Int. j. adv. multidisc. res. stud. 2026; 6(1):377-387

Received: 19-11-2025
Accepted: 29-12-2025

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

An Economic Analysis of Agri-Business Growth Models in Maize Productions: A Case Study of Small and Medium Farmers in Chinsali Block B

[1] Chongo Setty, [2] Dr. Chisala Bwalya
[1] Information and Communication University, Lusaka, Zambia
[2] Lecture: School of Humanities, Information and Communication University, Lusaka, Zambia

Corresponding Author: **Chongo Setty**

Abstract
Agriculture remains a cornerstone of Zambia's economy, contributing significantly to food security, employment, and rural livelihoods. Among staple crops, maize plays a central role in both consumption and income generation, particularly for small and medium-scale farmers. In Chinsali Block B, maize production represents a critical component of local agri-business activities, yet farmers face multiple challenges that affect productivity, profitability, and sustainability. The general objective is to analyze the dynamics of maize production in this context, focusing on the operational, technological, and financial factors that shape farmer outcomes. Specifically, the study examines input costs associated with maize production, evaluates the adoption and effects of advanced agricultural technologies and climate-smart agriculture practices, and assesses the profitability of maize production for small and medium-scale farmers. By understanding these factors, the study aims to inform strategies that can enhance efficiency, sustainability, and income generation in maize-based agri-businesses in Chinsali. The study targeted small- to medium-scale maize farmers in Chinsali Block B. A convenience sampling approach was employed to select participants, resulting in a sample of 50 farmers. Data collection was conducted using a semi-structured questionnaire that included both open-ended and closed-ended questions, administered through structured surveys and interviews. Data were entered and analyzed using STATA, with descriptive statistics presented in Microsoft Excel 365. For inferential analysis, ANOVA and regression were applied to examine associations between variables, while Chi-square tests were used to determine relationships among categorical variables. The study revealed considerable variability in both production costs and outputs. Seed costs averaged 848 ZMW per hectare, fertilizer 7,890 ZMW, labor 760 ZMW, land preparation 356 ZMW, harvesting 278 ZMW, and weedkiller 636 ZMW, while average maize yields were 137 kg per hectare, generating mean revenues of 41,300 ZMW. Regression analysis showed that land preparation and weedkiller costs positively influenced production outcomes, while higher labor costs negatively affected performance, with the model explaining 93.8% of revenue variation ($R^2 = 0.938$, $p < 0.001$). Adoption of modern farming technologies was high (84%), with tools such as precision agriculture and soil sensors used most frequently, and 64% of farmers reporting improved yields. Climate-smart agriculture (CSA) practices were adopted by 80% of respondents, predominantly crop rotation (64%) and agroforestry (28%), with effectiveness perceived as high by 40%. Profitability analysis indicated moderate profitability for most participants (66%), with maize contributing an average of 54% to total farm income. Government policies were cited as the largest factor influencing profitability (46%), and 64% of farmers planned to expand maize production in the next five years, reflecting overall optimism about future agri-business growth. The study recommends that Chinsali maize farmers optimize key input costs, expand the use of modern farming technologies and climate-smart practices, and access training to overcome knowledge and cost barriers. Supportive government policies and market access should be strengthened, while farmers strategically plan for sustainable production growth to improve yields and profitability.

Keywords: Artificial Intelligence, Project Performance, Construction Industry, AI Effectiveness, Technology Integration, Construction Project Optimization, AI in Construction

1. Introduction

1.1 Background

Maize is one of the most vital staple crops globally, serving as a fundamental component of food security, economic stability, and agricultural sustainability (Langner, 2019). In many parts of the world, including Africa, maize is a primary source of nutrition, contributing significantly to caloric intake. Globally, maize production has seen remarkable growth due to advancements in agricultural technology, improved crop varieties, and enhanced farming practices (Erenstein, 2022).

In Zambia, maize is the most important crop, accounting for a significant proportion of the country's agricultural output

(Mulungu, 2021). Chinsali, a district in the Muchinga Province of Zambia, presents a unique agro-ecosystem characterized by specific climatic conditions, soil types, and socio-economic factors. The region's agricultural practices, largely driven by smallholder farmers, play a crucial role in shaping the local economy and food security.

From 2004 to 2011, spending on the Farmer Input Support Programme (FISP) constituted an average of 30% of total GRZ agricultural sector spending and 47% of its agricultural sector Poverty Reduction Programme spending. Through FISP, the GRZ provides beneficiary farmers with subsidized fertilizer and hybrid maize seed (Mason, 2013).

The phenomenon of maize production in Chinsali has wide-ranging effects on the local community. Economically, it provides income for smallholder farmers and supports local markets (Rashid, 2019). Positive outcomes include improved livelihoods, enhanced food security, and economic stability for farming households. However, challenges such as soil degradation, water scarcity, and vulnerability to climate change pose significant risks (Nhemachena, 2020). Addressing these challenges requires a holistic approach that integrates sustainable agricultural practices, policy support, and community engagement to ensure the long-term viability of maize production in the Chinsali agro-ecosystem.

1.2 Statement of the Problem

In recent years, Zambia has witnessed fluctuating maize yields, which have led to both surplus and deficit scenarios, impacting national food security and economic stability. According to the Ministry of Agriculture, in the 2021/22 season, Zambia achieved its largest corn crop on record, producing 3.6 million tons, a seven percent increase from the 3.4 million tons produced in 2020/21. Over the past two decades, Zambia has more than doubled its corn production by expanding both the cultivation area and productivity, transforming the country into a net corn exporter. It is estimated that Zambia consumed approximately 2.4 million tons of corn in 2021/22, leaving a surplus available for export to neighboring countries (Esterhuizen, 2021). However, this increase masks underlying issues such as inconsistent rainfall patterns, inadequate access to quality seeds and fertilizers, and poor farming practices. Moreover, the Zambia Statistics Agency reported that over 60% of the rural population relies on maize as their primary food source and income. Despite this reliance, smallholder farmers, who produce the majority of the maize, often experience low productivity due to limited access to credit, extension services, and modern farming technologies (Fan, 2020).

1.3 Objectives

1.3.1 General Objectives

To analyze the agri-business dynamics of maize production within the Chinsali Block B agro-ecosystem.

1.3.2 Specific Objectives

1. To analyze the input costs associated with maize production within the Chinsali Block B agro-ecosystem.
2. To assess the efficacy and adoption rates of advanced agricultural technologies and climate-smart agriculture (CSA) practices among maize producers in the Chinsali.
3. To analyze the profitability of maize production in the Chinsali Block B agro-ecosystem.

1.4 Research Questions

1. What is the cost structure associated with maize production in the Chinsali Block B agro-ecosystem?
2. How effective are modern farming technologies and climate-smart agriculture (CSA) practices, and what are the adoption rates among local maize producers?
3. How profitable is maize production in the Chinsali Block B agro-ecosystem?

