluation of how bad a hazard is and how likely it is to happen if we introduce the crop and many farmers start using it successfully. The problem formulation helps us figure out which risks are important to study and which ones we can ignore. In this survey, the risk is the chance of food shortages in Kenya if farmers start using the moderately drought-tolerant GM maize quickly. They might do this because the GM maize yields more than the regular drought-tolerant maize when grown in similar conditions.

Assessment endpoint is a clear way of saying what's important in the environment and how it can be harmed. For example, if the crops fail, it could lead to widespread and severe food shortages in areas where farmers have quickly started using GM varieties that then fail to grow properly.

As a first step of risk assessment, problem formulation is conducted to:

a) Postulate reasonable risk scenarios that might result in a harmful consequence arising from an activity or use of the GM plant or its processed form.

b) Select relevant assessment endpoints based on Kenya’s policy and protection objective

c) Determine what data is required to assess the risks

In the second step, the risk is determined by analyzing the collected data for a hypothetical risk scenario (Johnson et al., 2007). The third and final step involves making a recommendation on whether this hypothesized risk scenario is likely to happen or not. This recommendation is based on the study's findings, assuming the successful introduction and adoption of drought-tolerant GM maize in Kenya.

This study focuses on identifying potential negative outcomes (hazards) to guide risk assessment. It considers the possible scenarios in which these hazards might occur. The concerns about releasing GM maize are influenced by these identified hazards and the likelihood of their occurrence. This is done through a scoping assessment, which involves a field survey of 372 maize-growing farmers in four counties of Kenya.

The hypothesized risk scenario describes a problem that starts with the release of GM maize varieties. It assumes that if these varieties are successfully introduced and adopted by many farmers, but fail to perform as expected, there could be widespread crop loss and severe food shortages.

Recommendations are made based on the data analysis. If the analysis suggests that introducing GM maize varieties could lead to unacceptable socioeconomic changes, mitigation strategies will be suggested. Mitigation measures will be considered if the results indicate frequent drought occurrence in the surveyed counties, which could significantly affect maize yield and lead to perpetual food shortages. However, there is perceived value in introducing drought-tolerant GM maize varieties despite this risk.

The focus of this study is on the potential consequences of GM maize failure on food security. It considers the scenario where the successful introduction and adoption of GM maize leads to widespread crop failure and significant food shortages in the market.

2.2 Risk Determination

Risk determination in assessing the impact of rapidly adopting drought-tolerant genetically modified (GM) maize on food security in Kenya involves a comprehensive approach considering socioeconomic and environmental factors is essential to ensure sustainable food security improvements.

2.2.1. Risk Scenario

In the risk scenario described in this study, the potential for severe food shortages arises from the possibility of GM maize varieties failing under harsh drought conditions. These varieties have been introduced and adopted by farmers, leading to an increase in maize cultivation and a decline in traditional drought-resistant crops like sorghum, millet, and sweet potatoes. The extent of this hazard depends on farmers' willingness and ability to adopt these new drought-tolerant GM maize varieties.

Analysis of maize cultivation trends compared to other crops such as sorghum, millet, and sweet potatoes provides insights into the potential outcomes following the introduction of GM maize. It is observed that farmers in Kenya predominantly cultivate maize over other crops. Additionally, the adoption of improved hybrid maize seeds has been successful, with farmers showing a favourable attitude towards adopting new varieties, even if they are conventional ones.

Risk scenario	Assessment endpoint	Exposure	Hazard	Ranking
The widespread acceptance of genetically modified maize hybrids resilient to moderate drought in Kenya will likely prompt farmers to expand maize cultivation while	Severe food shortages in Kenya	High	High	Moderate

disregarding their traditional drought-resistant crops like sorghum and millet. This shift could exacerbate food scarcity during severe droughts, when crop failure is almost total.				

Table 1: Risk scenario

2.2.2 Hazard identification

Maize farming in Kenya faces several challenges that affect its productivity. These include drought, pests, diseases, difficulty accessing farming supplies, and a lack of information (De Groote, 2002). Water scarcity, especially during droughts, is a significant problem limiting maize production (Owuor, 2010). Depending solely on rainfed agriculture exposes farmers to unpredictable weather, leading to lower yields, food shortages, and financial losses (Ministry of Agriculture, 2005). To improve maize production, African farmers need to adopt new technologies such as drought-resistant maize varieties and reliable irrigation systems (Onyango, 1997). However, accurately assessing the impact of drought is becoming more complicated due to climate change, which is altering traditional weather patterns (Loomis, 1997; White & Elings, 1997).

The adoption of new agricultural technologies varies depending on factors like location, time period, target audience, and the type of product. In Kenya, the diffusion of maize hybrids has been rapid since the introduction of the first hybrid in the 1970s, outpacing the adoption rates seen in the U.S. Corn Belt during the 1930s-1940s (Gerhart, 1975; Karanja, 1996; Smale & Jayne, 2010). Currently, about 80% of maize farmers in Kenya use hybrid seeds, marking Kenya's maize hybrid adoption as a global success story (Byerlee and Eicher 1997; Smale & Jayne, 2010). Notably, Kenya's first hybrid maize H611, introduced in 1963, spread faster among Kenyan farmers than similar hybrids did in the U.S.A Corn Belt during the 1930s-1940s (Gerhart, 1975; Lynam & Hassan 1998; De Groote et al. 2005).

Maize production in Kenya is struggling to keep pace with the increasing demand driven by population growth (Ministry of Agriculture, 2005). This challenge is exacerbated by land fragmentation, reduced land available for maize farming, and recurrent droughts due to global warming (Kirimi et al., 2011). Although maize production has expanded into marginal areas, productivity remains low due to Kenya's variable weather conditions, with drought being a significant limiting factor. Consequently, the adoption of drought-resistant maize varieties is on the rise (Karanja, 1996).

The adoption of hybrid maize seeds in Kenya has increased steadily over the past few decades, with farmers saving minimal amounts of hybrid seeds from each harvest for the next season (Morris et al., 1999; Smale & Olwande, 2011). However, the extent of hybrid seed use fluctuates from season to season, influenced by factors like the availability of free seeds from government and NGOs, as well as access to credit (Suri, 2006). The Rift Valley Province of Kenya has the highest proportion of maize hybrid adoption. Surveys indicate that between 1990 and 2006, approximately 62% to 68% of maize area was planted with hybrids nationally (Langyintuo et al., 2010; Hassan et al., 2001; Lopez-Pereira and Morris 1994). In specific regions, adoption rates varied, with high potential areas reaching adoption rates of up to 80% and lower midland areas around 40% (De Groote et al., 2005).

Recent research suggests that adoption rates have remained stable between 60-80% across most of Kenya, with little variation between regions (Langyintuo et al., 2010; Hassan et al., 2001; Lopez-Pereira and Morris, 1994). Improved seed use has become popular among maize farmers, with adoption rates ranging from nearly 70% to 100% in different regions, depending on their climatic conditions (De Groote et al., 2005). In high potential areas where adoption rates exceed 70%, farmers often grow multiple hybrids in a single season, gradually replacing older varieties with newer, more effective ones (Hassan, 1998). However, older hybrid varieties can remain popular if they demonstrate superior performance, such as the maize hybrid H614D, which has maintained its popularity among Kenyan farmers more than 26 years after its release.

2.2.3 Exposure Characterization

In the analysis conducted in section 2.2.2, it is apparent that maize farmers in Kenya have a long-standing practice of embracing new and improved maize varieties. Therefore, the introduction of new genetically modified (GM) maize varieties, specifically those tolerant to drought, may follow a similar pattern. If these new varieties are adopted as swiftly as the Hybrid H614, there is a risk that farmers may assume they can withstand severe drought conditions, when in reality, they may only offer moderate drought tolerance, approximately 20-35% more effective than existing conventional varieties (Africa Agricultural Technology Foundation, 2011). Consequently, prolonged periods of severe drought could lead to significant maize shortages in the market, exacerbating food insecurity.

In this context, "exposure" refers to farmers' inclination and readiness to adopt new improved maize seeds available in the market, while "hazard" encompasses their potential and capacity to rapidly adopt to the extent of expanding the cultivation of the new variety and possibly abandoning other crops that are traditionally drought-resistant. This inclination may be driven by the frequent recurrence of drought in maize-growing regions of Kenya, where farmers rely solely on rainfed agriculture. This reliance often results in diminished maize yields and perpetual crop losses (Onyango, 1997). The introduction of drought-tolerant varieties is likely to incentivize farmers to adopt them quickly as a strategy to mitigate the impact of recurrent droughts, which consistently lead to reduced yields and income losses.

Literature on the effectiveness of the transgenic drought-tolerant maize expected to be introduced in Kenya by 2017 indicates that the tolerance mechanism extends the variety's resilience for a period of two weeks before and after flowering (Africa Agricultural Technology Foundation, 2011). Thus, if drought persists beyond this four-week period encompassing flowering, the efficacy of these varieties may not sufficiently alleviate the effects of drought on the crop. If farmers adopt these varieties rapidly, akin to their adoption of Hybrid maize HD614, under the belief that they can withstand even severe droughts, prolonged drought conditions exceeding the prescribed intervention period could result in substantial losses, posing a threat to food security in the country.

CHAPTER THREE

3.0 SURVEY AREA AND METHODOLOGY

3.1 BACKGROUND INFORMATION OF THE SURVEY COUNTIES

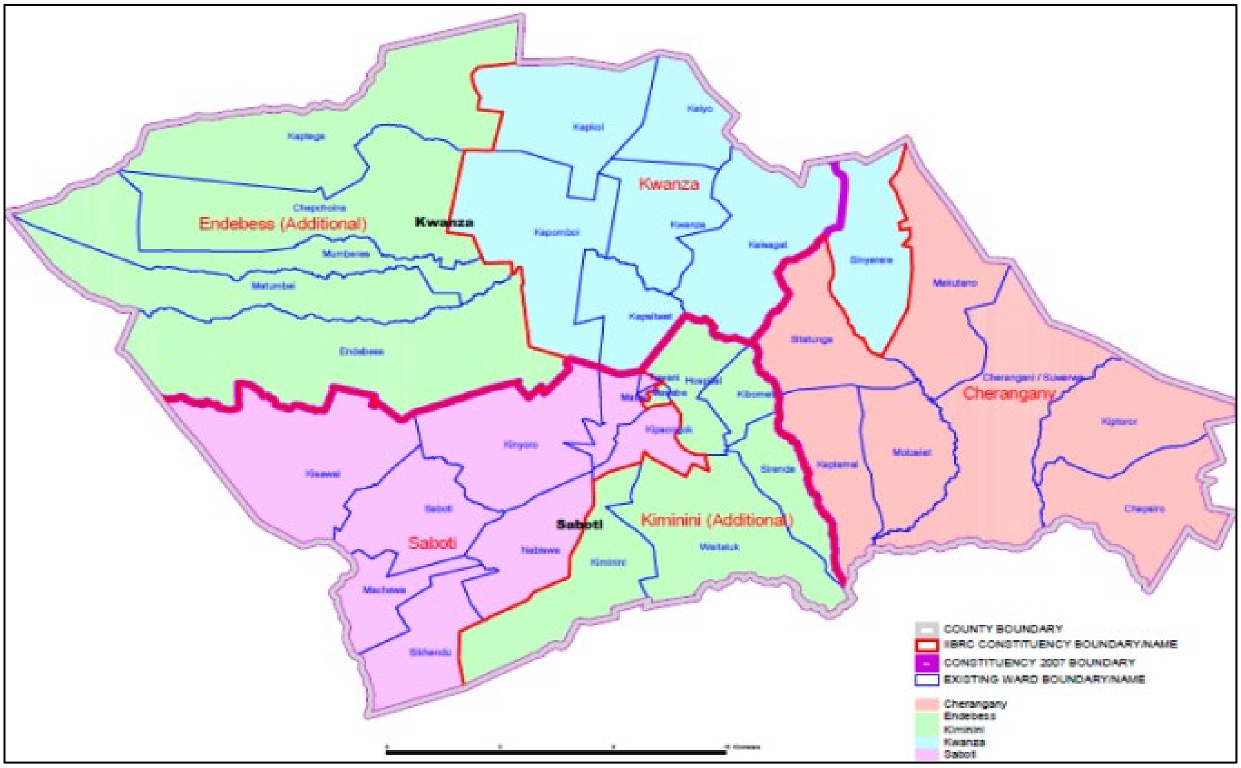
For this study, four counties were specifically chosen: Trans-Nzoia, Uasin Gishu, Elgeyo Marakwet, and Nandi. The selection process was guided by the significance of maize cultivation for food security and the prevalent challenge of drought in the region (Korir, 2011). These counties were identified as major contributors to the maize supply chain within the Kenyan market. Any factor influencing maize production within these regions would consequently have a substantial impact on maize availability, thus affecting the nation's food security status (Onyango, 1997). These selected counties exhibit diverse climatic conditions, ranging from the arid conditions of Elgeyo Marakwet to the comparatively more favourable rainfall patterns observed in Trans-Nzoia County. Despite this diversity, all four Counties are susceptible to drought, albeit with variations in intensity and frequency of occurrence (Onyango, 1997).

The rationale behind the county selection process lies in their collective representation of Kenya's maize production landscape, encompassing both the challenges posed by climate variability and the crucial role maize plays in sustaining food security. By examining these counties, researchers aim to gain insights into the broader dynamics of maize cultivation, resilience to climatic stressors, and implications for national food security strategies. It is within this context that the study aims to elucidate the intricate interplay between climatic conditions, agricultural practices, and food security outcomes, with a particular focus on maize production in these key regions. Through a systematic analysis of these factors, the study seeks to contribute to a more nuanced understanding of the challenges and opportunities inherent in sustaining maize-based food systems amidst climatic variability.

