THE EVALUATION OF IRISH POTATO PRODUCTION TECHNOLOGIES AMONG FARMERS OF MARAKWET WEST, ELGEYO MARAKWET COUNTY, KENYA

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DECLARATION

Declaration by Student

This thesis is my original work and has not been submitted for any academic award in any institution; and shall not be reproduced in part or full, or in any format without prior written permission from the author and/ or University of Eldoret.

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DEDICATION

I dedicate this thesis to my beloved family, whose unwavering love, prayers, and encouragement have been my greatest source of strength throughout this journey.

To my supervisors, for their invaluable guidance, patience, and wisdom that shaped my academic growth and inspired me to pursue excellence.

And to my friends, for their constant support, understanding, and laughter that lightened even the most challenging moments, thank you for walking this path with me.

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ABSTRACT

Potato (*Solanum tuberosum L*) is a major food and cash crop in the Kenyan highlands like Elgeyo Marakwet county. It is widely grown by smallholder farmers and it contribute to food security, rural employment, and household income. Despite the crop potential, productivity remains low due to limited access to improved technologies, poor seed quality, pests and diseases and inadequate market linkages. A survey was conducted in Moiben/ Kuserwo, Cherang'any/ Chebororwa, Lelan and Kapsowar ward in Marakwet West Sub-County. The study evaluates potato production technologies among farmers in Marakwet West Sub-County, Elgeyo Marakwet County, Kenya. The specific objectives were to:(i) describe socioeconomic characteristics of potato farmers, (ii) identify potato production practices and technologies used, (iii) assess the perception of farmers on suitability of potato varieties adopted and, (iv) assess the extent to which potato production technologies affect yield. The study employed a descriptive research design using structured questionnaires, interview schedules, and field observations. Data was collected from a sample of 173 selected potato farmers and analyzed using both descriptive and inferential statistics. The results showed that 62% of the farmers were male, aged 41-50 years, had potato growing experience of less than 5 years, attained secondary level of education, were members of Cooperative society and operating on land size of below 5 acres. Besides, most farmers were not trained in potato production technologies, but were implementing the technologies. Moreover, the household head determined the decision on to the application of the technology. While improved technologies such as certified seed use, fertilizer, and pest and disease management among others were known, adoption remained partial due to high input costs, and weak extension support. It was also established that, farmers were not using the certified seed but instead they majorly sourced seeds from other farms. This is because the seeds were either not available to them, expensive, or lacked information about them. From this study, it was also concluded that, *Shangi* potato variety was grown by majority of the farmers in the region because of its first maturity rate, it is of high yield, and good market demand. *Tigoni*, *Asante* and *Kerr's Pink* were potato varieties grown by very small group of farmers (5%). In the regression model, it is shown that the model is significant at 5% level. This indicates that the independent variables predict the dependent variable. The R Square is 0.312, meaning that 31.2% of the variance in the yield of potato is explained by education, gender, visit by extension, technology implementation and others. From the study only few variables were run hence the low R square. The study recommends enhancing extension services, improving access to affordable inputs and, promoting farmer preferred sustainable technologies. These measures would increase productivity, strengthen household incomes and contribute to food security.

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LIST OF ACRONYMS

ADC	Agricultural Development Corporation
AFA.	Agricultural and Food Authority
ARIMA	Auto-regressive Integrated Moving-Average
CS	Certified Seed
CSA	Central Statistical Agency
FAO	Food Agricultural Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FFS	Farmer field school
FSS	Farmer Saved Seed
GDP	Gross Domestic Product
KALRO	Kenya Agricultural Livestock Research Organization
MOA	Ministry of Agriculture
MOALF	Ministry of Agriculture, Livestock and Fisheries
MVP	Marginal Value Product
USAID	United States Agency for International Development
NPCK	National Potato Council of Kenya

LIST OF OPERATIONAL TERMS

Sustainable: In this study it means; practices or techniques that the smallholder farmers have been able to maintain in the course of their production system

Technologies: Application of scientific knowledge, tools, machinery and innovative to improve practices to improve the efficiency, productivity, quality, and sustainability of potato farming.

Agricultural productivity: In this study it is the measure of how efficiently agricultural inputs are used to produced agricultural output

Food security: This is a situation where all people at all times, have access to sufficient, safe, and, nutritious food for an active and healthy life.