1.5 Conceptual Framework

This framework illustrates the intricate relationships between key factors that affect maize production within the Chinsali agro-ecosystem, highlighting how multiple aspects interact to influence the overall business performance of maize farming. Specifically, it examined how critical factors such as input costs, technology adoption, climate conditions, market access, farmer knowledge, and government support shape the cost structure, yield, efficiency, and profitability of maize production. Input costs covering expenditures on seeds, fertilizers, labor, and equipment directly impact production costs, which in turn affect overall profitability. Technology adoption, including mechanization, irrigation, and climate-smart agriculture (CSA) practices, plays a significant role in enhancing productivity and optimizing resource use, contributing to increased yields and greater production efficiency

2. Literature Review

2.1 The cost structure associated with maize production in an agro-ecosystem

Input costs are a critical component of the overall expenses in maize production, encompassing the various resources necessary to cultivate and maintain a healthy crop (Tarus, 2019) [33]. The quantity and type of fertilizer used can significantly affect the cost. Additionally, the timing and method of fertilizer application also impact its efficiency and the overall cost, requiring careful planning and management to maximize the return on investment (Lyu, 2021).

Pesticides are another vital input, used to protect the maize crop from a variety of pests and diseases that can severely impact yield (Lyu, 2021). The costs associated with land preparation can be substantial, especially if mechanized equipment like tractors and plows are used. The use of machinery, while increasing efficiency and reducing labor time, also entails expenses related to fuel, maintenance, and depreciation of equipment. In areas where mechanization is limited, manual land preparation can be labor-intensive and time-consuming, adding to the overall cost (Biswas, 2022).

2.2 Effectiveness and adoption rates of modern farming technologies and climate-smart agriculture (CSA) practices among maize producers

Precision agriculture represents a revolutionary shift in farming practices, leveraging advanced technologies such as GPS-guided tractors, drones, and sensor systems to enhance agricultural efficiency and productivity (Kasenzu, 2024) [12]. GM seeds, engineered through biotechnology, offer various advantages over traditional seed varieties (Adewusi, 2024). These seeds are designed to withstand specific challenges such as pest infestations, diseases, and environmental stressors. For instance, GM maize varieties resistant to certain pests can reduce the need for chemical pesticides, which not only lowers production costs but also minimizes environmental harm. Additionally, GM seeds can be engineered to tolerate extreme weather conditions, such as drought or excessive rainfall, enhancing crop resilience and stability in the face of climate variability (Ahmad, 2020).

Irrigation technologies have undergone significant advancements, revolutionizing how water is managed in agriculture (Shah, 2020). Key innovations include drip irrigation, sprinkler systems, and moisture sensors, each playing a crucial role in optimizing water usage and improving crop productivity. Drip irrigation is one of the most efficient methods, delivering water directly to the plant roots through a network of tubes and emitters. This system minimizes evaporation and runoff, ensuring that water is applied precisely where it is needed. For crops like maize, which require consistent moisture for optimal growth, drip irrigation provides a reliable solution in water-scarce regions. By targeting the root zone, drip systems not only conserve water but also enhance nutrient uptake and reduce weed growth, leading to healthier and more productive crops.

Fertilizer management is another critical aspect of modern agriculture, with technologies such as precision fertilizer spreaders and soil nutrient sensors playing key roles in enhancing nutrient use efficiency. Precision fertilizer spreaders are equipped with advanced controls and GPS technology that allow for the accurate application of fertilizers. These systems can vary the rate of application based on specific field zones, ensuring that nutrients are distributed according to crop needs and soil conditions. By avoiding over-application, precision spreaders help optimize fertilizer use, improve crop yields, and reduce environmental impact (Naz, 2021).

Soil nutrient sensors provide valuable information about the nutrient content of the soil, enabling farmers to make data-driven decisions about fertilizer applications. These sensors measure levels of essential nutrients such as nitrogen, phosphorus, and potassium, allowing for the precise adjustment of fertilizer inputs. By understanding the nutrient status of the soil, farmers can tailor their fertilizer applications to address specific deficiencies and avoid excess, which can lead to nutrient runoff and pollution of water bodies. This targeted approach not only enhances crop growth and productivity but also promotes environmental sustainability by minimizing the negative impacts of over-fertilization (Naz, 2021).

2.3 Profitability of maize production within an agro-ecosystem

The profitability of maize production within an agro-ecosystem is influenced by a complex array of factors that interplay to determine the economic success of maize farming (Lorenzetti, 2024). Maize, a staple crop in many regions around the world, is grown in diverse agro-ecosystems, each with its unique set of climatic, soil, and economic conditions. Understanding these factors is essential for evaluating profitability and developing strategies to enhance the economic viability of maize production. The climate and soil conditions of an agro-ecosystem significantly impact maize production. Maize requires a favorable climate with adequate rainfall and moderate temperatures for optimal growth. Agro-ecosystems with reliable rainfall and well-distributed precipitation throughout the growing season typically support higher maize yields (Ababa, 2019) [1]. Conversely, regions experiencing drought or irregular rainfall patterns face challenges, as water stress can lead to reduced yields and increased production costs due to the need for supplementary irrigation.

Soil quality is equally crucial. Fertile soils with good structure and nutrient content support high maize productivity. In contrast, soils that are degraded, nutrient-deficient, or prone to erosion can hinder crop growth and yield. Effective soil management practices, such as soil testing, use of organic and inorganic fertilizers, and conservation tillage, are necessary to maintain soil health and enhance maize production (Ababa, 2019) [1]. Agro-ecosystems with access to fertile soils and effective soil management practices generally experience higher profitability. Agricultural practices directly influence the productivity and profitability of maize production. Adoption of modern farming technologies and practices, such as high-yielding maize varieties, precision agriculture, and integrated pest management, can significantly improve yields and reduce costs. In addition to technological improvements, practices such as crop rotation and conservation agriculture (including minimal tillage and cover cropping) contribute to soil health and productivity. These practices help prevent soil degradation, manage pests and diseases, and enhance nutrient availability. By improving the efficiency of resource use and reducing environmental impact, these practices can boost profitability.

Economic factors play a critical role in determining the profitability of maize production. Key economic considerations include the costs of inputs (seeds, fertilizers, pesticides, labor), market prices, and access to financial resources. Initial investments in inputs and technology can be substantial, and access to affordable credit or subsidies can help mitigate these costs. Market prices for maize fluctuate based on supply and demand dynamics, both locally and globally. Farmers in agro-ecosystems with stable market access and price stability are better positioned to achieve profitability. Conversely, regions with volatile prices or poor market infrastructure may face challenges in achieving consistent profitability. Developing robust market linkages, improving transportation infrastructure, and implementing price stabilization mechanisms can help improve economic outcomes for maize producers.

3. Research Methodology

3.1 Research Design

The study embraced a cross-sectional survey study design, employing a quantitative methodology for gathering primary data.