3.1.1 Trans-Nzoia County

Trans-Nzoia County, situated within the Rift Valley Province of Kenya, shares its borders with the Republic of Uganda to the Northwest, and is flanked by several Kenyan counties: West Pokot to the North, Elgeyo Marakwet to the East, Uasin Gishu and Kakamega to the South, and Bungoma to the West and Southwest. With a populace of 990,341 individuals, evenly split between males and females, the county accommodates approximately 170,117 households. Encompassing an estimated area of around 2,495.5 square kilometers, Trans-Nzoia County experiences an average annual rainfall of 11,200 millimeters, while its temperatures vary from an average annual low of 10°C to a mean high of 37°C. Positioned at a latitude of 1° 03' 42" and a longitude of 35° 02' 25" E, the county is geographically defined by its coordinates. The geographical depiction of Trans Nzoia County is illustrated in Figure 5, as documented by Soft Kenya in 2024.

Figure 5: Contribution of regions to national production: 2000-2008

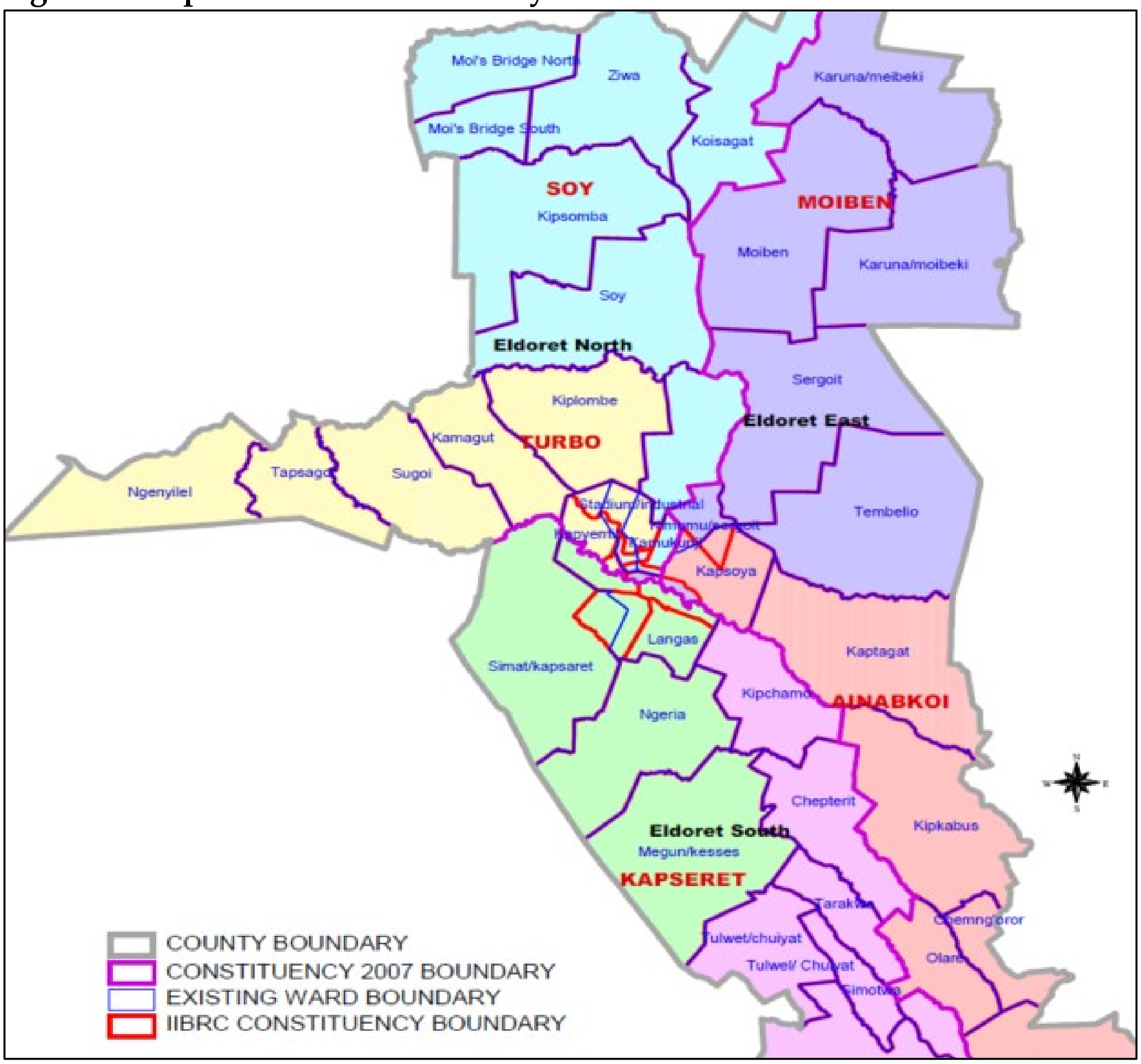


Source: Independent and Electoral Boundaries Commission of Kenya, 2024.

3.1.2. Uasin Gishu County

Uasin Gishu County occupies a longitudinal position of 0° 32' 22" N and a longitude of 35° 19' 11" E. Situated within the mid-western region of the Rift Valley, it shares borders with six neighboring counties: to the North lies Trans-Nzoia, to the East is Elgeyo Marakwet County, to the Southeast is Baringo, to the Southwest is Nandi, and to the West is Bungoma. Encompassing an approximate area of 3,345.2 square kilometers, it is home to a population of around 1.163 million individuals, equally split between genders, with a total of 304,943 households (Kenya Population and Housing Census Report, 2019). The county experiences temperatures ranging from a minimum of 8.4 degrees Celsius to a maximum of 27 degrees Celsius. Its climate is characterized by two distinct rainy seasons, contributing to an average annual rainfall of 900mm to 1,200mm. This information, sourced from Soft Kenya (2024), underscores the geographic and demographic features of Uasin Gishu County. Additionally, a map illustrating the spatial extent of the county is provided in Figure 6 for reference.

Figure 6: Map of Uasin Gishu County

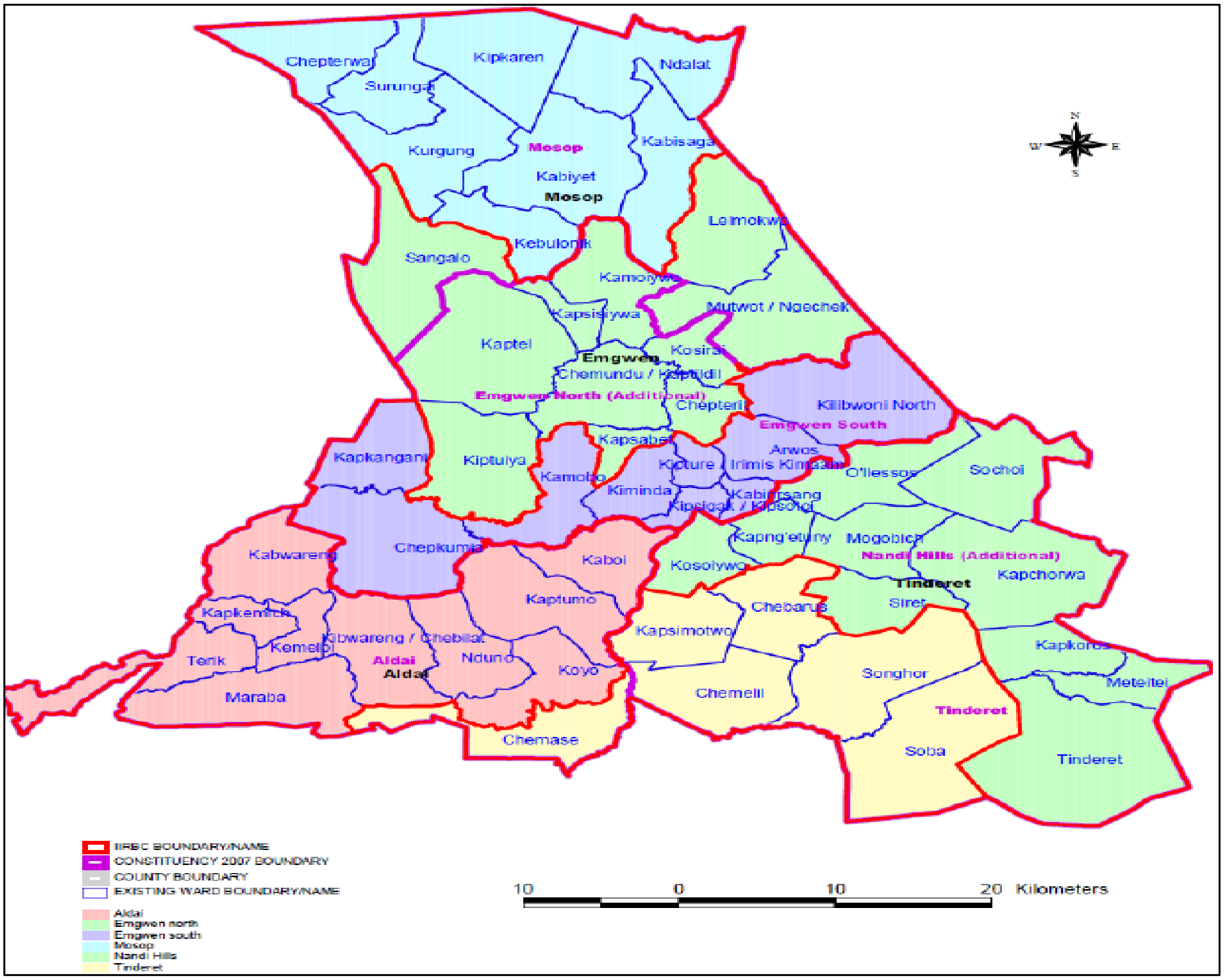


Source: Independent and Electoral Boundaries Commission of Kenya, 2024.

3.1.3 Nandi County

Nandi County, situated within the Rift Valley in Kenya, shares boundaries with several neighboring counties. To its North and East lie Uasin Gishu, while Kericho borders it to the Southeast. Moving further South, it adjoins Kisumu, followed by Vihiga to the Southwest, and Kakamega to the West. According to the 2019 national census, the County has a population of 883,634 with 199,426 households (Kenya Population and Housing Census Report, 2019). The climatic conditions in Nandi County exhibit moderate temperatures throughout the year, with an average annual minimum temperature of 12°C and a mean maximum temperature of 23°C. Precipitation levels vary between 1,200mm and 2,000mm annually. Encompassing an approximate area of 2,884.2 square kilometers, Nandi County is positioned at an altitude of 0° 12' 29" N and a Longitude of 35° 09' 00" E, according to Soft Kenya (2024). The geographic information provided by Soft Kenya (2024) includes a map, depicted as Figure 7, illustrating the spatial layout of Nandi County.

Figure 7: Map of Nandi County

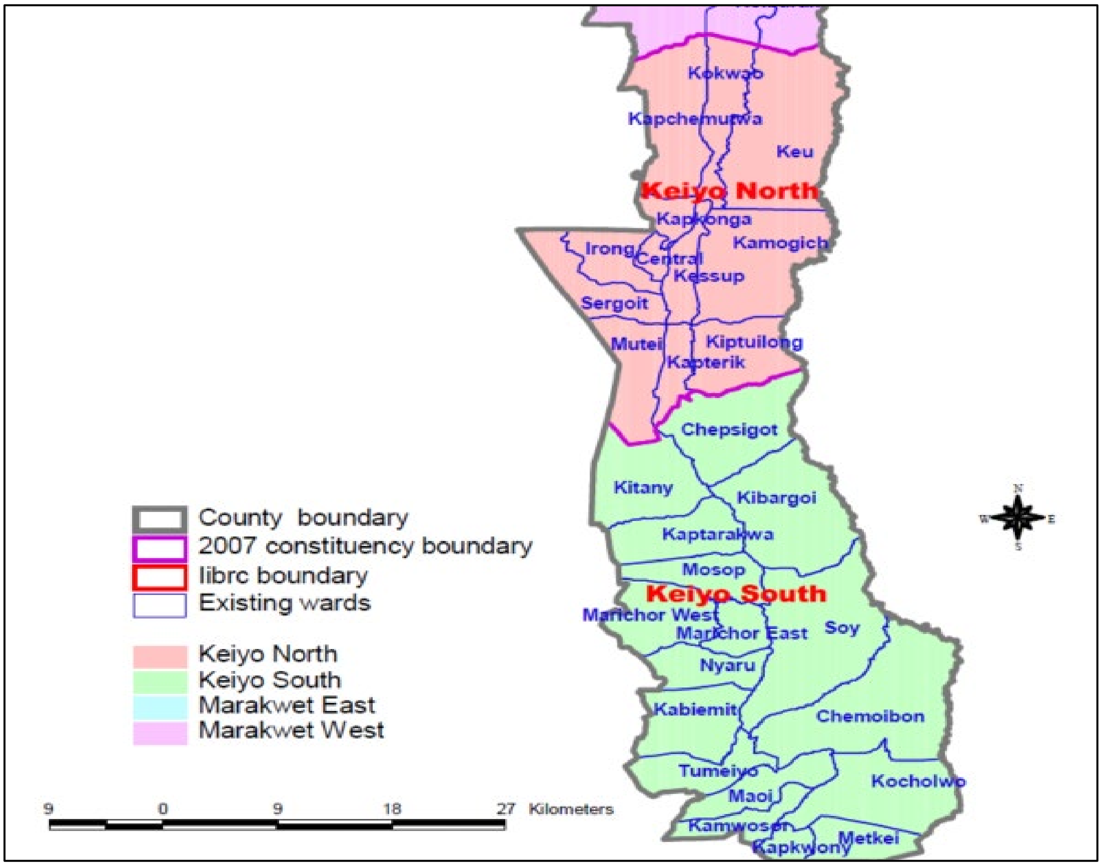


Source: Independent and Electoral Boundaries Commission of Kenya, 2024.

3.1.4. Elgeyo Marakwet County

Elgeyo Marakwet County is located within the Rift Valley region, positioned at a latitude of 1° 04' 15" N and a longitude of 35° 28' 54" E. It shares boundaries with neighboring Counties: West Pokot to the North, Baringo to the East, Southeast, and South, Uasin Gishu to the Southwest and West, and Trans-Nzoia to the Northwest. Encompassing an approximate area of 3,029.8 square kilometers, the county experiences temperatures ranging from 14°C to 24°C. Its annual rainfall varies between 400mm and 1,400mm (Soft Kenya, 2024). The demographic landscape of Elgeyo Marakwet County, as per the 2019 national census, portrays a population of 453,403 individuals distributed across 99,861 households (Kenya Population and Housing Census Report, 2019). A visual representation of the county's geographical layout is depicted in Figure 8 below. These statistical insights provide a foundational understanding of the geographic and demographic characteristics of Elgeyo Marakwet County within the broader context of Kenya's regional landscape.