Assessment: Process of evaluating or examining how potato production technologies are being used or adopted by farmers in the study area.

Smallhoder farmers: In this context, they are the main producers of potato and often grow on small area of about 2 hectares and rely on traditional methods, but are gradually adopting improved technologies.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

The potato (*Solanum tuberosum*) is one of the crops cultivated by farmers worldwide. It is the world's fourth largest consumed crop after wheat, rice and maize (FAO, 2019). Potatoes are grown mostly for local consumption, while some countries export little. The maturity of Potatoes is 3-4 months and could yield about 40 tons/ha and thus, it is suitable in regions where land is small in size and abundant labour (FAO, 2014). Potato production in the world in 2021 was done on about 18.1 million hectares of land. China is the leading country with about 5.8 million hectares of land. It was followed by China mainland and India (FAOSTAT, 2021) (Table 1).

The world potato production was approximately 383.0 million tons (FAOSTAT 2021). China was ranked first in world potato production with a production of 95.5 million tons, China mainland was ranked second with 95.20 million tons and India was ranked third with 60.10 million tons. It is seen that the countries that have a say in the world production in the last five years are China and India. Being the leader in the world, China meets 25 % of the world's total potato production in 2021 (FAOSTAT, 2021)

Table 1: Comparison of world potato cultivated area (million ha) and production (metric tons) between 2018 and 2022

	YEAR									
	2022			**2021**	**2020**		**2019**		**2018**	
COUNTRY	Production	Area	Production	Area	Production	Area	Production	Area	Production	Area
China	95.6	5.8	94. 36	5.78	92.85	4.68	89.56	4.04	90.32	4.76
China Mainland	95.2		94. 30	5.78	92.80	4.67	89.50	4.04	90.26	4.76
India	60.1	2.33	54. 23	2.25	48.56	2.05	50.19	2. 17	51.31	2.14
Ukraine	21.4	1.33	21. 36	1.28	20.84	1.33	20.27	1. 31	22.50	1.32
United States	20.0	3.66	18. 58	3.69	19.05	3.79	9.25	3.8	20.42	4.1
Russian Federation	19.4	2.03	18. 30	1.142	19.61	1.18	22.07	1. 24	22.39	4.77
World Production	383.0	16.8	376.12	18.1	371.14	1.69	368. 83	1. 65	365.70	1.72

Source (FAOSTAT, 2021)

In Africa, Kenya was ranked fourth in terms of potato production with 2.1 million tons after Egypt with 6.9 million tons, Algeria with 4.4 million tons, and South Africa with 2.6 million tons in 2021 (FAOSTAT, 2021) (Table 2). Rwanda doubles its potato production in the last 5 years and its among top 5 producers in Africa because of the two cycle season. There are about 159 countries in Africa with potato crops covering 17.80 million hectares.

Table 2: Potato production (Tons), Area (ha), and Productivity (T/ha) for the top producing countries in Africa in 2021.

Country	Production (T)	Area (ha)	Productivity (T/ha)
Egypt	6902816	262706	26.28
Algeria	4360880	136855	31.86
South Africa	2595280	69725	37.22
Malawi	1465000	73105	18.3
Kenya	2107824	214600	9.82
Morocco	1641853	51787	31.70
Nigeria	1216884	319180	3.81
Rwanda	908000	119744	15.90

(FAOSTAT, 2022)

The average production in Kenya is estimated at about 10 MT per hectare (FAOSTAT, 2021) compared to a global average yield of 17 MT per hectare (FAOSTAT, 2019). Additionally, smallholder, medium scale and large-scale farmers undertake Potato production. The smallholder farmers constitute about 800,000 engage in potato production and are estimated to cultivate about 83% of land under potato production, which is between 0.2 to 0.6 hectares of land, while 17 per cent of potato cultivation belongs to

medium to large scale farmers who cultivate 2 to 10 hectares of potato (Janssen's et al., 2013).

Potatoes are mainly grown in the highlands of central, Eastern and Rift Valley regions in Kenya. These areas include slopes of Mt. Kenya, the Mau escarpment, the Nandi escarpment, Cherang'any hills and the slopes of Mount Elgon (Kirumba et al., 2004) The altitude of these areas ranges between 1500-3000 meters above sea level (Kiiya et al., 2006). There are two potato cycles due to bimodal rainfall in several potato producing regions (USAID-KAVES, 2014). There are at least 30 potato varieties that are grown in Kenya, but *Shangi* and *Tigoni* were the most cultivated varieties because of its high market demand and farmer preference (Kaguongo et al., 2010).