3.2 Target Population

The target population for this study were small to medium scale farms in Chinsali.

3.3 Sample Size

The study consisted of 100 small-Medium scale farmers in Chinsali.

3.4 Sampling

The study employed convenience sampling technique.

3.5 Data Collection Methods
The main research tool used in the study was a semi-structured. These methods involved the use of standardized questionnaires and face-to-face interview but mostly electronic questionnaire to gather data on the research variables.

3.6 Data Analysis
Data entry and analysis was done using STATA. Descriptive statistics, including frequencies, percentages, and means, was used to summarize data. Chi - square was used to establish associations between variables.

3.7 Triangulation
The study employed triangulation as a research strategy to enhance the validity and reliability of the findings.

3.8 Ethical Consideration
The study upheld ethical aspects including obtaining informed consent, safeguarding participant confidentiality and privacy, and utilizing acquired information solely for academic reasons. Stringent confidentiality measures were maintained. Equal and unbiased treatment was given to all participants, who held the choice to participate or decline without any adverse effects. This research carried no risk of physical harm.

3.9 Study Limitations
The study faced several limitations, including its geographic focus on Lusaka, which restricts the generalization of findings to other regions with differing challenges and AI adoption levels.

4. Result Presentation
4.1 Presentation of results on background characteristics of the respondents
The age of respondents ranged from a minimum of 29 years to a maximum of 65 years. The mean age was 46.46 years, with a standard deviation of 6.738, indicating that the majority of respondents were middle-aged with some variation.

Table 1: Age

Descriptive Statistics						
	N	Range	Minimum	Maximum	Mean	Std. Deviation
Age	100	36	29	65	46.46	6.738
Valid N (listwise)	100					

Out of 100 respondents, 86 (86%) were male and 14 (14%) were female, indicating a significant male dominance in the sample.

Table 2: Participants gender

		Frequency	Valid Percent	Cumulative Percent
Valid	Male	86	86.0	86.0
	Female	14	14.0	100.0
	Total	100	100.0	

The educational background of the respondents varied, with the majority having secondary (44%) and tertiary education (42%). A smaller portion had no formal education (12%), and only 2% had completed primary education.

Table 3: Participant's education background

		Frequency	Valid Percent	Cumulative Percent
Valid	No formal education	6	12.0	12.0
	Primary education	1	2.0	14.0
	Secondary	22	44.0	58.0
	Tertiary education	21	42.0	100.0
	Total	100	100.0	

Participants reported between 3 and 34 years of farming experience, with an average of 17.54 years. The standard deviation of 6.786 indicates that there is considerable variation in farming experience among the respondents.

Table 4: Years of Farming Experience

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
	100	3	34	17.54	6.786
Valid N (listwise)	100				

A large majority (82%) of respondents owned the land they farmed on, 14% partially owned their land, while only 4% did not own any land. The size of farms ranged from 8 to 43 hectares, with a mean farm size of 19.78 hectares.

Table 5: Farm Size

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
	100	8	43	19.78	8.185
Valid N (listwise)	100				

The primary sources of income were predominantly farming, with 36% of respondents focusing on crops and 28% on livestock. Employment (non-agricultural) was the source for 26%, while 8% relied on business/trading, and 2% on remittances.

Table 6: Primary Source of Income

		Frequ	Valid %	Cumulative %
Valid	Farming (crops)	18	36.0	36.0
	Farming (Livestock)	14	28.0	64.0
	Business/trading	4	8.0	72.0
	Employment (non-agricultural)	13	26.0	98.0
	Remittances	1	2.0	100.0
	Total	100	100.0	

Less than half of the respondents (46%) had access to agricultural credit or loans, while the majority (54%) did not have such access.

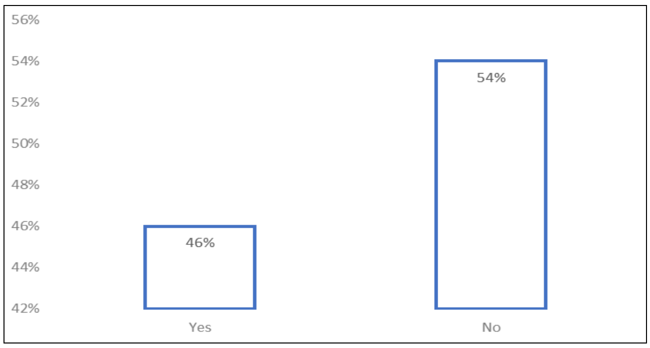

Fig 1: Access to Agricultural Credit

4.2 Agri-business production growth strategies adopted by small and medium maize farmers in Chinsali Block B

The study found that 30% of farmers use family-based subsistence farming, while 28% engage in contract farming, and 24% participate in cooperatives. Only 18% operate independently on a commercial scale.

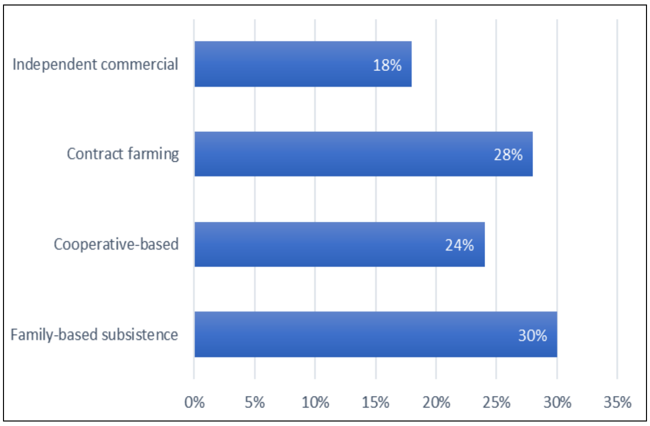

Fig 4.2.1: Type of maize farming model

Most respondents (40%) finance maize production through personal savings, followed by 20% using cooperative/community funds. Government grants and NGO support account for 16% and 14% respectively, while bank loans are the least utilized at 10%.

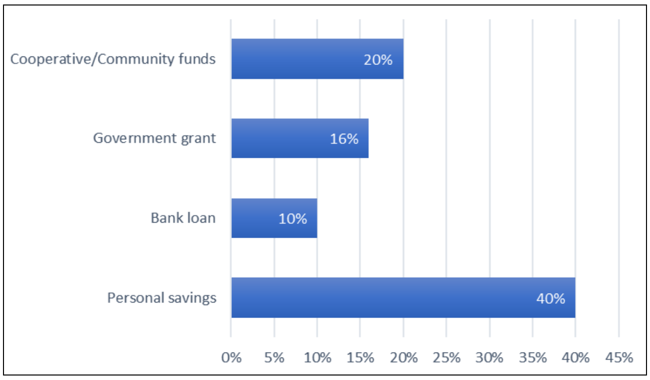

Fig 4.2.2: Main source of funding

The majority of farmers (36%) sell maize in local markets, with 30% using middlemen/traders. Only 10% sell directly to processing companies, and 20% sell via cooperatives. This shows that direct market linkages are underdeveloped, potentially reducing profit margins.