Figure 8: Map of Elgeiyo Marakwet County



Source: Independent and Electoral Boundaries Commission of Kenya, 2024.

3.2 METHODOLOGY

3.2.1 Sampling and data collection

The study focused on farmers residing in four significant maize-producing regions of Kenya, encompassing Trans-Nzoia, Uasin Gishu, Elgeiyo Marakwet, and Nandi counties. Conducted between August and September 2024, the survey targeted a total of 372 households engaged in maize cultivation. The selection process involved random sampling of farmers within each county. Assistance in identifying suitable respondents was obtained from County Agricultural Officers (CAOs) stationed in the respective regions.

Data collection relied on a semi-structured questionnaire administered to the participating households. This method allowed for systematic gathering of information relevant to the study objectives. By employing a standardized approach, the enumerators aimed to ensure consistency and reliability in the data collected across the four surveyed counties.

Trans-Nzoia, Uasin Gishu, Elgeiyo Marakwet, and Nandi emerged as focal points due to their prominence in maize production within the Kenyan agricultural landscape. The inclusion of these counties provided a comprehensive representation of maize farming practices and challenges prevalent in the region.

3.2.2 Statistical analysis

Ensuring the representative selection of farmers is fundamental for accurately estimating characteristics of an entire population. In this study, four distinct sampling units were scrutinized: (i) Tans Nzoia County, (ii) Elgoiyo Marakwet County, (iii) Nandi County, and (iv) Uasin Gishu County.

Within each sampling unit, an approach was adopted wherein, if the population numbered less than 35 individuals, all identifiable members were either interviewed individually or participated in a Focus Group Discussion. However, when the population size fell below 35, the adequacy for the application of the Central Limit Theorem was compromised.

Conversely, for populations surpassing the threshold of 35, a systematic procedure for sample size determination was employed. The selection of farmers was predicated on a compilation of maize-producing landowners within the aforementioned counties. The target sample size was an estimate with a level of confidence of 95%. For this purpose, the sample size **n** was obtained using the following formula:

$\boldsymbol{n} \geq \frac{Z_{0.95}^{2} P(1-P)}{e^{2}}$ (Equation *1*) (Cochran, 1977; Bartlett II et al., 2001; United Nations, 2005)

Where n = the sample size; z =1.96 (95% confidence level); p = proportion of population; N=total population; e =5% is the margin of error.

This formular applies to large ($N \geq 10{,}000$) and therefore will be used for the selection of the farmers. The maximum sample size is obtained when p=0.5 and equation (1) becomes

$\boldsymbol{n} \geq \frac{1.96^{2} * 0.5 * 0.5}{0.05^{2}}$ (Equation **2**)

$\boldsymbol{n} \geq \mathbf{384.}$

Assuming that the response rate (r) will be 90%, $\boldsymbol{n_{srs}} = \frac{384}{r} = \frac{384}{0.90} = \mathbf{427}$

For the other category of stakeholders with small population size (government extension officials), a correction fraction will be applied to equation (1) to obtain the sample size **n1** as follows:

$\boldsymbol{n1} \geq \frac{Z_{0.95}^{2} P(1-P) * N}{(N-1)e^{2} + Z_{0.95}^{2} P(1-P)}$ (Cochran, 1977; Bartlett II et al., 2001; United Nations, 2005)

$\boldsymbol{n1} \geq \frac{1.96^{2} * 0.5 * 0.5 * N}{(N-1)0.05^{2} + (1.96)^{2} 0.5 * 0.5} = \frac{0.960 * N}{(N-1)0.05^{2} + 0.9604}$

Government extension officials were less than the sample size of 35 and, therefore, individual interviews were carried out. No sampling was required.

The information obtained was analysed using Statistical Package for the Social Sciences (SPSS) software version 28.0 and Windows 11. The farmers' responses were coded in accordance with the questionnaire. This analysis uses the mean and Pearson Co-relation between the different aspects of information obtained from the farmers.

This approach emphasizes that at 0 there is no relationship, above 0 to 0.2, it is a very weak relationship, above 0.2 to 0.4 it is a weak relationship, above 0.4 to 0.6, it is a moderate relationship, above 0.6 to 0.8 it is a strong relationship, and above 0.8 to 1 it is a very strong relationship. Similarly, the negative values imply negative relationship as enumerated above.

The presentation of analysis also used graphs, percentages and pie charts to represent data results.

CHAPTER FOUR

4.0 RESULTS

4.1. Interpretation of data results

The survey was conducted from November 2023 to April 2024 across four counties in the Rift Valley Region of Kenya: Trans-Nzoia, Uasin Gishu, Nandi, and Elgeiyo Marakwet (see Appendix II). These counties are primarily maize-growing regions where agriculture is the main source of livelihood for the majority of farmers. Data collection was facilitated using a predesigned questionnaire (see Appendix I). A total of 368 farmers were randomly sampled, with 92 farmers from each county. Coordination for farmer access was managed by the County Agricultural Office, assisted by divisional agricultural extension officers.

The primary aim of this risk assessment was to evaluate the willingness of farmers to adopt moderately drought-tolerant genetically modified (GM) maize varieties and to investigate the potential consequences of such adoption, including the abandonment of innately drought-tolerant crops like millet and sorghum, which could lead to widespread food shortages in Kenya. Literature review indicates that transgenic maize varieties, particularly those with herbicide tolerance and resistance to maize stalk-borer, have been cultivated in South Africa. In Kenya, three transgenic maize varieties have been approved for commercialization, pending the resolution of an ongoing court case. The potential adoption of these varieties raises concerns about health, environmental, and food security risks.

This study specifically analyzed the likelihood that rapid adoption of transgenic drought-tolerant maize by farmers in the surveyed counties could pose significant food security risks. Statistical analysis was employed to critically evaluate this possibility, and the findings were used to inform risk assessment recommendations. The objective was to provide a thorough understanding of the potential impacts on food security and to guide policy decisions regarding the introduction and management of GM maize varieties in Kenya.

4.2 Total Family Land Size Compared to Size of Land under Maize

Analysis of the collected data revealed that the average landholding of the sampled farmers over the past three years was 5.77 hectares. Concurrently, the average land area allocated to maize cultivation was 2.78 hectares. Consequently, maize crops occupied approximately 48% of the total landholdings. Detailed statistical representations, including mean values and Pearson correlation coefficients, are presented in Tables 2a and 2b, respectively.

	Mean (Ha)	Std. Deviation	N
Average land size in the last 3 years	5.77	11.926	368
Average land under maize in the last 3 years	2.78	7.621	368

Table 2a: Mean of the average land size and that of land size under maize

Table 2b below displays Pearson correlation coefficients between land ownership size and maize cultivation area among sampled farmers from 2020 to 2023.

		Average land size in three years	Average land under maize in three years
Average land size in the last three years	Pearson Correlation	1	.977**
	Sig. (2-tailed)		.000
	N	368	368
Average land under maize in the last three years	Pearson Correlation	.977**	1
	Sig. (2-tailed)	.000	
	N	368	368

Table 2b: P-Correlations of the total land size owned and land size under maize

**. Correlation is significant at the 0.05 level (2-tailed).

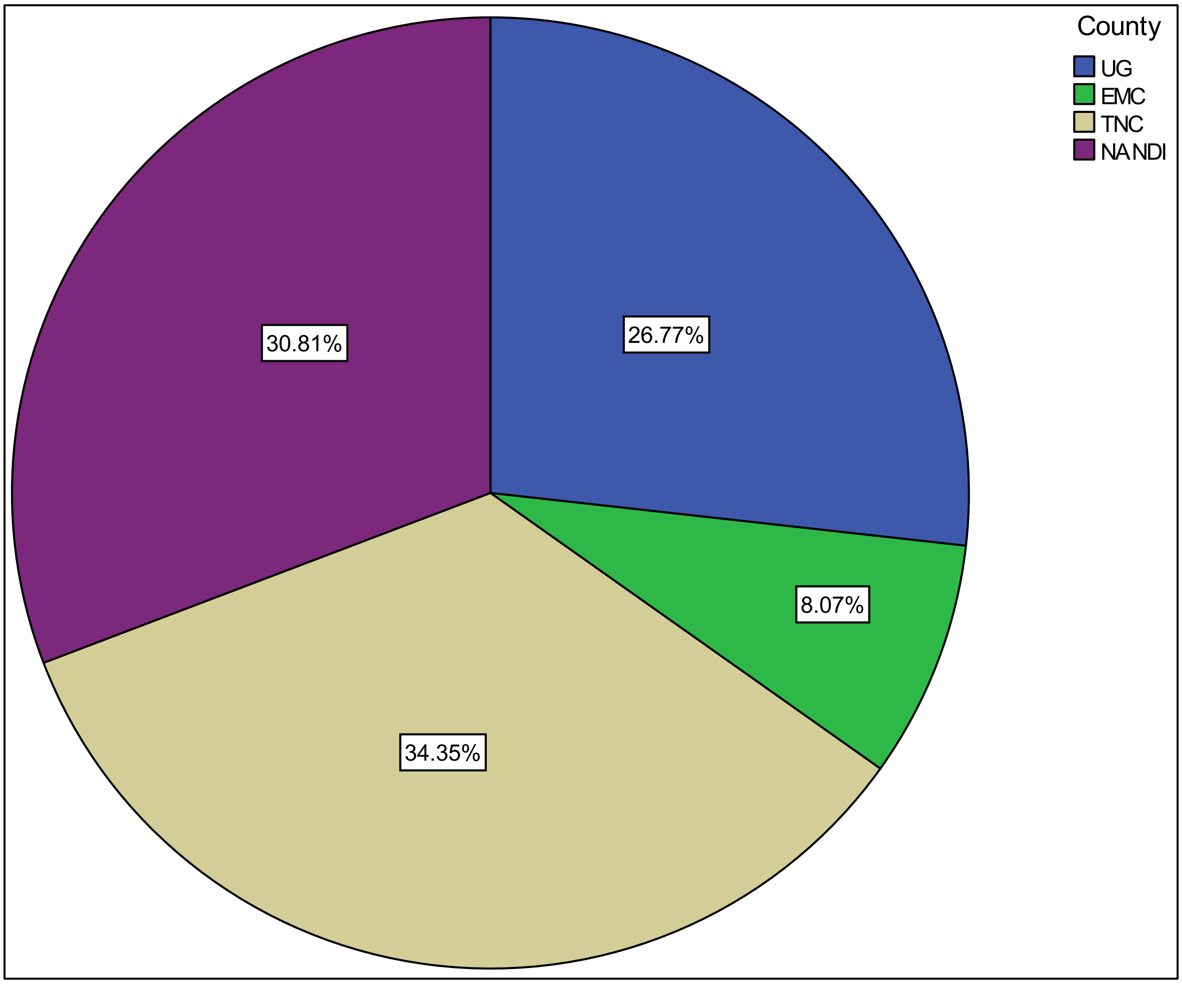
In this study, the Pearson correlation coefficient was calculated to be 0.977, demonstrating a strong positive relationship between the size of land dedicated to maize cultivation and the total land owned by farmers. This high correlation suggests that land holdings were associated with proportionately larger areas allocated to maize production regardless of their sizes. These findings align with the literature review, which indicated that maize production was the preferred agricultural activity among farmers in the sampled counties.

In these regions, maize served as both the primary food source and a crucial cash crop for the majority of households. The analysis further highlighted the critical role of maize production, illustrating that the area devoted to maize was directly influenced by the overall land available to farmers. Consequently, any failure in maize crops would have a profound impact on food security, given its predominance as the main agricultural enterprise among the farmers. These results underscored the vulnerability of the local food system to fluctuations in maize production, emphasizing the importance of ensuring the stability and resilience of maize yields to safeguard both food and economic security in the region.

4.3 Comparison of the total land size under maize in the three counties in relation to the drought years

As illustrated in Figure 9 below, the counties demonstrated substantial variation in land allocated to maize cultivation, despite the consistent sample size of 92 farmers per county. Notably, Trans-Nzoia County (TNC) exhibited the largest proportion of maize acreage, accounting for 34.35% of the total sampled land. This was followed by Nandi County, with 30.81%, and Uasin Gishu County (UG), which comprised 26.77% of the maize acreage. Elgeiyo Marakwet County (EMC) had the smallest portion, representing only 8.07% of the total sampled land. These findings underscore the significant differences in agricultural land use patterns among the counties studied.

Figure 9: Percentage representation of drought years in each of the counties



It was observed that Trans-Nzoia County had the largest total area of land under maize cultivation, correlating with a lower frequency of drought years; specifically, there were only three drought years in the past decade. Conversely, Elgeiyo Marakwet County, which experienced five drought years in the same period, had the smallest area of land under maize cultivation. Table 3 presents the number of drought years each county experienced over the last ten years. This data indicated that counties with fewer drought years had larger areas of maize cultivation. Consequently, the willingness to adopt improved drought-tolerant maize seed was highest in Elgeiyo Marakwet County, as illustrated in Figure 12.

County	Drought years in the last 10 years
Trans Nzoia	3
Uasin Gishu	4
Elgeiyo Marakwet	5
Nandi	3

Table 3: Drought years in each of the four Counties

4.4 Harvest in years with sufficient rainfall compared to those with insufficient rainfall

The analysis of the collected data revealed a recurrent pattern of drought during the primary maize cropping seasons across all four counties under study. However, the severity and frequency of these droughts varied between counties. In particular, Elgeyo Marakwet County experienced the highest recurrence of severe droughts, enduring five such seasons over the past decade, which significantly impacted maize production. Statistical analysis, as presented in Table 4a, demonstrated that the average maize yield during years with adequate rainfall was 4.33 tons per hectare (T/Ha). Conversely, during drought-affected years, the mean yield dropped to 1.69 T/Ha. This data indicates a substantial average reduction of approximately 2.64 T/Ha in maize yield between years with sufficient rainfall and those impacted by drought.