Potato is on the diet of many African country's families due to its nutritious tubers. (Liu et al., 2014). The dietary diversification among those living in the urban areas as well as food restaurants and roadside small-scale fryers has led to increase in the demand for potato as it is used for French fries, crisps and salads (Tesfaye, et al., 2010). But the production is insufficient to meet the ever-growing demand.

Low productivity per acre has been attributed to lack of quality inputs, especially certified seeds. Other challenges include lack of storage infrastructure, contributing to post-harvest losses (EAPS, 2022). The informal seed system currently dominates the sub-sector supplying about 95 per cent of the seeds. However, both the formal and informal seed systems supply less than 5 per cent of the national seed potato requirement (Kaguongo et al., 2010). This is attributed to limited seed production, lack of suitable varieties and insufficient distribution network for certified and clean seed potato.

The seasonality in production, lack of on-farm ware potato storage, high transaction costs, price inefficiencies and quality losses lead to low returns to the farmers (Kaguongo et al., 2008). The producers' lack market information and the perishability nature of potatoes coupled with price fluctuation contribute to low returns to the farmers. Also, the poor infrastructure network makes the transportation of potatoes to the market expensive (Hoeffler, 2005). Besides, the productivity of potato is 7.5 tons (FAO, 2008) and this is below the 50 tons, which is the potential yield. This has been attributed to poor technological adoption that includes low application of fertilizers and agrochemical, inadequate quality seed and challenges associated with climate change (CIP, 2011).

1.2 Statement of the problem

Potato production is the second most important crop in Kenya that contribute significantly to household food security, rural incomes, and employment opportunities among the farmers.

In Elgeyo Marakwet county, particularly Marakwet west sub- county, Potato is a key staple and cash crop for smallholder farmers. The average yield in Kenya per hectare is estimated at 7-10 tons compared to the potential of 25-30 tons under good crop husbandry practices. (FAOSTAT, 2022).

Despite these importance, productivity remains low and this yield gap is due to low adoption of improved production technologies as farmers rely on low-quality seeds, inadequate pest and disease control, traditional methods of planting, inadequate soil fertility management and social-economic constraints like lack of access to extension services, lack of membership to a group among others.

Therefore, there was need to assess Potato production technologies among farmers in Marakwet West Sub-county, in view of improving food security, employment and income for the farmers.

1.3 Justification of the study

Marakwet west includes highland and mid high land zones where temperatures are moderate, fertile soils, and adequate rainfall which are favorable for Irish potato, rainfall ranges depending on altitude offer potential for rain-fed or supplemental rain-fed potato farming. Irish Potatoes are grown in this region and other studies have found out that production technologies (use of certified seed, training, fertilizer) improve yields significantly. This suggests that with better inputs and management, there is scope to increase productivity.

This study would be useful therefore in promoting potato production in Marakwet West and evaluating the Irish production practices and technologies and analyze them from the smallest production unit of an individual potato farmer along the potato value chain. With target investments in seed systems, input access, extension services, and sustainable practices soil fertility management and pest control, potato farming can uplift rural livelihoods in the study area.

1.4 General objectives of the study

The purpose of the study was to Evaluate Irish potato production technologies among farmers in Marakwet West Sub-county, Elgeyo Marakwet County, Kenya.

1.4.1 Specific Objectives of the study

The objectives of the study were:

i. To describe socio-economic characteristics of potato farmers in Marakwet west sub-county, Elgeyo Marakwet County

ii. To identify potato production practices and technologies used by farmers in Marakwet West Sub-County, Elgeyo Marakwet County

iii. To assess the perception of farmers on the suitability of potato varieties adopted in Marakwet West Sub-County, Elgeyo Marakwet County

iv. To assess the extent to which sustainable potato production technologies affect yield in Marakwet West Sub-County, Elgeyo Marakwet County

1.4.2 **Research Questions**

The study aimed at answering the following study questions:

i. What are the socioeconomic characteristics of potato farmers' in Marakwet West Sub County?

ii. What are the potato productions practices and technologies used by farmers in Marakwet West SubCounty?

iii. What is the perception of farmers on suitability of potato varieties adopted in Marakwet West Sub-County?

iv. What is the extent to which sustainable potato production technologies affect yield in Marakwet West Sub-County, Elgeyo Marakwet County?