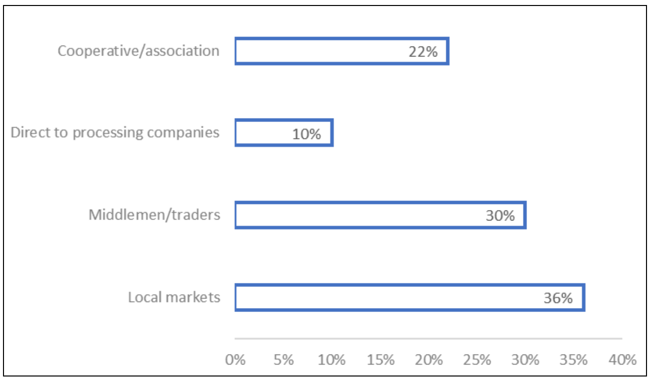

Fig 4.2.3: How maize is sold

Farmers most frequently use improved seed varieties (30%) and fertilizer application (28%) to increase maize yields. Crop rotation and mechanization are applied by 16% each, and irrigation methods by only 10%, indicating reliance on basic yield-enhancing techniques over modern or intensive strategies.

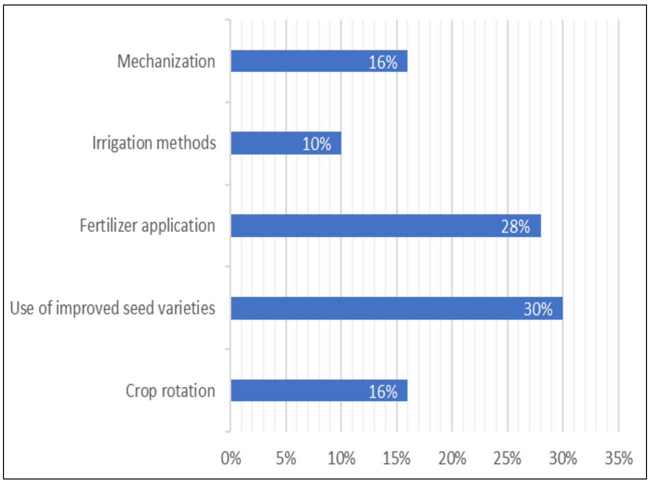

Fig 4.2.4: Strategy to increase yield

36% of farmers have accessed government extension services, while 24% participate in cooperative workshops. NGO programs and private consultants reach fewer farmers (14% and 10%), and 16% report no access to advisory support, highlighting gaps in extension coverage and knowledge transfer.

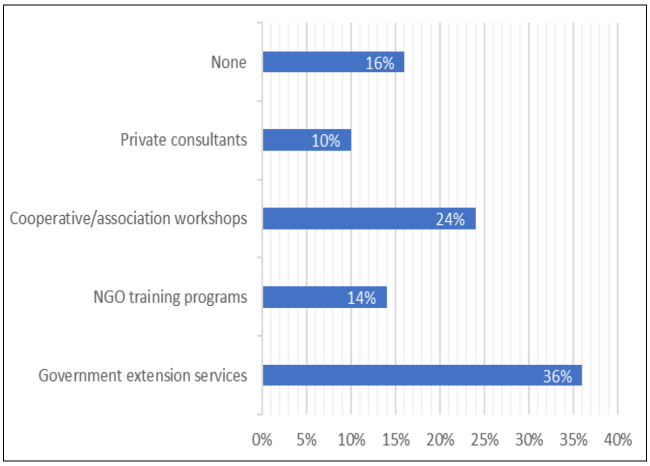

Fig 4.2.5: Training/advisory support

The leading factor influencing adoption of new strategies is potential yield increase (40%), followed by cost of implementation (20%). Peer advice and expert guidance influence fewer farmers (18% and 16%), while only 6% consider resource availability the main factor.

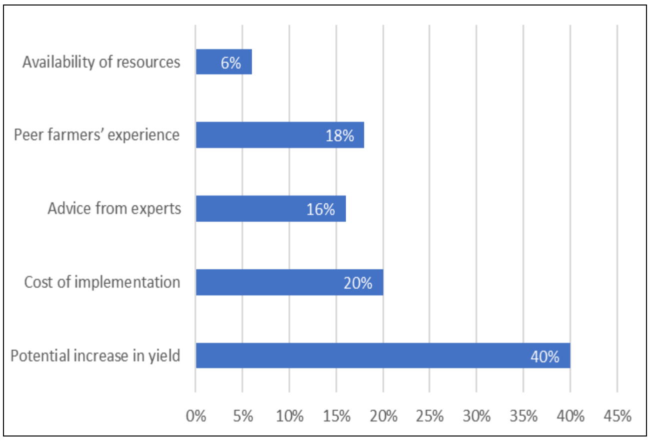

Fig 4.2.6: Factor influencing adoption

The cost of seeds per hectare ranged from 540 to 1,360 ZMW, with a total sum of 42,404 ZMW across all participants. The mean cost was 848.08 ZMW, with a standard deviation of 248.604, indicating moderate variability in seed costs.

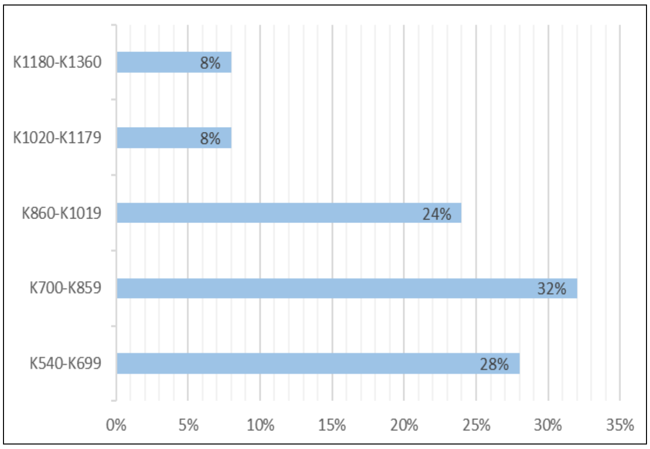

Fig 4.2.7: Average Cost of Seeds per Hectare for Maize Production

Participants reported spending between 7,500 and 8,200 ZMW on fertilizer per hectare, with a total of 394,500 ZMW. The mean cost was 7,890.00 ZMW, and the standard deviation was 192.989, showing relatively low variation in fertilizer costs.

Table 4.2.1: Fertilizer Cost per Hectare for Maize Production

	N	Minimum	Maximum	Mean	Std. Deviation
	100	7500	8200	7890.00	192.989
Valid N (listwise)	100				

Labor costs ranged from 500 to 1,000 ZMW, with a total sum of 38,000 ZMW. The average labor cost was 760.00 ZMW, with a standard deviation of 160.357, indicating some variation in labor expenses.