	Mean (Ha)	Std. Deviation	N
Yield in good year (with sufficient rain)	4.33	1.356	368
Maize yield in bad year (with insufficient rain)	1.69	0.688	368

Table 4a: Mean of maize yield in a year with adequate rainfall and that with insufficient rainfall

		Yield in good year (T/Ha)	Maize yield in bad year (T/Ha)
Yield in good year (T/Ha)	Pearson Correlation	1	.682**
	Sig. (2-tailed)		.000
	N	368	368
Maize yield in bad/drought year (T/Ha)	Pearson Correlation	.682**	1
	Sig. (2-tailed)	.000	
	N	368	368

Table 4b: P-Correlations between maize yield in a year with good rainfall and that with poor rainfall

**. Correlation is significant at the 0.05 level (2-tailed).

In the correlation data presented in Table 4b, the P-value was 0.682, indicating a significant relationship between drought and the amount of maize harvested per hectare. This correlation suggested that maize yields were higher during years with sufficient rainfall and lower during drought years, demonstrating a direct impact of drought on maize yield across all counties. Tables 4c and 4d provided the average yields for years with sufficient and insufficient rainfall in Elgeiyo Marakwet and Trans-Nzoia Counties, respectively. The data revealed substantial differences in maize harvest quantities between these two counties. In Trans-Nzoia County, the maize yield during a year with adequate rainfall was 4.93 T/Ha, whereas in Elgeiyo Marakwet, it was 2.89 T/Ha. This represented a 58.6% difference, underscoring the significant variability in maize production based on rainfall availability and highlighting the critical role of sufficient rainfall in achieving optimal maize yields. These findings corroborate the hypothesis that drought conditions adversely affect maize yields, and the extent of this impact can vary significantly between different regions.

	Mean (T/Ha)	Std. Deviation	N
Maize average yield in years with sufficient rainfall	2.89	1.0774	92
Maize average yield in in years with insufficient rainfall	0.92	0.735	92

Table 4c: Mean of maize harvest in years with sufficient and insufficient rainfall in Elgeiyo Marakwet County.

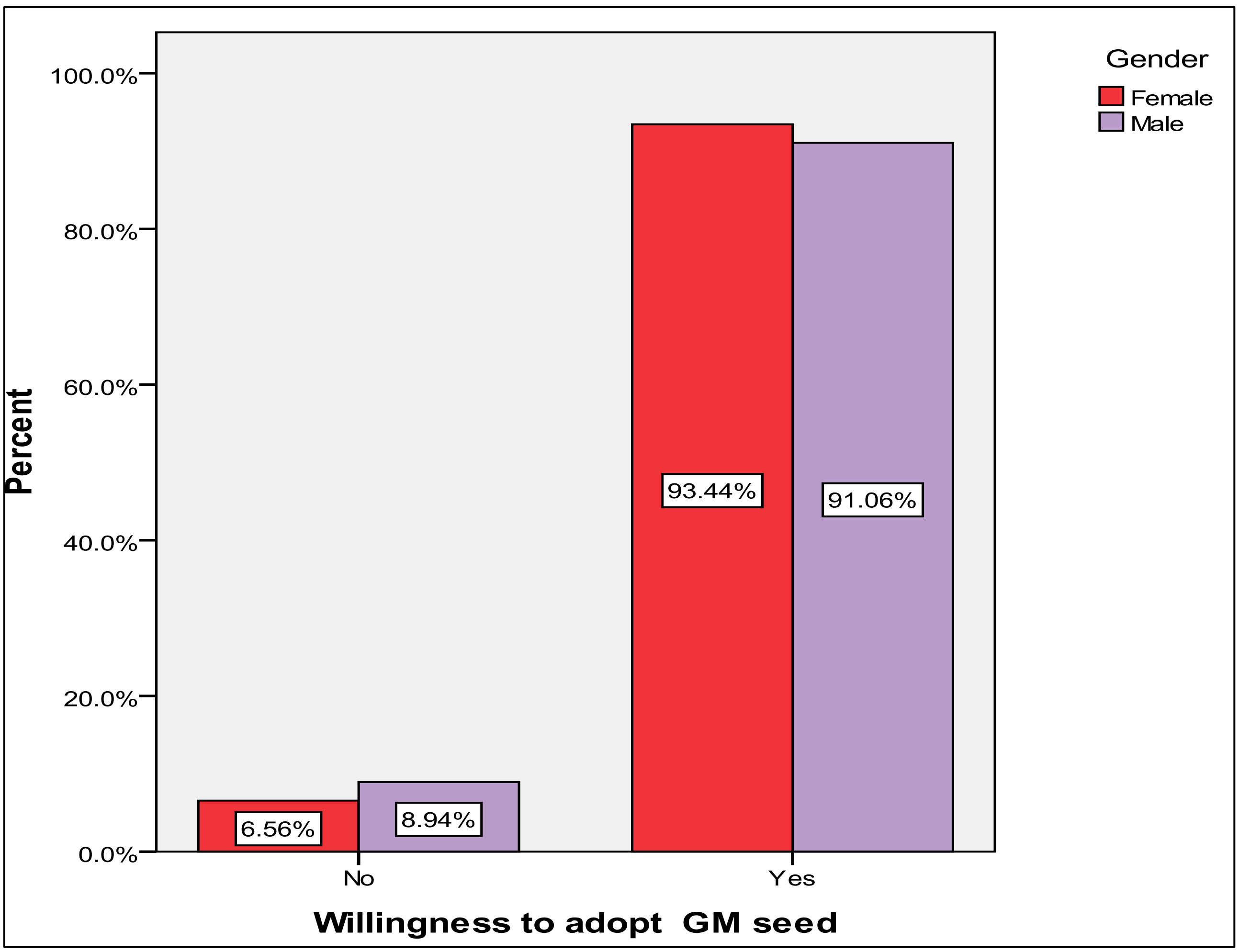
	Mean (T/Ha)	Std. Deviation	N
Maize average yield in years with sufficient rainfall	4.93	2.26	92
Maize average yield in in years with insufficient rainfall	1.83	0.887	92

Table 4d: Mean of maize harvest in years with sufficient and insufficient rainfall in Trans Nzoia County.

4.5 Perception of farmers on GM crop adoption in relation to gender and education levels

Among the farmers sampled, the majority expressed willingness to adopt genetically modified (GM) crops, provided these new crops demonstrated superior yields compared to their current cultivars. A detailed analysis revealed that 93.44% of female farmers had a positive perception of GM crops, compared to 91.06% of male farmers who shared this perception. Conversely, a small fraction of the sample population exhibited negative perceptions towards GM crop adoption. As illustrated in Figure 10, only 6.5% of female farmers and 8.94% of male farmers did not favour the adoption of genetically modified crops. These findings suggest a generally favourable attitude towards GM crops among the surveyed farmers, with a slightly higher acceptance rate among female farmers. The data underscore the importance of perceived yield benefits in influencing farmers' attitudes towards agricultural innovations.

Figure 10: Percentage representation of drought years in each of the counties



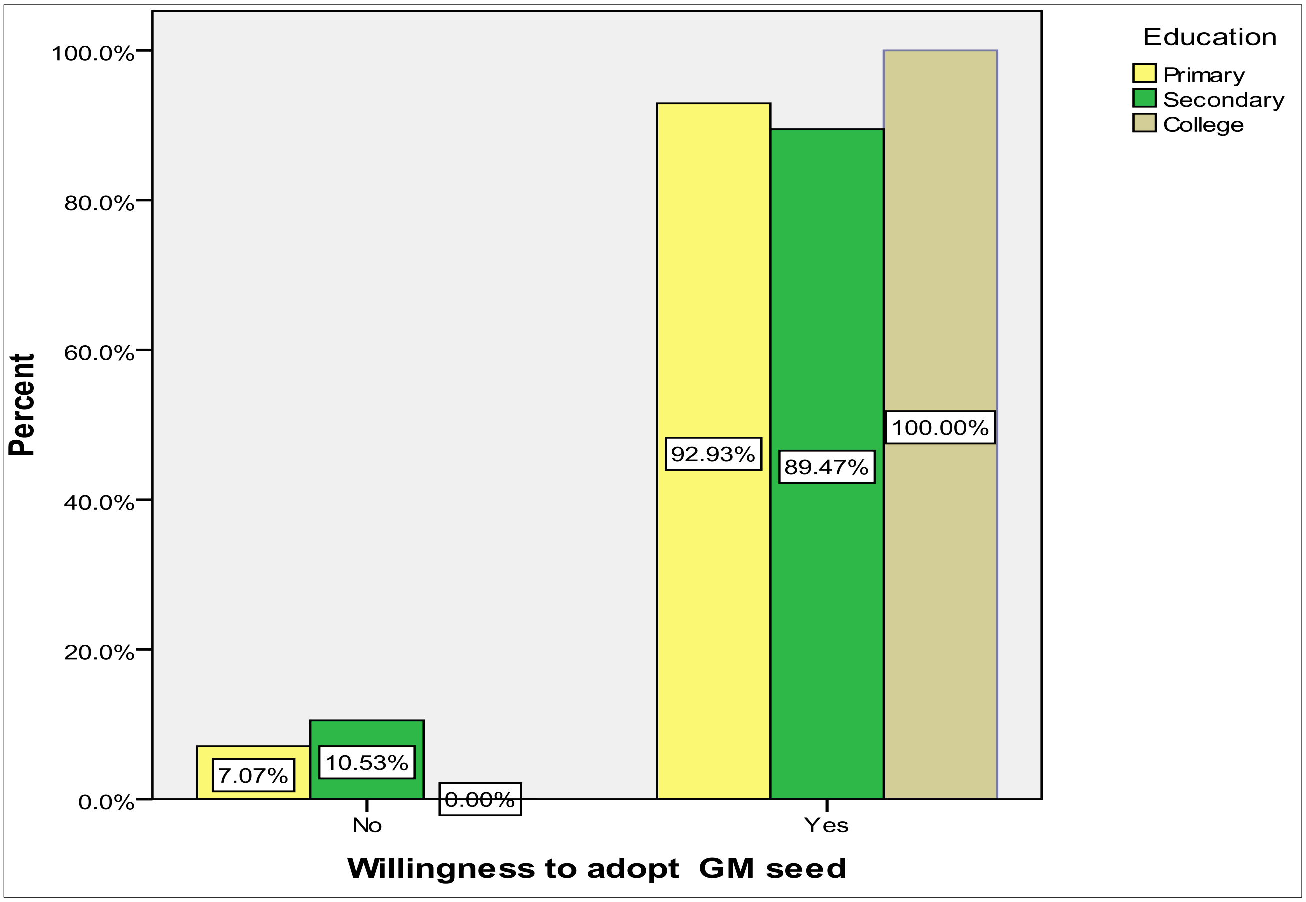
Based on the analytical data, it was evident that a majority of farmers, regardless of gender, expressed a willingness to adopt genetically modified (GM) seeds. This willingness was primarily motivated by the farmers' desire for crops capable of mitigating existing biotic and abiotic stresses that adversely affected crop production. The farmers showed a keen interest in adopting crop varieties with superior yields, which would generate higher income. The study revealed that if a GM crop with superior performance compared to the existing varieties were introduced, farmers would adopt it despite potential health and environmental risks.

The interviewed farmers implicitly demonstrated enthusiasm for adopting new varieties introduced to the market, largely due to the satisfactory performance of previously introduced varieties, particularly maize cultivars. That the majority of these new varieties had met the farmers' expectations. Consequently, the introduction of GM varieties that could effectively address their current agricultural challenges elicited significant willingness among the farmers to use them. This enthusiasm highlighted the farmers' priority on improving crop productivity and income, even in the face of potential risks associated with GM crops.

Figure 11 illustrates the perceptions of farmers regarding the adoption of genetically modified (GM) crops, stratified by their level of education. Farmers possessing at least a college education unanimously (100%) exhibited an absolute positive perception toward GM crop adoption. This response was predicated on the assumption of superior performance and efficacy of the GM varieties if introduced. These college-educated farmers indicated that their continued support for GM crops was contingent upon the crops consistently outperforming or at least matching the efficacy of existing conventional varieties. Any noticeable decline in performance or efficacy of the GM crops compared to conventional options would prompt these farmers to promptly discontinue their use.

Furthermore, 89.47% of farmers with secondary education demonstrated a positive perception toward GM crop adoption. This group, while slightly less enthusiastic than their college-educated counterparts, still showed a strong inclination towards the benefits of GM crops. Farmers with primary education displayed an even higher level of positive perception, with 92.93% expressing support for adopting GM crops. This trend suggests a generally favourable attitude towards GM crops among farmers, irrespective of their educational background, although the level of education did influence the degree of positivity. The data underscores the critical role of perceived performance and efficacy in shaping farmers' attitudes towards new agricultural technologies, with higher education levels correlating with a conditional but strong acceptance, contingent on the GM crops meeting high-performance expectations.

Figure 11: The willingness to adopt GM maize seed among farmers with different levels of education



The analysis elucidates that a substantial proportion of farmers, specifically 89% as illustrated in Figure 11, exhibit a favourable disposition towards the adoption of genetically modified (GM) crop seeds, irrespective of their educational backgrounds. This data underscores the broad-based acceptance of GM technology across diverse educational strata. Furthermore, the predominant agricultural practice among the surveyed counties is maize cultivation, which occupies a significant portion of the arable land. This trend highlights maize as the primary crop of choice among these farmers. In contrast, livestock keeping constitutes the secondary agricultural activity, indicating its relative importance in the agrarian economy of the region. Additionally, the cultivation of other crops, including sorghum, millet, and sweet potatoes, is minimal, occupying relatively negligible portions of farmland. These findings suggest a prioritization of maize and livestock over other crops, reflecting both the economic and possibly cultural preferences within these farming communities.