1.5 Limitations of the Study

The study on evaluating Irish potato production technologies in Marakwet West sub county was conducted with the goal of assessing the potential of the crop in improving food security and livelihoods. While the findings provide valuable insights, some of the limitations are; the study was limited to selected wards within the study are due to time, resources, and accessibility constrains. As a result, the sample may not fully represent the diverse agro-ecological and socioeconomic conditions across the entire county.

Also, the was a limitation of time frame where the study was conducted over a single growing season. Therefore, the results may not reflect long-term trends or year-year variations in production. Finally, most of the production and yield data were based on interviews with farmers and extension officers and mostly self-reported figures may be subject to recall bias or estimation errors, especially in the absence of formal record keeping by farmers.

1.6 Assumptions of the study

This study was conducted based on a set of assumptions considered essential for the accuracy, relevance, and applicability of its findings and recommendations. This include; the agro-ecological conditions will remain favorable, the farmers are open and willing to adopt improved agronomic practices, and agricultural inputs and extension services are available and accessible. The study assumes a continued commitment by national and county governments to support farmers, and also security and infrastructure remain stable in the study area.

1.7 Theoretical framework

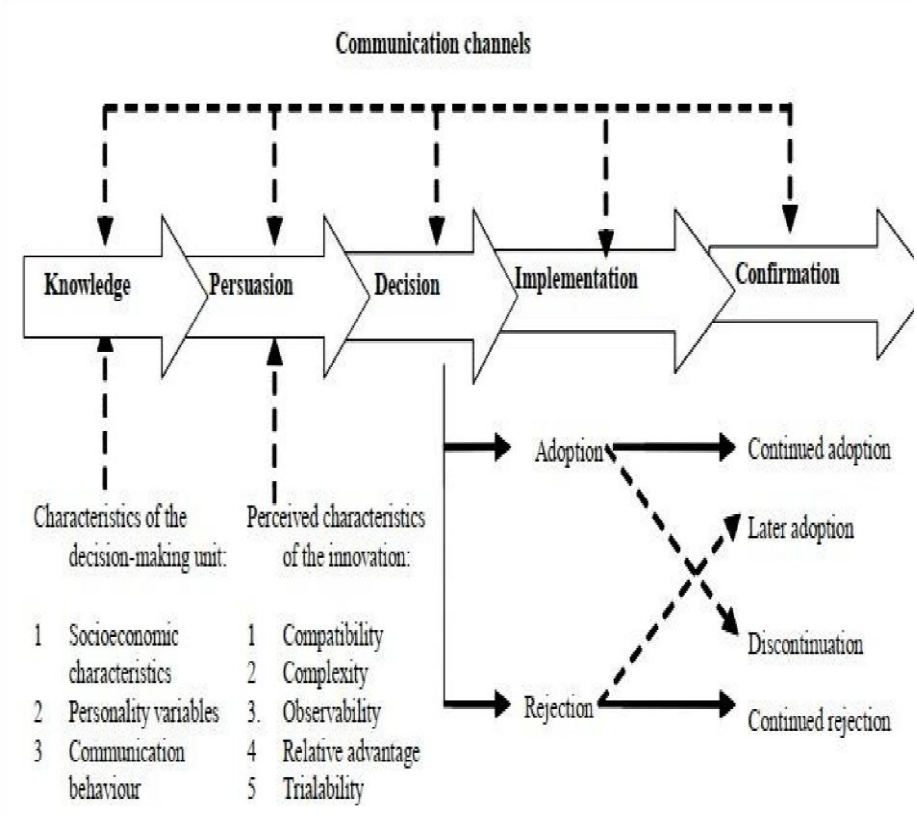

Figure 1: Diffusion of Innovation Theory (Adapted from Rogers 2005)

1.7.1 Adoption of Innovation Theory

Adoption decisions have been shown to occur following the innovation-decision process (Rogers, 1995). The innovation decision process consists of a series of actions and choices over time through which individuals or other decision-making unit evaluates a new idea and decides whether or not to include the innovation into existing practices.