Table 4.2.2: Labor Cost per Hectare for Maize Production

Descriptive Statistics						
	N	Range	Minimum	Maximum	Mean	Std. Deviation
	100	500	500	1000	760.00	160.357
Valid N (listwise)	100					

The cost of land preparation per hectare ranged from 100 to 600 ZMW, with a total sum of 17,800 ZMW. The mean was 356.00 ZMW, and the standard deviation was 160.560, indicating variability in preparation costs.

Table 4.2.3: Land Preparation Cost per Hectare

Descriptive Statistics						
	N	Range	Minimum	Maximum	Mean	Std. Deviation
	100	500	100	600	356.00	160.560
Valid N (listwise)	100					

Participants reported yields ranging from 0 to 450 kg per hectare, with a total sum of 6,850 kg. The mean yield was 137.00 kg, and the standard deviation was 138.803, suggesting a wide range in maize productivity.

Table 4.2.4: Average Maize Yield per Hectare

	N	Minimum	Maximum	Mean	Std. Deviation
	100	0	450	137.00	138.803
Valid N (listwise)	100				

Harvesting costs varied from 0 to 500 ZMW, with a total sum of 13,892 ZMW. The mean cost was 277.84 ZMW, with a standard deviation of 141.382, indicating significant differences in harvesting expenses.

Table 4.2.5: Harvesting Costs per Hectare

	N	Minimum	Maximum	Mean	Std. Deviation
	100	0	500	277.84	141.382
Valid N (listwise)	100				

The cost of weedkiller ranged from 500 to 800 ZMW, with a total sum of 31,780 ZMW. The mean cost was 635.60 ZMW, and the standard deviation was 79.723, showing relatively low variation in weedkiller costs.

Table 4.2.6: Weedkiller Cost per Hectare

Descriptive Statistics						
	N	Range	Min	Max	Mean	Std. Deviation
	100	300	500	800	635.60	79.723
Valid N (listwise)	100					

Revenue from maize sales ranged from 30,000 to 70,000 ZMW per hectare, with a total sum of 2,065,000 ZMW. The mean revenue was 41,300.00 ZMW, with a standard deviation of 7,259.758, indicating a wide range in income from maize sales.

Table 4.2.8: Average Revenue per Hectare from Maize Sales

Descriptive Statistics						
	N	Range	Minimum	Maximum	Mean	Std. Deviation
	100	40000	30000	70000	41300.00	7259.758
Valid N (listwise)	100					

The regression sum of squares is 186,521,917.808 with 1 degree of freedom (df), and the residual sum of squares is 2,395,978,082.192 with 48 degrees of freedom, leading to a total sum of squares of 2,582,500,000. The mean square for the regression is 186,521,917.808, and the residual mean square is 49,916,210.046.

Table 4.2.9: Fertilizer cost per hectare and the average revenue per hectare from maize sales

ANOVA[a]					
Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	186521917.808	1	186521917.808	3.737	.059[b]
Residual	2395978082.192	48	49916210.046		
Total	2582500000.000	49			
a. Dependent Variable: cost on Fertilizer Cost per Hectare for Maize Production					
b. Predictors: (Constant), Average Revenue per Hectare from Maize Sales					

The F-value is 3.737 with a p-value (Sig.) of 0.059, which is slightly above the common significance threshold of 0.05. This indicates that the relationship between fertilizer cost per hectare and the average revenue per hectare from maize sales is not statistically significant at the 5% level, but it is close, suggesting a potential relationship that may require further investigation with a larger or more refined dataset.

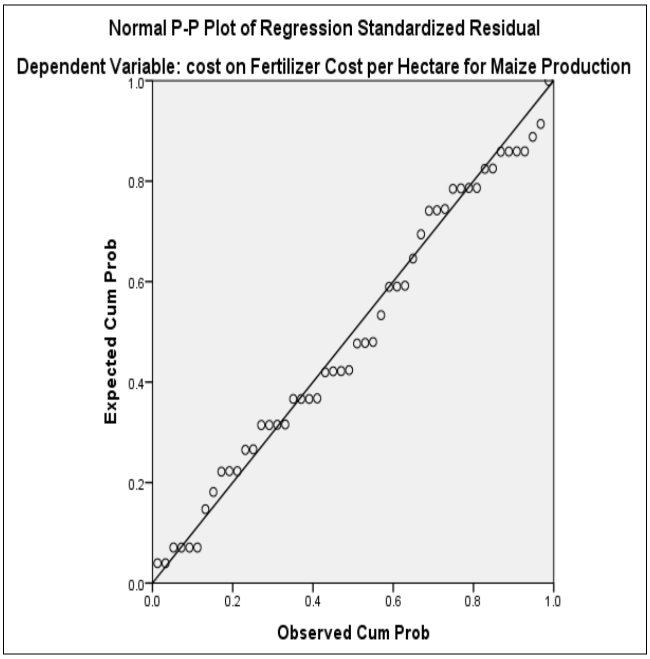

Fig 4.2.8: Relationship between fertilizer cost per hectare and the average revenue per hectare from maize sales

These statistics indicate that there is considerable variability in both the costs and revenues associated with maize production among participants, with expenses like labor, land preparation, and yields showing significant ranges. However, inputs like fertilizer and weedkiller exhibit more consistency across the sample.

The linear regression analysis reveals that the average costs of land preparation and weedkiller per hectare significantly and positively influence the dependent variable, with coefficients of 335.734 (p = 0.001) and 3635.14 (p = 0.027), respectively, highlighting their critical role in enhancing outcomes. Conversely, average labor costs per hectare exhibit a significant negative effect (coefficient: -213.443, p = 0.01), suggesting that higher labor expenses reduce performance. The cost of seeds shows a borderline positive impact (coefficient: 0.167, p = 0.058), while harvesting costs have no significant influence (coefficient: -6.175, p = 0.58). The model explains 93.8% of the variation in the dependent variable (R-squared = 0.938) and is statistically significant overall (F-test = 169.585, p < 0.001), emphasizing the importance of optimizing costs in land preparation and weed control to maximize performance.

Table 4.2.10: Linear regresson

	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
average cost of seeds per hectare	.167	.086	1.93	.058	-.006	.34	*
average labor cost per hectare	-213.443	80.134	-2.66	.01	-373.97	-52.915	**
average land preparation cost per hectare	335.734	96.931	3.46	.001	141.557	529.911	***
average harvesting costs per hectare	-6.175	11.091	-0.56	.58	-28.392	16.042	
Average cost of weedkiller	3635.14	1597.446	2.28	.027	435.071	6835.21	**

Mean dependent var	9580.645	SD dependent var	4596.144
R-squared	0.938	Number of obs	62
F-test	169.585	Prob > F	0.000

4.3 The effectiveness of modern farming technologies and climate-smart agriculture (CSA) practices among local maize producers

The responses to the question "How long have you been using modern farming technologies?" show that, on average, participants have been using these technologies for 5.92 years. The reported duration ranges from 0 to 10 years, with a standard deviation of 3.596, indicating some variation in the length of time respondents have been utilizing modern farming technologies.