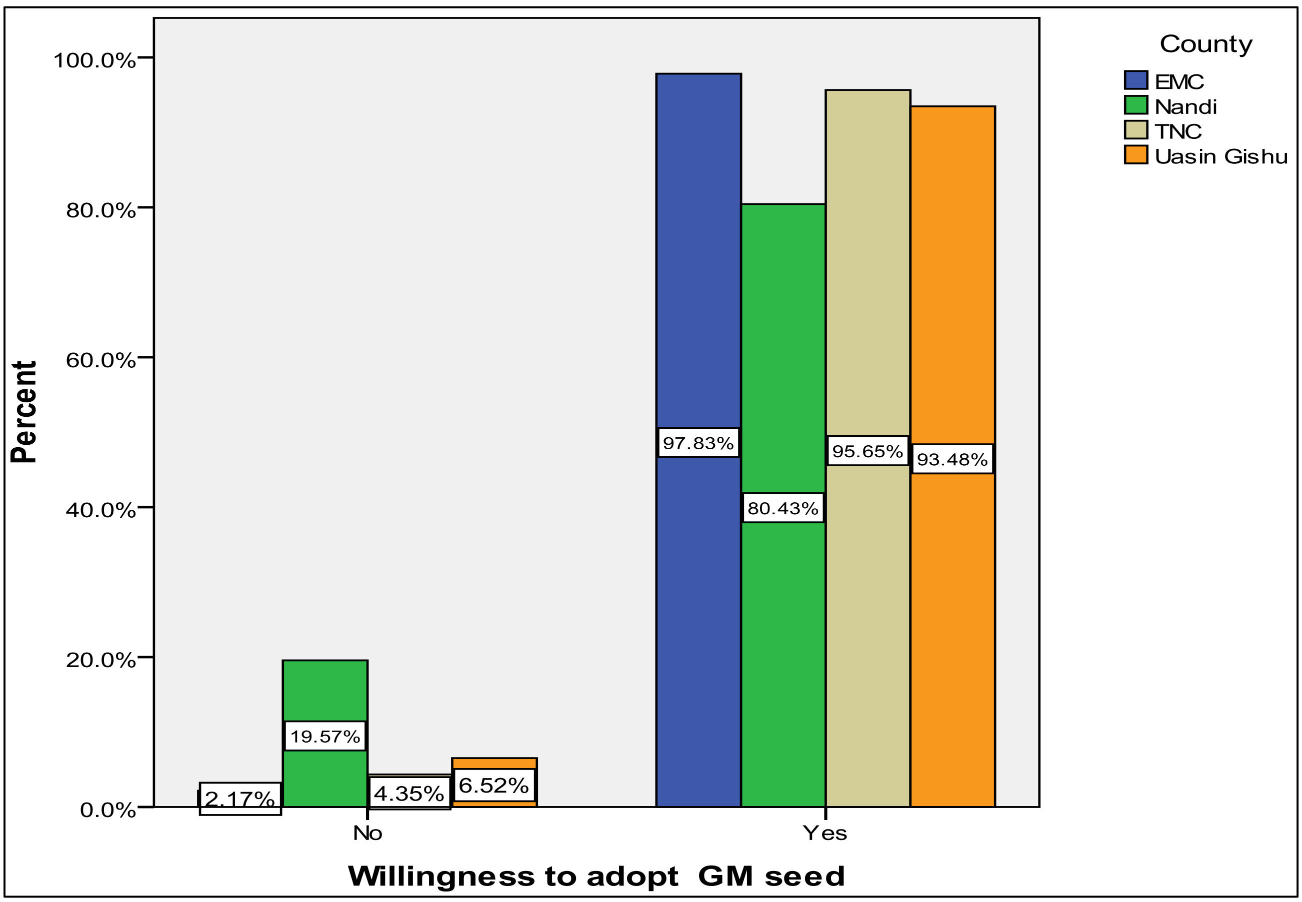
4.6 Farmers perception of GM crop adoption among the four counties

Across all four counties, an extensive collection of data reveals an overwhelmingly positive disposition among farmers towards the integration of genetically modified (GM) seeds or crops into their agricultural practices. As illustrated in Figure 12 below, it is conspicuous that upwards of 80% of farmers across these counties exhibit a favorable inclination and express readiness to embrace GM crops. Notably, Elgeiyo Marakwet county (EMC) stands out with the highest proportion of farmers displaying willingness to adopt GM maize seed. This phenomenon can be ascribed to the myriad challenges confronting farmers within this region.

EMC faces pronounced constraints, prominently characterized by a heightened frequency of drought occurrences. Over the past decade alone, EMC has weathered five significant drought episodes, precipitating marked declines in maize yields and perpetuating a cycle of food scarcity and malnutrition. In response to these challenges, farmers within this county demonstrate a heightened receptivity towards the adoption of alternative maize varieties, including GM seeds, provided they offer efficacious mitigation against the adverse impacts of drought on crop productivity.

This empirical evidence underscores the critical role of environmental factors, particularly recurrent drought, in shaping farmers' attitudes towards agricultural innovation. In regions like EMC, where climatic stressors exert substantial pressure on traditional farming practices, the allure of GM technology lies in its potential to confer resilience and adaptability to crops, thereby fortifying food security and alleviating vulnerability to climatic vagaries.

Figure 12: The perception of GM crop adoption among farmers in the four counties



In Nandi County, a noteworthy proportion, amounting to 19.57%, exhibits reluctance towards the adoption of genetically modified (GM) seeds. This hesitancy stems from the perceptible attenuation of constraints impinging upon crop cultivation, notably those linked with drought. Over the preceding decade, a mere trio of drought occurrences transpired. However, the severity of these episodes paled in comparison to the aridity experienced in the East Mau Complex (EMC). Consequently, the prevailing agricultural milieu in this locale denotes a diminished exigency for the integration of drought-tolerant maize cultivars. The discernible dearth of urgency among farmers underscores the imperative for nuanced and context-specific approaches in the promotion and dissemination of GM technologies within agroecological settings marked by varying degrees of climatic stress.

In the agricultural landscapes of Trans-Nzoia (TNC) and Uasin Gishu counties, a robust consensus emerges among surveyed farmers, with over 93% expressing a proclivity towards embracing genetically modified (GM) seeds upon their introduction. This resounding inclination underscores the potential for widespread adoption of GM drought-tolerant maize cultivars, provided their efficacy in mitigating drought-induced yield fluctuations is empirically substantiated. Nonetheless, it is imperative to acknowledge that adoption dynamics are multifaceted, extending beyond mere technological efficacy. Key determinants encompass the accessibility of GM seeds, including considerations of affordability and market availability, as well as the provision of comprehensive farmer education initiatives. Additionally, the establishment of viable market channels for surplus produce stands as a pivotal determinant shaping farmers' decisions regarding technology adoption. These nuanced considerations underscore the complex interplay of socio-economic and agricultural factors that underpin the successful integration of GM technologies into agricultural systems.

4.7 Willingness to buy GM seed at higher prices

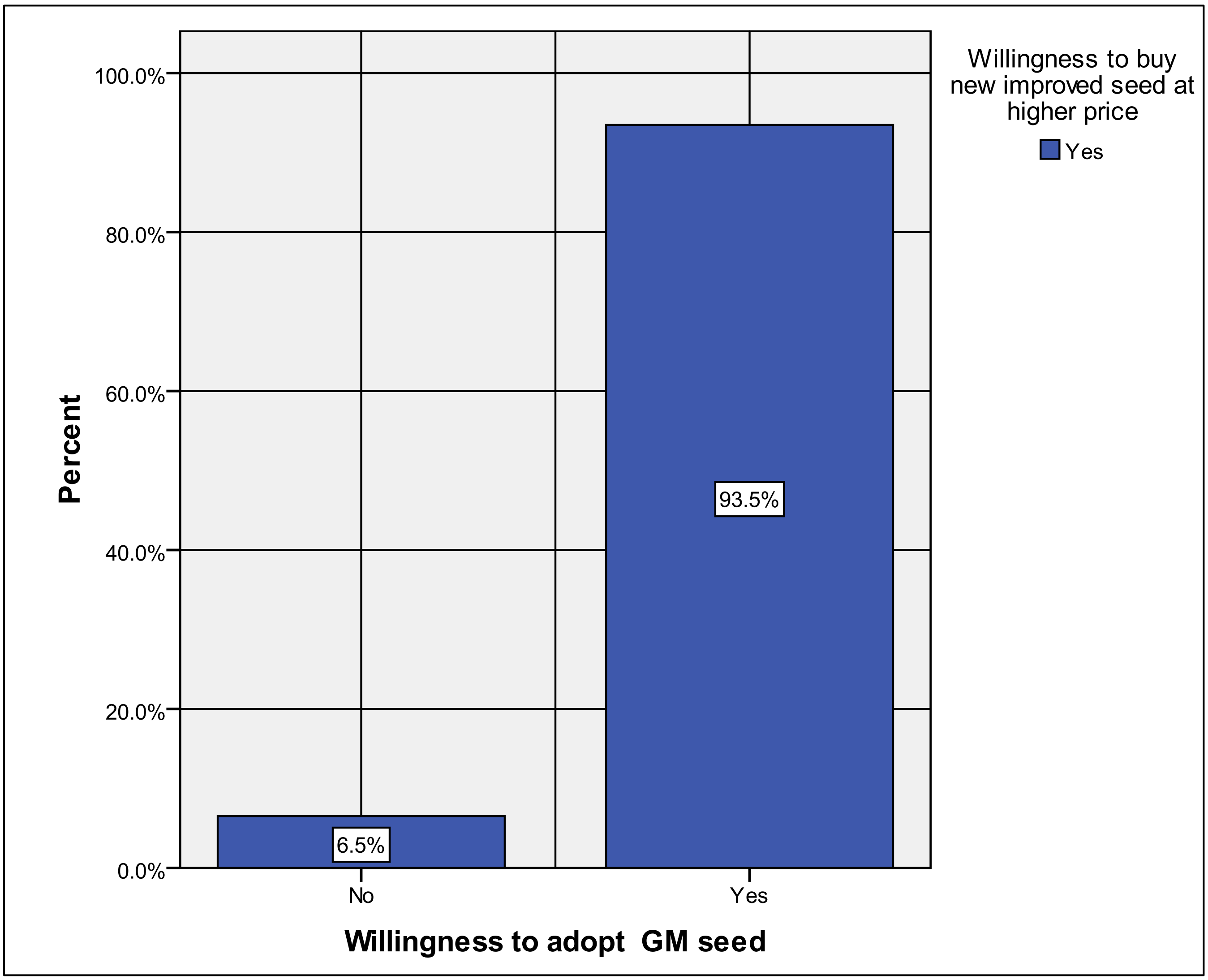
Across all Counties, the consensus among interviewed farmers reveals a prevalent inclination towards the adoption of novel crop varieties. This leaning is underpinned by the imperative to mitigate the adverse impact of drought on maize yields. Consequently, farmers exhibit a pronounced willingness to embrace any form of improved seeds, including genetically modified (GM) varieties. Their incentive stems from the desire for improved yields to secure both subsistence and surplus for household income. Illustrated in Figure 14, a noteworthy proportion of both large-scale and small-scale farmers—exceeding 93.5%—evinces readiness to procure drought-tolerant GM maize seeds at higher prices relative to conventional counterparts, provided the former demonstrates superior performance.

This predisposition can be attributed to the tangible benefits realized from previously introduced hybrids, which have proven advantageous to majority of farmers within the region. The recurrent incidence of drought across the surveyed territories has precipitated substantial income losses and exacerbated food scarcity among farming communities. Consequently, the introduction of any supposedly drought-tolerant maize variety, including GM variants, assumes precedence in agricultural discourse and policy.

The eagerness exhibited by farmers to invest in genetically modified seeds underscores their pragmatic approach towards addressing the exigencies posed by climate variability.

It reflects a strategic alignment of agricultural practices with prevailing environmental challenges, signalling a paradigm shift towards sustainable and resilient farming methodologies. Hence, the integration of drought-tolerant GM maize varieties into the agricultural landscape emerges as a pivotal intervention to bolster food security and enhance livelihoods amidst the prevailing climatic uncertainties.

Figure 13: Willingness to buy new improved seed at higher prices



4.8 Comparison of land under maize and land under sorghum/millet

Table 5a illustrates the mean acreage of land devoted to maize cultivation and the combined acreage for sorghum and millet across the four surveyed counties. The analysis reveals that the average land size allocated to maize cultivation among the sampled farmers is 2.78 hectares (Ha), while that for sorghum and millet collectively amounts to 0.42 Ha. This data underlines a notable trend wherein, despite the superior drought tolerance of sorghum and millet compared to maize, the majority of farmers exhibit a noticeable preference for maize cultivation, a phenomenon not exhaustively expounded within the scope of this study.

On the other hand, several factors contribute to this prevailing inclination towards maize cultivation. Primarily, maize is favoured due to its productivity and consequent profitability, factors which render it a more economically viable option for farmers. Furthermore, households demonstrate a clear preference for maize consumption over millet and sorghum, thereby incentivizing its cultivation. In addition, the presence of a robust and consistent market demand for surplus maize year-round further reinforces the attractiveness of maize cultivation to farmers. These multifaceted factors serve to explain farmers' preference for maize cultivation over sorghum and millet, despite the latter's heightened tolerance and diminished susceptibility to adverse weather conditions. Thus, while acknowledging the inherent advantages of sorghum and millet, it becomes evident that the economic, dietary, and market-related considerations associated with maize cultivation significantly influence farmers' decision-making processes in favour of maize cultivation.

	Mean (Ha)	Std. Deviation	N
Average land size under maize in the last 3 years	2.78	7.621	368
Average land size under sorghum/millet in the last 3 years	0.45	0.35	368

Table 5a: Mean of land under maize and that under millet/sorghum

The analysis indicates a discernible discrepancy in the correlation between land allocation for maize cultivation compared to sorghum and millet, contingent upon the size of the farmer's landholding. This suggests that the extent of land dedicated to sorghum may vary between farmers with divergent land sizes; specifically, a farmer with a 10-hectare landholding may allocate a larger area to sorghum cultivation than one with only 1 hectare, while maintaining a proportional allocation to maize cultivation. However, this observed trend does not necessarily imply a substantial correlation in land allocation adjustments.