Table 4.3.1: Duration of using modern farming technologies

Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
	100	0	10	5.92	3.596
Valid N (listwise)	100				

The use of technologies varied, with 32% using precision agriculture tools and another 32% using soil sensors. Drones were used by 24% of respondents, while automated irrigation systems were utilized by 12%.

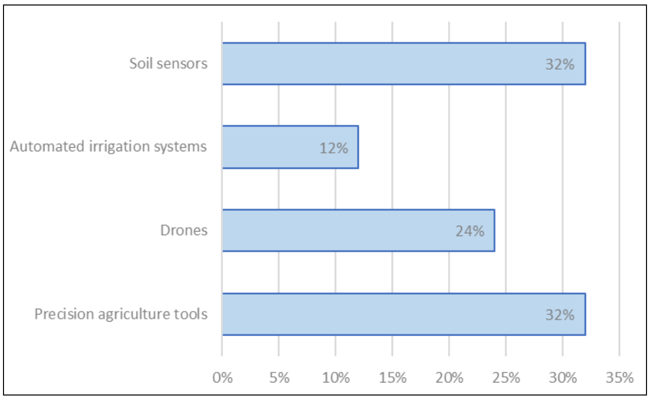

Fig 4.3.2: Type of Modern Farming Technology Used Most Frequently

The Pearson Chi-Square value is 5.357 with 2 degrees of freedom (df) and a p-value of 0.029, which is less than the standard threshold of 0.05. This indicates a statistically significant association between the use of modern farming technologies and farmers' perceptions of their effectiveness in increasing maize yields. The Linear-by-Linear Association has a value of 4.667 with a p-value of 0.031, suggesting a significant linear trend in the relationship between the use of modern technologies and perceived effectiveness in increasing yields.

Table 4.3.2: Association between the use of modern farming technologies and farmers' perceptions of their effectiveness in increasing maize yields

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.357[a]	2	.029
Likelihood Ratio	7.978	2	.019
Linear-by-Linear Association	4.667	1	.031
N of Valid Cases	100		

The Pearson Chi-Square value is 28.548 with 6 degrees of freedom (df) and a p-value of 0.0001 which is highly significant. This indicates a strong statistically significant association between the type of modern farming technology used and farmers' perceptions of its effectiveness in increasing maize yields.

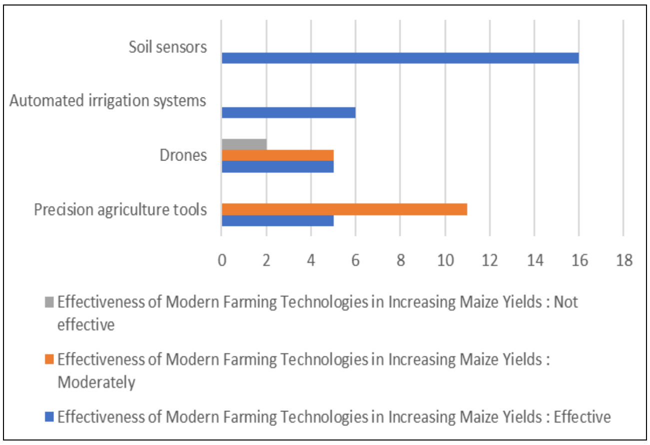

Fig 4.3.5: Association between the type of modern farming technology used and farmers' perceptions of its effectiveness in increasing maize yields

Most respondents (94%) reported that 26-50% of their maize farming activities involve modern technologies. A small percentage (2%) reported less than 25%, while another 2% indicated that more than 75% of their activities involve modern technologies.

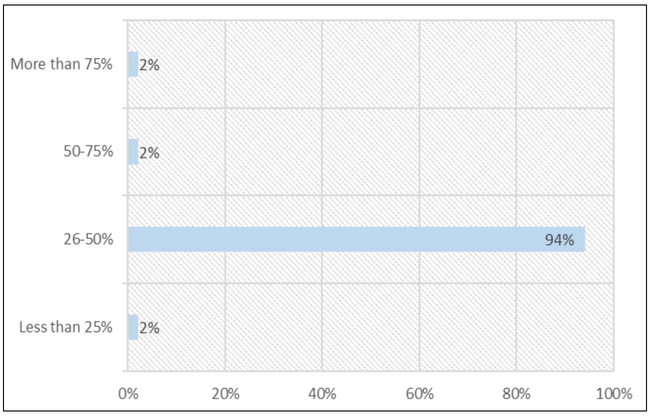

Fig 4.4.6: Percentage of Maize Farming Activities Involving Modern Technologies

Crop rotation was the most widely adopted practice (64%), followed by agroforestry (28%), conservation tillage (6%), and water harvesting (2%).

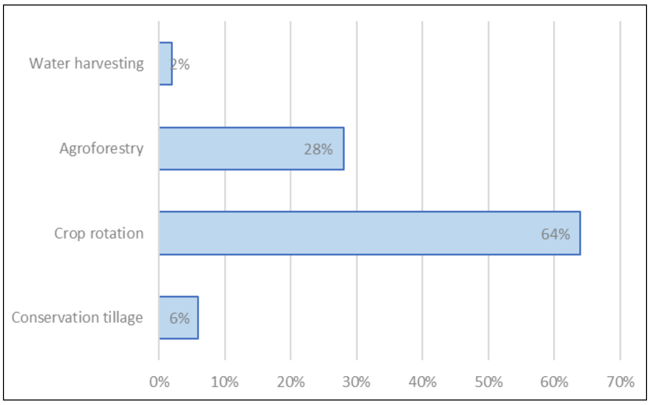

Fig 4.4.8: CSA Practices Adopted

Agriculture NGOs were the primary source of information for 42% of respondents, followed by online resources (34%), farmer cooperatives (16%), and government extension services (8%).

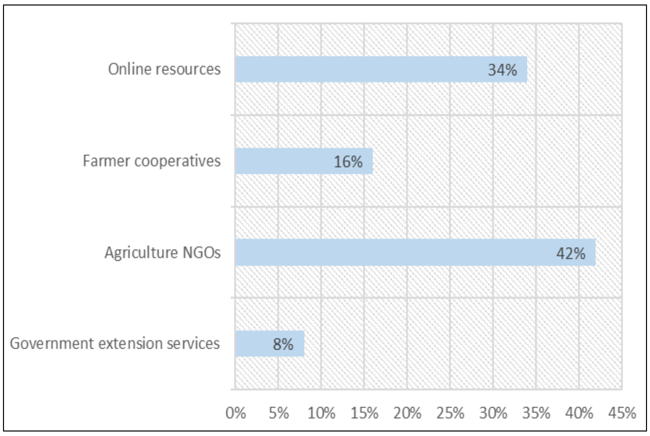

Fig 4.4.10: Main Source of Information About Modern Farming Technologies and CSA Practices

The biggest barrier was the high cost (50%), followed by a lack of knowledge (34%), lack of access to technology (6%), and resistance to change (10%).

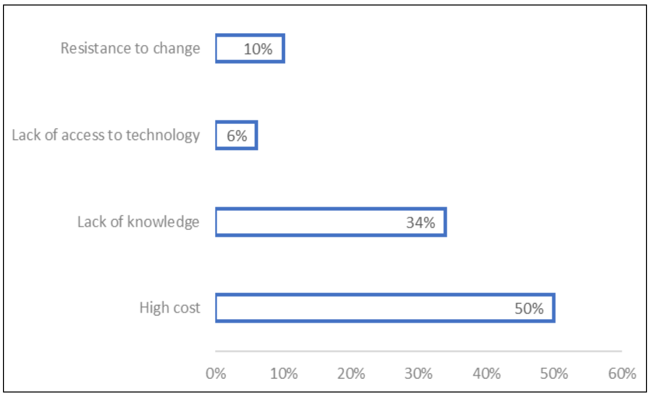

Fig 4.4.11: Main Barriers to Adopting Modern Farming Technologies and CSA Practice

4.4 Profitability of maize production in the Chinsali agro-ecosystem

The average selling price of maize reported by participants is 5,532 currency units per ton. The prices ranged between 4,500 and 6,500, with a standard deviation of 426.39, indicating moderate variability in the price among participants.

Table 4.5.1: Figure Average Selling Price of Maize per Ton

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
	100	4500	6500	5532.00	426.394
Valid N (listwise)	100				

On average, participants reported that 54% of their total farm income comes from maize production. The reported percentages ranged from 10% to 80%, with a standard deviation of 18.93, suggesting a broad range of dependency on maize as a source of income.

Table 4.5.2: Percentage of Total Farm Income Derived from Maize Production

Descriptive Statistics						
	N	Range	Min	Max	Mean	Std. Deviation
	100	70	10	80	54.00	18.925
Valid N (listwise)	100					

The majority (52%) indicated that maize profitability has increased slightly over the last five years. Around 34% said it has stayed the same, while 8% reported a significant increase. Only 6% observed a decrease in profitability, indicating an overall positive or stable trend in profitability for most participants.

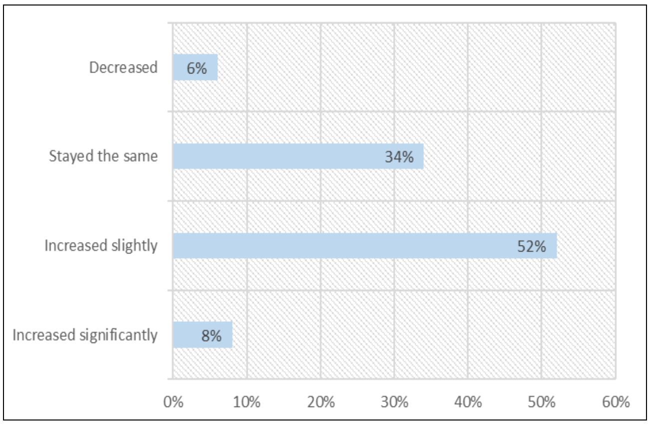

Fig 4.4.2: Profitability Changes Over the Past Five Years

Participants attributed the greatest influence on profitability to government policies (46%), followed by yield levels (20%), input costs (18%), and market prices (16%). This indicates that external factors like government interventions play a significant role in determining profitability.

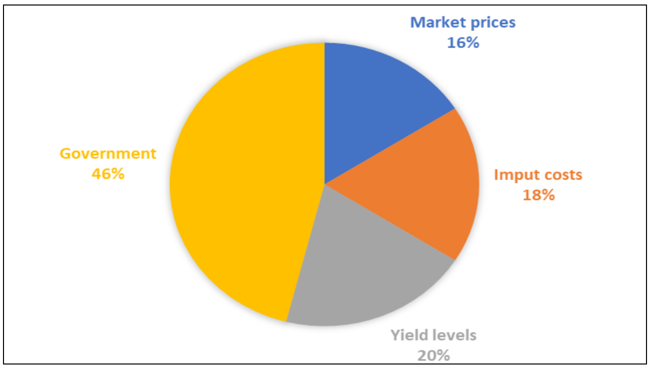

Fig 4.4.3: Factors Influencing Maize Profitability

5. Discussion of Study Findings

The study found that small and medium maize farmers in Chinsali Block B use varied growth strategies driven by financial capacity, market access, technology adoption, and advisory support. Most farmers rely on family-based or cooperative farming, with limited use of commercial or mechanized approaches due to financial and technical barriers. Production is largely financed through personal savings or community funds, while access to bank loans remains low. Market participation is dominated by local sales and intermediaries, limiting profitability, though cooperatives offer potential for improved bargaining power. Farmers mainly adopt basic yield-enhancing methods such as improved seed and fertilizer use, while advanced technologies like irrigation and mechanization remain underused. Extension services are unevenly accessed, with many farmers lacking consistent advisory support. Input costs, particularly fertilizer, significantly affect total production costs, and high variability in seed and labor expenses reflects differing access to resources. Modern technologies and climate-smart agriculture practices show high adoption and perceived effectiveness, though barriers such as cost and limited knowledge persist. Maize production is moderately profitable for most farmers, influenced mainly by government policies, input costs, and market conditions. While profitability has slightly improved over five years and many farmers plan expansion, financial, technical, and market challenges continue to constrain sustainable growth in the Chinsali agro-ecosystem.

5.1 Conclusion

The findings suggest that while the relationship between fertilizer costs and revenue is not statistically significant at the 5% level, the proximity to this threshold signals potential economic impacts that merit further exploration. On the other hand, the widespread adoption of modern farming technologies, reported by 84% of respondents, showed a strong association with increased maize yields. Precision agriculture tools, soil sensors, and drones are among the most commonly used technologies, with a clear positive correlation between technology usage and perceived effectiveness in yield improvement.