It is evident from the findings that farmers exhibit a pronounced preference for maize cultivation over sorghum and millet. This preference is particularly evident, with maize emerging as the predominant crop enterprise among the sampled farmers. The data presented in Table 5b below, underscores this preference, depicting a 2-tailed Pearson correlation analysis between the average land size allocated to maize cultivation over the past three years and that allocated to sorghum within the same timeframe. These results emphasize the agricultural dynamics within the study area, highlighting the prevailing preference hierarchy among farmers for maize cultivation. This preference may stem from various factors such as market demand, crop versatility, or historical cultivation practices. Further examination of the underlying determinants driving this preference hierarchy could yield valuable insights for agricultural policy formulation and extension strategies aimed at promoting sustainable crop diversification and enhancing food security.

		Average land under maize in 3 years	Average land under sorghum in the last 3 years
Average land under maize in the last 3 years	Pearson Correlation	1	.461**
	Sig. (2-tailed)		.000
	N	368	368
Average land under sorghum in the last 3 years	Pearson Correlation	.461**	1
	Sig. (2-tailed)	.000	
	N	368	368

Table 5b: Correlations of land under maize and that under sorghum and millet

**. Correlation is fairly significant at the 0.05 level (2-tailed).

4.9 Land under maize in relation to improved seed planted

Table 6a presents a comprehensive analysis of the mean land area dedicated to maize cultivation and the quantity of hybrid seeds utilized over the preceding three years across various surveyed counties. On average, maize cultivation occupied 2.78 hectares (Ha) of land, with an accompanying average seed consumption of 6.03 kilograms. Notably, the data indicates an average requirement of approximately 25 kilograms of hybrid seeds per hectare for planting purposes. This affirms the standard seed requirement of 25 kilograms per hectare for conventional maize varieties.

The findings emphasize a prevalent adoption of maize hybrids among sampled farmers, with an inferred utilization rate nearing 100%. This inference suggests a prevailing trend where farmers predominantly procure their maize seeds from designated seed distributors and local agro-dealers, indicative of a structured market for hybrid seeds within the agricultural landscape. The utilization of hybrid maize seeds carries significant implications for agricultural practices and productivity. Hybrid varieties are often favoured for their improved traits, including higher yields, enhanced resistance to pests and diseases, and adaptability to diverse agro-climatic conditions. Consequently, the widespread adoption of hybrid seeds points out a strategic shift towards modernized agricultural approaches aimed at optimizing production efficiency and ensuring food security amidst evolving environmental and socioeconomic dynamics.

Furthermore, the observed reliance on hybrid seeds reflects broader trends in agricultural innovation and commercialization, wherein farmers increasingly engage with formalized seed markets to access improved germplasm tailored to their specific agronomic needs and production objectives.

	Mean	**Std. Deviation**	**N**
Average land size (Ha)under maize in 3 years	2.78	7.631	368
Average quant of Hybrid Maize seed (Kg) used in the last 3 years	69.03	19.070	368

Table 6a: **Mean of average land under maize and that of seeds used**

The Pearson correlation analysis presented in Table 6b below demonstrates a robust and statistically significant association between land size and seed quantity utilized. With a Pearson correlation coefficient of 0.999, it is evident that the vast majority of farmers opt for hybrid maize seed varieties. This implies a direct and highly correlated relationship, suggesting that larger land holdings correspond to increased usage of hybrid maize seeds.

		Average land under maize in three years	**Maize Hybrid seed (Kg) in the last 3 years**
Average land under maize in 3 years	Pearson Correlation	1	.999**
	Sig. (2-tailed)		.000
	N	368	368
Maize Hybrid seed (Kg) in the last 3 years	Pearson Correlation	.999**	1
	Sig. (2-tailed)	.000	
	N	368	368

Table 6b: P-Correlations between average land under maize in 3 years and maize hybrid used

**. Correlation is significant at the 0.05 level (2-tailed).

4.10 Replacement of Sorghum/Millet by drought tolerant GM maize varieties

Table 7 illustrates the tendency of farmers to substitute approximately 0.40 hectares of inherently drought-tolerant crops, specifically millet and sorghum, presently cultivated on their lands, with improved varieties. The prevailing land allocation for these traditionally resilient crops (sorghum and millet) averages 0.45 hectares, indicating an approximate 88.8% replacement rate. This phenomenon bears substantial ramifications for the accessibility of grains derived from these crops for households and the broader market. The envisaged shift in crop cultivation patterns could potentially disrupt the established supply chain dynamics, affecting both local consumption patterns and market-driven demands. Consequently, comprehensive assessments and strategic interventions are warranted to address the emergent challenges and mitigate potential disruptions in food security and economic stability within affected regions.

	Mean (Ha)	Std. Deviation	N
Land currently under sorghum and millet to be replaced with DT GM maize	0.40	0.30	368
Average land under sorghum/millet in the last three years	0.45	0.35	368

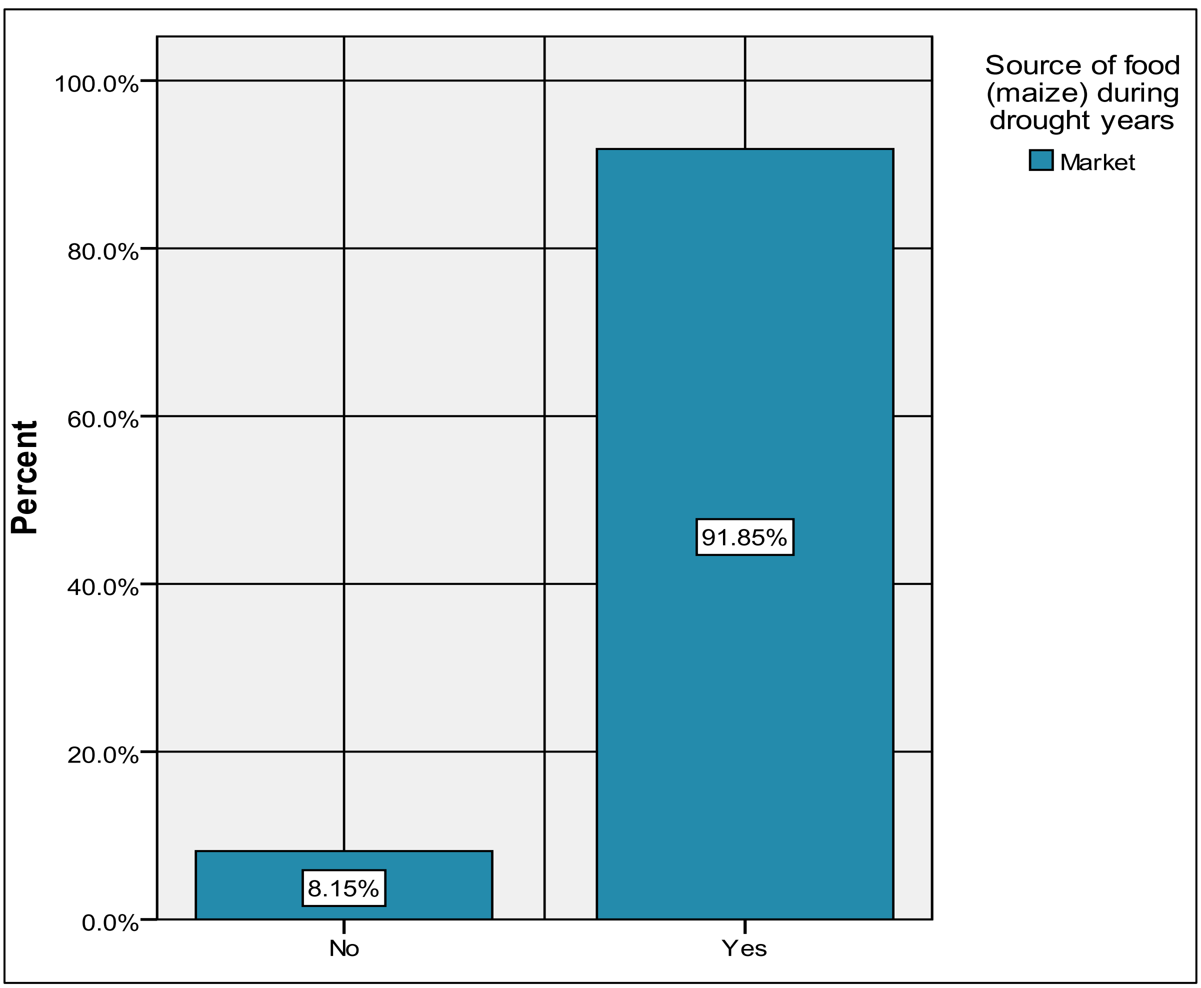
Table 7: The mean of the size of land under millet/sorghum and the one of the same crop the farmers are willing to replace with DT GM maize varieties to be introduced

4.11 Source of food (maize) during drought years

The survey encompassed an inquiry into the procurement patterns of maize for sustenance amidst drought conditions. A notable proportion of the surveyed farmers conveyed reliance on market purchases for their dietary maize requirements. This propensity implies a prevailing trend wherein a majority of farmers opt not to preserve maize within their personal inventories, especially in the face of bountiful harvests. The accessibility of maize within local markets is contingent upon the influx of surplus grain from neighbouring farming communities. The empirical data gleaned from the survey underscores the vulnerability inherent in this dependency structure: during instances of pervasive scarcity within the maize market, households reliant on commercial sources for sustenance confront heightened susceptibility to malnutrition and food insecurity.

Figure 15, below, delineates the prevalence of market reliance across the surveyed populace. Remarkably, over 91% of participants spanning all four counties indicated procurement of maize from commercial avenues during drought-induced exigencies. This statistical insight serves as an affecting indicator of the overarching market dependency observed among farming communities. In light of this observation, it becomes necessary to examine potential interventions aimed at bolstering local resilience to food shortages during periods of draught, knowing that majority of farmers rely on market for their maize grain needs, as opposed to their own storage.

Figure 14: Source of food during drought years



CHAPTER FIVE

5.0 DISCUSSION OF RESULTS

The focus of this study was to investigate the potential repercussions stemming from the successful adoption of genetically modified (GM) moderate drought-tolerant maize cultivars. The hypothesis suggesting that the rapid adoption of GM maize varieties resilient to drought conditions could result in the abandonment or substitution of indigenous drought-resistant crops, thus exacerbating food scarcity in Kenya, in the event of severe drought, has been thoroughly scrutinized. This supposition was grounded in the recurring droughts experienced by farmers over time, compelling them to seek out technologies that could perform more effectively under such circumstances.

An extensive analysis revealed that, on average, each of the sampled counties in Kenya has encountered four drought years within the past decade, indicating a notable adverse impact on food security and agricultural income. Notably, the frequency of drought occurrences exhibited marginal disparities across counties, ranging from three to five years over the same ten-year period. For instance, Elgeiyo Marakwet County experienced five drought years within the past decade, equating to a drought incidence rate of once every two years for farmers in this region. Consequently, farmers in Elgeiyo Marakwet County are consistently exposed to recurrent crop losses, precipitating food shortages and economic setbacks.

This finding underlines the imperative for proactive measures to mitigate the adverse effects of drought on agricultural productivity and food security. While the advent of GM drought-tolerant maize varieties holds promise for addressing these challenges, careful consideration must be given to the potential consequences, such as the displacement of indigenous crops and the perpetuation of food insecurity cycles. Efforts to promote sustainable agricultural practices and enhance resilience to climate variability are essential for safeguarding livelihoods and ensuring food availability for future generations.

Research findings reveal significant disparities in the impact of drought across different counties. For instance, analysis of agricultural data, as presented in Table 4c and 4d, illustrates the stark contrast between Elgeiyo Marakwet County and Trans-Nzoia County regarding maize yield under varying rainfall conditions. In Elgeiyo Marakwet County, the average maize yield stood at 2.89 Tons per Hectare (T/Ha) during a year with ample rainfall. Conversely, Trans-Nzoia County exhibited a higher yield of 4.93 T/Ha during seasons characterized by sufficient precipitation.

Moreover, distinct variations emerged in maize harvests during drought periods between the two counties. Elgeiyo Marakwet County experienced a notable reduction, with an average yield plummeting to 0.92 T/Ha during drought years. In contrast, Trans-Nzoia County displayed a relatively higher resilience, yielding an average of 1.83 T/Ha during similar drought conditions. These findings underscore the pronounced inequality in grain supply to the market and the corresponding household demand, perpetuating economic losses associated with drought-induced maize production decline across surveyed regions.

The study also identifies a potential solution to mitigate these losses through the introduction of genetically modified (GM) maize varieties with drought tolerance traits. This innovation holds promise for farmers who have suffered from recurrent and protracted drought episodes, eliciting considerable interest and willingness among them to adopt the technology. The data indicates that farmers are prepared to replace approximately 0.4 hectares (Ha) of land currently allocated to inherently drought-resistant crops such as millet and sorghum with drought-tolerant GM maize varieties.

Considering that the average land allocation for sorghum and millet cultivation is 0.45 Ha, the anticipated adoption rate of 88.8% (0.4 Ha) underscores the strong inclination towards adopting GM maize varieties as a resilient alternative to traditional crops susceptible to drought. This transition not only highlights the potential for enhancing agricultural resilience but also underscores the socio-economic implications of adopting innovative solutions to mitigate the adverse effects of climate change on food security and livelihoods.

Analysis of the study responses reveals a robust inclination among farmers across all counties, with over 93%, towards embracing drought-tolerant maize cultivars, even at premium prices compared to prevailing variants. Ouma et al. (2002) and Salasya et al. (2002) documented elevated farmer confidence in adopting enhanced maize hybrids in Kenya, attributed to the consistent efficacy of extant varieties. This investigation reinforces such findings, indicating a striking 98% adoption rate of improved seeds among sampled farmers in the four counties. The palpable enthusiasm for drought-tolerant varieties underscores a proactive stance towards climate resilience and crop productivity enhancement. These findings underscore the pragmatic approach of farmers towards embracing agricultural innovations, delineating a fertile ground for sustainable agricultural development strategies. The convergence of empirical evidence further accentuates the viability and desirability of promoting resilient crop varieties within agricultural landscapes.