6. References

1. Ababa A. Ministry of Agriculture Sustainable Land Management Program, 2019.
2. Adewusi AO, Asuzu OF, Olorunsogo T, Iwuanyanwu C, Adaga E, Daraojimba DO. AI in precision agriculture: A review of technologies for sustainable farming practices. World Journal of Advanced Research and Reviews. 2024; 21(1):2276-2285.
3. Ahmad SF, Dar AH. Precision farming for resource use efficiency. Resources Use Efficiency in Agriculture, 2020, 109-135.
4. Amondo E, Simtowe F, Rahut DB, Erenstein O. Productivity and production risk effects of adopting drought-tolerant maize varieties in Zambia. International Journal of Climate Change Strategies and Management. 2019; 11(4):570-591.
5. Andorf C, Beavis WD, Hufford M, Smith S, Suza WP, Wang K, *et al*. Technological advances in maize breeding: Past, present and future. Theoretical and Applied Genetics. 2019; 132:817-849.
6. Avadí A, Cole SM, Kruijssen F, Dabat MH, Mungule CM. How to enhance the sustainability and inclusiveness of smallholder aquaculture production systems in Zambia? Aquaculture. 2022; 547:p.737494.
7. Biswas R, Molla MMU, Faisal-E-Alam M, Zonayet M, Castanho RA. Profitability analysis and input use efficiency of maize cultivation in selected areas of Bangladesh. Land. 2022; 12(1):p.23.
8. Erenstein O, Jaleta M, Sonder K, Mottaleb K, Prasanna BM. Global maize production, consumption and trade: Trends and R&D implications. Food Security. 2022; 14(5):1295-1319.
9. Fan S, Rue C. The role of smallholder farms in a changing world. The role of smallholder farms in food and nutrition security, 2020, 13-28.
10. Kamara A, Conteh A, Rhodes ER, Cooke RA. The relevance of smallholder farming to African agricultural growth and development. African Journal of Food, Agriculture, Nutrition and Development. 2019; 19(1):14043-14065.
11. Kansanga M, Andersen P, Kpienbaareh D, Mason-Renton S, Atuoye K, Sano Y, *et al*. Traditional agriculture in transition: Examining the impacts of agricultural modernization on smallholder farming in Ghana under the new Green Revolution. International Journal of Sustainable Development & World Ecology. 2019; 26(1):11-24.
12. Kasenzu B. Role of Precision Agriculture Technologies in Enhancing Farm Productivity in Kenya. American Journal of Agriculture. 2024; 6(2):1-12.
13. Katengeza SP, Holden ST, Lunduka RW. Adoption of drought tolerant maize varieties under rainfall stress in Malawi. Journal of Agricultural Economics. 2019; 70(1):198-214.
14. Langner JA, Zanon AJ, Streck NA, Reiniger LR, Kaufmann MP, Alves AF. Maize: Key agricultural crop in food security and sovereignty in a future with water scarcity. Revista Brasileira de Engenharia Agrícola e Ambiental. 2019; 23:648-654.Ba-1
15. Lamichhane S, Thapa S. Advances from conventional to modern plant breeding methodologies. Plant Breeding and Biotechnology. 2022; 10(1):1-14.
16. Lorenzetti LA, Fiorini A. Conservation Agriculture Impacts on Economic Profitability and Environmental Performance of Agroecosystems. Environmental Management. 2024; 73(3):532-545.
17. Lyu Y, Yang X, Pan H, Zhang X, Cao H, Ulgiati S, *et al*. Impact of fertilization schemes with different ratios of urea to controlled release nitrogen fertilizer on environmental sustainability, nitrogen use efficiency and economic benefit of rice production: A study case from Southwest China. Journal of Cleaner Production. 2021; 293:p.126198.
18. McFadden J, Njuki E, Griffin T. Precision agriculture in the digital era: Recent adoption on US farms, 2023.
19. Meyo ESM, Egoh IM. Assessing the impacts of variable input costs on maize production in Cameroon, 2020.
20. Mulungu K, Tembo G, Bett H, Ngoma H. Climate change and crop yields in Zambia: Historical effects and future projections. Environment, Development and Sustainability. 2021; 23:11859-11880.
21. Mujeyi A, Mudhara M. Economic analysis of climate-smart agriculture technologies in maize production in smallholder farming systems. African Handbook of Climate Change Adaptation, 2020, 1-16.
22. Napasintuwong O. Maize Seed Production in Thailand: Costs, Returns, and Contract Participation. Journal of Agricultural Science and Technology. 2022; 24(3):505-520.
23. Naz MY, Shukrullah S, Ghaffar A. Sensors detecting controlled fertilizer release. In Controlled Release Fertilizers for Sustainable Agriculture. Academic Press, 2021, 131-153.
24. Nhemachena C, Nhamo L, Matchaya G, Nhemachena CR, Muchara B, Karuaihe ST, *et al*. Climate change impacts on water and agriculture sectors in Southern Africa: Threats and opportunities for sustainable development. Water. 2020; 12(10):p.2673.
25. Palacios-Rojas N, McCulley L, Kaeppler M, Titcomb TJ, Gunaratna NS, Lopez-Ridaura S, *et al*. Mining maize diversity and improving its nutritional aspects within agro-food systems. Comprehensive Reviews in Food Science and Food Safety. 2020; 19(4):1809-1834.
26. Phiri J, Malec K, Majune SK, Appiah-Kubi SNK, Gebeltová Z, Maitah M, *et al*. Agriculture as a determinant of Zambian economic sustainability. Sustainability. 2020; 12(11):p.4559.
27. Rajesh CM, Jadhav A, Manohar KN, Bhat PP, Prasad R, Anil K, *et al*. A Review on Adaptive Strategies for Climate Resilience in Agricultural Extension Services in India. Archives of Current Research International. 2024; 24(6):140-150.
28. Rashid S, Getnet K, Lemma S. Maize value chain potential in Ethiopia: Constraints and opportunities for enhancing the system. Gates Open Res. 2019; 3(354):p.354.
29. Santpoort R. The drivers of maize area expansion in Sub-Saharan Africa. How policies to boost maize production overlook the interests of smallholder farmers. Land. 2020; 9(3):p.68.
30. Shah T, Namara R, Rajan A. Accelerating irrigation expansion in Sub-Saharan Africa: Policy lessons from the global revolution in farmer-led smallholder irrigation. IWMI, 2020.
31. Sheng Y, Ding J, Huang J. The relationship between farm size and productivity in agriculture: Evidence from maize production in Northern China. American

Journal of Agricultural Economics. 2019; 101(3):790-806.
32. Habeenzu M, Silva JV, Baudron F, Ngoma H, Nyagumbo I, Simutowe E, *et al*. Narrowing maize yield gaps across smallholder farming systems in Zambia: What interventions, where, and for whom? Agronomy for Sustainable Development. 2023; 43(2):p.26.
33. Tarus CB. Maize crisis: A position paper on strategies for addressing challenges facing maize farming in Kenya. East African Scholars Journal of Education, Humanities and Literature. 2019; 2(3):149-158.
34. Umar BB. Adapting to climate change through conservation agriculture: A gendered analysis of eastern Zambia. Frontiers in Sustainable Food Systems. 2021; 5:p.748300.
35. Zizinga A, Mwanjalolo JGM, Tietjen B, Bedadi B, Pathak H, Gabiri G, *et al*. Climate change and maize productivity in Uganda: Simulating the impacts and alleviation with climate smart agriculture practices. Agricultural Systems. 2022; 199:p.103407.