According to Smale et al. (2024), Kenya exhibits one of the most noteworthy rates of maize hybrid seed adoption globally. This phenomenon is largely attributed to the superior performance of introduced varieties, instilling farmers with confidence to embrace novelty. The present survey substantiates this assertion. Findings reveal that over 90% of surveyed farmers exhibit keenness to adopt any drought-tolerant maize seed variety, including genetically modified (GM) crops. Moreover, a remarkable willingness is observed among farmers to allocate up to 88.8% of their current sorghum and millet cultivation area to DT GM maize varieties. These outcomes underscore a robust inclination towards embracing innovative agricultural practices among Kenyan farmers, particularly in response to challenges like drought. Such insights not only validate existing literature but also emphasize the critical role of agricultural innovation in addressing food security concerns in regions vulnerable to climatic variability.

Farmers' adoption of new crop varieties is heavily influenced by the performance of preceding ones. According to Mwabu et al. (2007), this adoption is primarily driven by the desire for increased yields under prevailing environmental conditions. Smallholder farmers typically prioritize maize production for food and surplus for income generation. As demonstrated in Table 7 of Section 4.10, farmers express willingness to replace inherently drought-tolerant crops like sorghum and millet with moderately drought-tolerant genetically modified (GM) maize varieties. However, this presents potential risks, as the GM maize varieties are only moderately drought tolerant. In the event of severe drought, widespread food shortages may ensue, as inherently drought-tolerant crops can still thrive. Maize, being susceptible to severe drought, could fail as a food source, exacerbating food insecurity. Therefore, while the adoption of GM maize offers potential benefits, careful consideration of its limitations, particularly in the face of extreme weather events, is crucial to mitigate risks and ensure food security.

However, unlike the proven success of previously introduced maize seed hybrids like HD614, the effectiveness of recently developed drought-tolerant varieties remains unverified under actual farming conditions. Despite this uncertainty, farmers have shown considerable interest in adopting these new varieties, demonstrating a willingness to expand maize cultivation by replacing traditionally drought-tolerant crops such as sorghum and millet, provided the efficacy of the new varieties is established. Maize holds a preeminent position as the preferred food crop among farmers across the four surveyed counties.

The findings revealed an average maize cultivation area of 2.78 hectares per farmer, whereas the average total land ownership per farmer stood at 5.77 hectares. Consequently, maize cultivation occupies approximately 48% of the available farmland. This high allocation of land to maize underlines its significance in the agricultural landscape and highlights the potential impact of successful adoption of drought-tolerant varieties on overall crop distribution and food security within these communities.

Based on the findings of this study, should the implementation of drought-resistant genetically modified (GM) maize varieties prove successful and garner swift adoption by farmers, there exists a significant probability of them forsaking their conventional seed varieties. This abandonment encompasses indigenous drought-tolerant crops like sorghum and millet, as evidenced in the aforementioned data. The allure of enhanced crop resilience and yield associated with the new GM varieties may outweigh the perceived benefits of traditional crops, potentially leading to a gradual phasing out of the latter in favour of the former, thus altering the agricultural landscape.

The findings from the data analysis conducted in section 4.9 reveal that farmers applied 25 kilograms of hybrid seed per hectare, constituting significant utilization of hybrid seeds. While this practice is prevalent, the adoption of genetically modified (GM) maize varieties with moderate drought tolerance could potentially mitigate the impact of drought, a persistent environmental challenge significantly limiting maize cultivation in these regions. This suggests a promising avenue for enhancing maize productivity and resilience to adverse climatic conditions, underscoring the potential benefits of integrating GM technology into agricultural practices within these counties.

As per findings from the Africa Agricultural Technology Foundation's TELA project, the ongoing national performance trials (NPT) in Kenya reveal that transgenic drought-tolerant maize varieties exhibit a modest effectiveness, estimated to be only 20-35% more tolerant than conventional drought-tolerant maize strains available in the market. Projections suggest that these varieties may augment yields by approximately 25-35% under conditions of moderate drought (AATF, 2023). However, these data imply that the transgenic varieties might not confer absolute resilience against drought-induced impacts on maize productivity. The potential ramifications of this limited efficacy are substantial, particularly if farmers, who have shown a strong inclination, surpassing 90%, towards adopting these varieties, are inadequately informed about their performance during severe drought conditions. Without proper education on the actual capabilities of the crop in such scenarios, farmers face considerable risk. Thus, a comprehensive understanding of these nuances is crucial for informed decision-making and sustainable agricultural practices.

Amidst drought years, when farmers struggle to yield sufficient maize for household subsistence, research reveals that 91% of their maize grain procurement emanates from local markets. As expounded in the literature (section 1.2.1), the Tegemeo Institute (2009) asserts that local farmers predominantly supply maize grain to these markets. Consequently, when severe drought disrupts maize cultivation, resulting in diminished market maize stocks, households encounter difficulty purchasing grain for sustenance, compounded by the absence of traditional crop reserves due to maize-centric cultivation practices.

This potential predicament underscores the significance of the present study's findings. A market maize scarcity not only deprives farmers of an alternative procurement avenue but also precipitates a food insecurity crisis. In this context, households reliant on market grain face heightened vulnerability to hunger, thereby accentuating the socio-economic repercussions of drought-induced agricultural disruptions. By illuminating this nexus between market dynamics, crop diversification, and household food security, this study offers valuable insights for policymakers and agricultural stakeholders striving to mitigate the adverse impacts of drought on vulnerable farming communities.

According to Nyoro et al. (1999), farmers typically sell their surplus maize when harvests are plentiful, directing it towards local markets or government-owned National Cereals and Produce Board (NCPB) stores, which are widespread across local markets (Chamberlin & Jayne, 2009). During periods of drought, farmers rely on these markets to acquire maize grain. This reliance on surplus harvests is closely linked to adequate rainfall, given that rainfed agriculture accounts for the majority of maize production in Kenya (Ministry of Agriculture, 2005). Analysis of responses from sampled farmers, as depicted in Figure 15 of Section 4.11, revealed that during drought years, 91.85% of households source their maize grain from local markets. The dependence on local markets during drought stresses their critical role in ensuring food security.

Considering the pivotal role of rainfall in maize production, the adoption of genetically modified (GM) maize varieties engineered for moderate drought tolerance may not suffice during severe drought conditions. This limitation suggests that grain shortages in the market could persist even with the adoption of drought-tolerant GM maize varieties. Therefore, while such varieties may offer benefits in mitigating moderate drought, they may not adequately address the challenges posed by extreme drought events. Thus, the reliance on surplus maize during periods of abundance and the prevalence of rainfed agriculture underscore the significance of rainfall in maize production and highlight the potential limitations of drought-tolerant GM maize varieties in addressing severe drought conditions.

Given the evident interest expressed by farmers in acquiring enhanced seed varieties resilient to drought conditions, the implementation of genetically modified (GM) maize seeds with drought tolerance traits is poised to gain widespread acceptance among agricultural communities. Across all surveyed counties, over 90% of farmers consistently report significant yield declines during periods of drought, with an average household yield of 1.76 tons per hectare (T/Ha) and an annual consumption rate of 1.82 tons per household. These figures underscore a prevalent deficit in maize grain production during drought years. Should farmers transition to the use of improved GM maize seeds, forsaking their traditional drought-tolerant crops, the risk of widespread food shortages looms large. Such a shift carries the potential consequence of abandoning conventional drought-resistant maize varieties and inherently resilient crops like sorghum and millet.

The allure of the introduced GM varieties, deemed superior and highly effective against severe drought conditions, may lead to their mass adoption. However, this transition presents the ultimate risk of exacerbating food insecurity, as reliance on a singular crop variety vulnerable to unforeseen challenges could destabilize food availability. Thus, while the adoption of GM maize seeds offers promise in addressing drought-induced yield losses, careful consideration of its implications on overall food security is imperative.

The findings suggest that the proposed hypothesis is probable. Presently, sorghum and millet cultivation cover an average area of 0.45 hectares, in comparison with an average land ownership of 5.77 hectares. Consequently, sorghum and millet cultivation represent merely 7.8% of total land use, while maize crops dominate at 48.1%. This highlights the marginalization of traditional crops, considered less favoured by farmers. While acknowledging potential risks, this study did not comprehensively ascertain the severity and scope. Further investigation is warranted to elucidate the full extent of these risks.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The aim of this research was to conduct a comprehensive risk assessment regarding the potential impact of introducing moderately drought-tolerant maize varieties on food security. In this analysis, the focus, also known as the hazard, pertains to the occurrence of food shortages. Conversely, the exposure factor involves the extent of adoption of these varieties, wherein farmers opt to replace both the inherently drought-resistant crops and the conventional maize varieties presently cultivated.

It was observed that a substantial majority of farmers, exceeding 90%, expressed readiness to embrace the genetically modified drought-tolerant varieties. Moreover, there exists a significant willingness among farmers to substitute the inherently drought-tolerant crops, with an adoption rate of 88.8%. Notably, the proportion of land currently dedicated to these inherently drought-tolerant crops compared to that allocated for maize cultivation is relatively minor. Specifically, sorghum and millet collectively occupy only 7.8% of the total land, while maize covers a substantial portion, accounting for 48.1%. Therefore, the assessed level of risk can be characterized as moderately high. This classification stems from the elevated hazard level, attributed to the widespread willingness (exceeding 90%) to adopt the drought-tolerant varieties. However, it is noteworthy that the exposure factor, as indicated by the proportion of land occupied by inherently drought-tolerant crops, remains moderate at 7.8%. Hence, while the hazard presents a significant concern, the overall exposure remains somewhat constrained, resulting in a moderately high-risk assessment.

The study findings reveal a recurring challenge among farmers, wherein drought significantly impairs maize production. Farmers, however, have progressively embraced improved maize seed varieties known for their high yield capacity. This shift underscores farmers' confidence in and readiness to adopt new varieties upon confirmation of their efficacy. Intriguingly, this willingness to adopt transcends demographic boundaries such as gender, educational attainment, farm size, and geographical location.

The motivation for embracing drought-tolerant genetically modified (GM) maize varieties emerges from the palpable reduction in crop yields attributed to drought and various unexplored factors impacting production. Analysis indicates a notable inclination among farmers towards adopting these GM varieties, potentially surpassing the usage of traditionally drought-resilient crops like sorghum and millet. The preference towards drought-tolerant GM maize is indicative of its perceived capacity to mitigate the adverse effects of drought on crop yields. The data suggests a pivotal implication: widespread adoption of drought-tolerant GM maize could pose a dual scenario. Firstly, in the event of a severe drought, the failure of these GM varieties may precipitate significant grain supply shortages in the market, thereby exacerbating food insecurity. Secondly, the observed trend of farmers procuring maize grain from markets during drought years highlights the vulnerability of market-dependent food access systems to disruptions in maize grain supply.

However, the successful transition to drought-tolerant GM maize hinges on a series of conditions. Foremost among these is the necessity for a sustained and severe drought scenario coinciding with rapid adoption rates. Such circumstances could potentially prompt farmers to entirely forego their reliance on traditionally drought-resistant crops in favour of GM maize varieties. The envisaged outcome is a landscape where a substantial portion of farmland is dedicated to monoculture cultivation of drought-tolerant GM maize. This shift in agricultural practices towards monoculture cultivation of drought-tolerant GM maize carries inherent risks. Dependence on a single crop variety renders agricultural systems susceptible to catastrophic losses in the face of unforeseen challenges such as pest infestations or diseases specific to the cultivated variety. Furthermore, monoculture practices can exacerbate soil degradation and reduce biodiversity, posing long-term sustainability challenges for agricultural systems.

In light of these findings, policy interventions aimed at promoting diversified agricultural strategies may serve as a prudent approach to mitigate the risks associated with monoculture cultivation of drought-tolerant GM maize. Initiatives focusing on crop diversification, soil conservation, and sustainable agricultural practices could enhance resilience to environmental perturbations while safeguarding food security. While the adoption of drought-tolerant GM maize presents a promising solution to mitigate the impact of drought on maize production, careful consideration of associated risks and implementation of complementary strategies are imperative to ensure the long-term sustainability and resilience of agricultural systems.

The hypothesis posits that the swift uptake of moderately drought-resistant maize varieties among Kenyan farmers could potentially lead to a food shortage scenario. Substantiated by preceding discussions, presented evidence suggests farmers' inclination towards adopting these drought-tolerant maize varieties. Farmers have displayed a readiness to expand the cultivation area dedicated to these varieties, potentially by substituting currently cultivated inherently drought-resistant crops. This conjecture stems from the intersection of various factors inherent to Kenya's agricultural landscape. Primarily, the prevailing susceptibility of maize crops to drought stress highlights the necessity for resilient varieties to mitigate yield losses. The documented manifestations of climate change, typified by erratic rainfall patterns and prolonged dry spells, accentuate the urgency for adaptive agricultural practices. In this context, the inclination towards adopting drought-tolerant maize varieties emerges as a pragmatic response to mitigate climate-induced production risks. The observed proclivity towards expanding the cultivation of these varieties suggests a strategic shift in farmers' cropping patterns. This transition implies a potential displacement of traditionally cultivated crops, presumably those less resilient to drought stress. Such a transition, while indicative of farmers' adaptive capacity, also warrants careful consideration of its ramifications on food security dynamics.

The nexus between rapid adoption of drought-tolerant maize varieties and potential food shortages underscores the complexity inherent to agricultural adaptation strategies. While the adoption of resilient varieties offers promise in enhancing agricultural resilience, the unintended consequences, such as shifts in cropping patterns and subsequent impacts on food security, necessitate nuanced evaluation and proactive mitigation measures. Thus, revealing the intricacies of this dynamic interplay holds significance in formulating sustainable agricultural policies geared towards enhancing food security in the face of climate variability.

6.2 Recommendations

The hypothesis proposed in this investigation posits that the validity of the observed risk associated with the introduction and rapid proliferation of drought-tolerant genetically modified (GM) maize varieties in Trans-Nzoia, Uasin Gishu, Eldgeiyo Marakwet, and Nandi Counties hinges solely upon the factors scrutinized within this study. To effectively mitigate this risk, several recommendations emerge:

1. Guidelines on seed distribution is necessary to manage the acreage under cultivation of drought-tolerant GM maize varieties. By controlling the quantity of seeds accessible to farmers, authorities can manage the extent of adoption and thereby curtail potential risks.
2. A collaborative engagement among seed companies, distributors, and public agricultural extension officers is crucial to ensure farmers receive comprehensive education on responsible use of this technology. Effective dissemination of information regarding safe practices and the balanced adoption of GM maize varieties is crucial for minimizing associated risks.

3. Thorough and comprehensive risk assessment exercise prior to the introduction of drought-tolerant GM maize varieties is essential. This assessment should encompass a wide array of potential impacts, both positive and negative, to enable the formulation of pre-emptive mitigation strategies. By pre-proactively identifying and addressing potential risks, stakeholders can better navigate the challenges associated with the technology adoption.
4. Learning from the experiences of successful adoption of similar technologies in other parts of the world can be very helpful. These past examples can guide the introduction of drought-tolerant GM maize varieties, helping in understang what works best and what challenges to avoid.

The efficacy of the hypothesized risk associated with the introduction and rapid adoption of drought-tolerant GM maize varieties in Trans-Nzoia, Uasin Gishu, Eldgeiyo Marakwet, and Nandi Counties is contingent upon the variables examined within this study. To effectively mitigate this risk, it is imperative to implement regulatory measures, adopt comprehensive education initiatives, conduct thorough risk assessments, and integrate lessons from past experiences. By adopting a multifaceted approach informed by empirical evidence and stakeholder collaboration, the potential risks associated with the adoption of drought-tolerant GM maize varieties can be effectively managed and minimized.

This study did not explore several factors that could substantially impact the effectiveness and acceptance of any drought-resistant genetically modified (GM) seed variety entering the market. These include the level of resources invested, the intensity of drought conditions, the performance of the seed variety, the accessibility of information provided by seed companies or breeders, and the availability of financial support. To comprehensively assess the potential risks highlighted in this study, it is imperative to delve deeper into both the aforementioned factors and those already examined, aiming for more definitive conclusions.

Examining the resources invested is crucial as it directly affects the scale of adoption and utilization of GM seeds. Additionally, understanding the severity of drought conditions in different regions provides insights into the practical applicability of these seeds. The performance of the seed variety under various conditions determines its real-world effectiveness. Likewise, accessible and accurate information from seed providers facilitates informed decision-making among farmers. Finally, the availability of financial support, such as credit facilities, can significantly influence farmers' ability to invest in and adopt GM seed technology. By thoroughly investigating these factors, a more nuanced understanding of the risks associated with introducing drought-resistant GM seeds can be achieved.

REFERENCES

2019 Kenya population and housing census: volume I: Population by County and sub-County

AATF, 2011. Reducing maize insecurity in Kenya: The WEMA project

AgbioInvestor. 2024. Total GM Crop Areas Increased in 2023

Banziger, M. and De Meyer, J. 2002. 'Collaborative Maize Variety Development for Stress-Prone Environments in Southern Africa', in Cleveland, D. A. and Soleri, D. (Eds.) Farmers, Scientists and Plant Breeding: Integrating Knowledge and Practice, CABI

Benjamin K. , Lalit K. , Richard., Champika S., and Kariyawasam. 2023. Modelling Climate Suitability for Rainfed Maize Cultivation in Kenya Using a Maximum Entropy (MaxENT) Approach

Bozzola, M., Smale, M., & Di Falco, S. 2021. Maize intensification among smallholder farmers in Kenya: understanding the impacts of climate. In C. Spindell Berck, P. Berck, & S. Di Falco (Eds.), Agricultural Adaptation to Climate Change in Africa Food Security in a Changing Environment (Environment for Development).

Byerlee D. and C.K. Eicher. 1997. Africa's Emerging Maize Revolution. Boulder, CO.: Lynne Rienner PublishersByerlee, D. and Traxler, G. 1995. National and international research in the post-green revolution period: evolution and impacts, American Journal of Agricultural Economics 77, 268–278

Byerlee, D.,M.L. Morris, and M.A. López-Pereira. 1994. Technical Change in Maize Production: A Global Perspective. CIMMYT Economics Working Paper 94-02. Mexico City: International Maize and Wheat Improvement Center (CIMMYT)

Byerlee, D. and P.W. Heisey. 1997. Evolution of the African maize economy. In Africa's emerging maize revolution, ed. Eicher, C.K., and D. Byerlee. Boulder, CO: Lynne Rienner

Chamberlin, J. and T. S. Jayne. 2009. Has Kenyan Farmers' Access to Markets and Services Imprvoed? Panel Survey Evidence: 1997-2007. Tegemeo Working Paper, Tegemeo Institute, Nairobi, Kenya

De Groote H. 2002. Maize Yield Losses from Stemborers in Kenya. Insect Sci. Appl. 22: 89-96.

Djurfeldt, A. A. & Wambugu, S. K. 2011. In-kind transfers of maize, commercialization and household consumption in Kenya. Journal of Eastern African Studies, 5**,** 447-464.
Gerhart, J. D. 1974. The diffusion of hybrid maize in western Kenya

George K., Jennifer N., and Charles O.,. 2023. Maize Output Supply Response to Climate Change in Kenya: An Econometric Analysis. https://repository.kippra.or.ke/bitstream/handle/123456789/4028/PB22-2022-23.pdf?sequence=1&isAllowed=y

Government of Kenya. 1994. Sessional Paper No. 2. National Food Policy. Government printer, Nairobi, Kenya.

Heisey, P. W. & Edmeades, G. O. 1999. Maize production in drought-stressed environments: technical options and research resource allocation.

Hayes KR, Kapuscinski A, Danna G, Sifa L. 2007. Overview of the risk assessment framework. In: Kapuscinski A, Hayes KR, Sifa L (eds) Environmental risk assessment of Genetically Modified Organisms, Volume 3: methodologies for transgenic fish. CABI Publishing, Wallingford

Hill RA . 2005. Conceptualizing risk assessment methodology for genetically modified organisms. Environ Biosafety Res 4(2):67–70

IEBC, 2012.The revised preliminary Report of the proposed Boundaries of Constituencies and Wards Volume1 55

Ifejika Speranza, C., Kiteme, B. & Wiesmann, U. (2008). Droughts and famines: the underlying factors and the causal links among agro-pastoral households in semi-arid Makueni district, Kenya. Global Environmental Change, 18, 220-233.

Johnson KL, Raybould AF, Hudson MD, Poppy GM. 2007. How does scientific risk assessment of GM crops fit within the wider risk analysis? Trends Plant Sci 12(1):1–5

Kameri-Mbote, P., Africa, B. T. A. B. T., Organisms, G. M. O. G. M. & Protection, I. P. P. I. P. 2009. Regulation of GMO Crops and Foods Kenya Case Study. Faculty of Law University of Nairobi. nd Accessed on, 2.

Kandji ST. 2006. Drought in Kenya: Climatic, Economic and Socio-Political Factors. New Stand Points November-December 2006

Kirimi, L., Sitko, N., Jayne, T. S., Karin, F., Muyanga, M., Sheahan, M., Flock, J. & Bor, G. 2011. A Farm Gate-to-Consumer Value Chain Analysis of Kenya's Maize Marketing

Kornher, Lukas 2018. Maize markets in Eastern and Southern Africa (ESA) in the context of climate change: The state of agricultural commodity markets.

KORIR, L. K. 2011. Risk Management Among Agricultural Households And The Role Of Off-Farm Investments In Uasin Gishu County, Kenya. *Research Theses*.

Kunyanga Nkirote Catherine ,B. Roy Mugiira, and N. Josephat Muchiri 2023: Public Perception of Genetically Modified Organisms and the Implementation of Biosafety Measures in Kenya

Lynam, J. and R.M. Hassan. 1998. A new approach to securing sustained growth in Kenya's maize sector. In Maize technology development and transfer: A GIS application for research planning in Kenya, ed. R.M. Hassan. London: CAB International and Overseas Development Institute (CABI)

Mathenge, M. K., Smale, M. & Olwande, J. 2012. The Impact of Maize Hybrids on Income, Poverty, and Inequality among Smallholder Farmers in Kenya.

Mboya, R., Tongoona, P., Derera, J., Mudhara, M. & Langyintuo, A. 2011. The dietary importance of maize in Katumba ward, Rungwe district, Tanzania, and its contribution to household food security. *Afr. J. Agric. Res,* 6**,** 2617-2626.

Ministry of Agriculture. 2009. Strategic Plan 2008- 2012. Nairobi: Kenya Ministry of Agriculture.

Ministry of Agricuture and Livestock Development. Kenya Natonal variety list, 2023. https://kilimo.go.ke/wp-content/uploads/2024/02/NATIONAL-VARIETY-LIST-APRIL-2023.pdf

Meiguran, 1Dr. Washington Adede Ochola, 1Dr. Martha Nyangau, 2023, IMPACT OF FARMER GROUP DYNAMICS ON MAIZE-SEED VALUE CHAIN PARTICIPATION IN BARINGO SOUTH, KENYA; https://doi.org/10.51193/IJAER.2023.9506

Ministry of Agriculture. 2005. Kenya Strategy for Revitalizing Agriculture (2004-2014), Nairobi, Kenya.

Monetary Policy Committee Agriculture Sector Survey, 2023.

Nickson, T. E. 2008. Planning environmental risk assessment for genetically modified crops: problem formulation for stress-tolerant crops. Plant physiology, 147**,** 494-502.

Nyoro J, Ayieko M and Muyanga M. 2007. The Compatibility of Trade Policy with Domestic Policy Interventions Affecting the Grains Sector in Kenya.

Nyoro J. K, Mary W. Kiiru and T.S. Jayne. 1999. Evolution of Kenya's Maize Marketing Systems in the Post Liberalization Era. Tegemeo Working Paper.

Nyoro, J., M. Ayieko and J. Songa. 2006. Country Report: Kenya. Program for Africa's Seed Systems (PASS). Mimeo. Tegemeo Institute, Nairobi, Kenya 56

Onyango, R. M. A. 1997. A review of Practices and constraints for Maize production in the North Rift part of Kenya.

Oock, P. R. 1981. Education and technical efficiency in small-farm production. Economic development and cultural change, 29**,** 723-739.

Owuor, B. 2010. The Maize Subsector in Kenya: Mending the Granary. Nairobi, Kenya: Heinrich Böll Foundation Regional Office for East & Horn of Africa.

Peden, D., Ottichilo, W. & Mwendwa, H. 1986. Estimating pre-harvest production of maize in Kenya using large-scale aerial photography and radiometry. International Journal of Remote Sensing, 7**,** 1669-1677.

Raybould A. 2006 Problem formulation and hypothesis testing for environmental risk assessments of genetically modified crops. Environ Biosafety Res 5(3):119–125

Smale, M. & Olwande, J. 2011. Is Older Better? Maize Hybrid Change on Household Farms in Kenya. Food Security International Development Working Papers.

Smale, M., D. Byerlee and T.S. Jayne. 2011. Maize Revolutions in Sub-Saharan Africa. Policy Research Working Paper 5659. Development Research Group, World Bank, Washington, DC. Maize paper

Smale, M., and T. S. Jayne. 2010. "Seeds of Success" in Retrospect: Hybrid Maize in Eastern and Southern Africa.

Suri, T. 2011.Selection and Comparative Advantage in Technology Adoption. Econometrica 79 (1): 159-209

Suri, T. 2006. Selection and Comparative Advantage in Technology Adoption. Center Discussion Paper No.944, Economic Growth Center, Yale University

Tegemeo Institute, Egerton University, 2009. Kenya Food Security

Tsedeke A. , Monica F., Tahirou A., Girma T., Rodney L., Paswel M. and Woinishet A,. 2017. Characteristics of maize cultivars in Africa: How modern are they and how many do smallholder farmers grow?

USDA-FAS, 2023. Agricultural Biotechnology Annual Report

Van I., M.K, van Bussel L., Wolf J., Grassini P., van Wart J., Guilpart N., Claessens L., de Groot H., Wiebe K., Mason-D'Croz D., Yang H., Boogaard H., von Oort J., van Loon M., Saito K., Adimo O., Adjei-Nsiah S., Agali A., Bala A., Chikowo R., Kaizzi K., Kouressy M., Makoi R., Ouattara K., Tesfaye K., Cassmann G,. 2016. Can sub-Saharan Africa feed itself? PNAS 113(52): 14964-14969.

APENDIX 1

Respondent's Information and Feedback

Farmer's name..Male ( )   Female (   )

Farm location

County	Sub-County

Farmer's Level of education…………………………………………………………..

Never went to school	Primary	Secondary	Higher education

1. How many hectares do you own? (either leased or own)
   ……………. Ha

2. What crops do you grow on your land? (indicate acreage of each)?
   i).....................
   ii)....................
   iii)...................
   iv)...................

3. What size of your land is under maize?
   --------------Ha

4. How many bags (90kg/bag) of maize do you harvest in your best year (with sufficient rainfall – More than 1100mm per year)? …………..bags

5. In the last 10 years, how many good years (with sufficient rainfall) have you had?

6. Within the last 10 years (between 2013 – 2023), how many bags did you harvest in your worst year (the year with insufficient rainfall)?

7. In the last 10 years, how many worst years have you had (years with insufficient rainfall – less than 800mm/year)?

8. If the Drought Tolerant maize variety being developed is available in this region, would you consider changing the proportion of land under crops you currently grow on your farm?
   1. Yes 2. No

9. If yes, which crop and by what percentage increase (in Ha)?

10. After experiencing drought, does that affect your ability to access improved maize seed for planting the preceding season?
    1. Yes 2. No
11. If your answer in 10 above is yes, does that affect the proportion of land under improved maize seed in the subsequent season?

12. During this year's planting, where did you access your maize seed from?

Source	2023 Quantity (Kg)	Average Quantity (Kg) in the last 10 years
Purchase from Seed dealers		
Donation from government/NGO's/Church		
Own saved seed		
Obtain from neighbour/relative/friend		
Other sources		

13. Do you always get your seed for the named source (s) above?

14. If a new Drought Tolerant maize variety is introduced, would you be interested in planting it?

    1. Yes 2. No

15. If your answer in 14 above is yes, and that the variety is Genetically Modified (GM), would that affect your decision to plant it?

    1. Yes 2. No

16. If the companies producing this variety charges slightly higher (27% from KES. 2,100 to KES. 2,600 per 10kg of seed), would you still consider purchasing the seed?

    1. Yes 2. No

17. What is the main source of diet in your family?

18. If there is crop failure due to severe drought, where would you get your food from?