The process (Figure 1.) evolves through the following stages: the knowledge stage; the persuasion stage; the decision stage; implementation stage; and the confirmation stage (Rogers, 1995). The technologies should also fulfill the farmers' varied needs. Perceptions

of farmers towards technologies have been found to affect adoption of technologies (Yehuala et al., 2013).

This approach anchored this study as it recognizes that a variety of factors influence the adoption of potato technologies among the farmers in Marakwet West sub-county.

Adoption is a decision-making process whereby an individual gain knowledge about an innovation, develop an attitude towards innovation, decide to adopt or reject, put into practice the new ideas and confirm his/her decision (Rogers, 1995). This adoption furthermore depends on how technology itself was diffused through a social system.

Research and development scientists from diverse discipline such as agriculture to marketing, have adopted this theory with the aim of increasing adoption of innovative products and practices. Farmers accept and utilize the improved practices basing on their capacities to acquire and use information about new techniques and put knowledge into practice (Mariano et al., 2012). The following are the general attributes that consistently influenced the adoption of innovations.

First, when an innovation has an advantage over other innovations or the present circumstance then it will be regarded as of advantage to the adopters. Social status, short-term and long-term benefits are among the factors influencing the relative advantage (Huckett, 2010). Hence, farmers were asked if the technologies they have adopted have benefits than what it supersedes.

Secondly, an innovation is regarded as compatible when there is apparent consistency of the new technology with the adopter's current situation, values and beliefs, past experiences and perceived needs of potential adopters (Meijer et al., 2015). The adopted

potato technologies were evaluated if it fits with the farmers need for high potato production.

Thirdly, an innovation should be easy to be understood and implemented and that will be easily adopted by the adopters (Miller, 2015). If more effort is required to implement the technology, then the complexity increases, failing its adoption by the end users. Hence farmers' will easily opt the technologies, which are easy to understand and implement.

Fourthly, an innovation should be tested on a small-scale and can increase the capacity for adoption of new technology. This will reduce the uncertainties, which may be associated with adoption since it can be realized earlier by the potential adopter (Mwangi et al., 2015). It also provides an opportunity to learn new skills essential in the implementation of the innovation.

Fifthly, an innovation should be with measurable effects, which are visible to the adopter and the community and thus encourages its adoption. A study by (Maina et al., 2012) explained that easy observability promotes evaluation for relative advantage by potential adopters in the social system, hence increases the chances of farmer uptake in adoption of improved agricultural technologies among smallholder farm households in Nakuru District.

In regards to this theory, when innovations are compatible with the farmers predetermined objectives and demonstrate high degrees of relative advantage, trial ability, easy observability and fewer complexities, then, it will ease the uptake of potato technologies among the farmers. A study by Odame (2016) also confirms the same regarding the adoption of greenhouse technologies by growers in Nyeri County.

CHAPTER TWO

LITERATURE REVIEW

This chapter reviewed the theoretical and empirical literature. In the theoretical review, the history of potato production in Kenya was discussed, while the empirical review discussed farmer's socioeconomic characteristics in relation to use of potato production technologies, farmers' perception of potato suitability, assessment of sustainable potato production technologies on yield and the conceptual framework.

2.1 Theoretical Literature

2.1.1The history of potato production in Kenya and Globally

Potato (*Solanum tuberosum L)* is the world's fourth most important food crop after maize, rice and wheat. It contributes significantly to food security, rural incomes, and employment. (FAO,2021).

European settler farmers did the introduction of potato to Kenya in 19thcentury in Kiambu, Murang'a and Nyeri districts. The native Kenyan farmers did the cultivation of potato in 1920. *Kerr's pink* was the cultivated variety during that time. The varieties introduced to Kenya eventually from Europe were not adapted to Kenya. Thus, the commencement of research was done after the establishment of national agricultural laboratories, Kabete in 1903 and at the plant breeding station, Njoro, in 1927. The potato dehydration plant was started in Kerugoya in Kirinyaga District and Karatina in Nyeri district for purposes of supplying the British troops in North Africa and Asia in 1945. The demand could not be met due to low yields resulting from viruses and bacterial wilt infection. Consequently, *Eburu* (B53), *Dutch Robyjn, Anett, Maritta, Feldeslohn,* and *Desiree,* among others

varieties were imported from Europe. Due to incidence of bacterial wilt in Central province, the production of Potatoes was transferred to Meru and Molo (Ministry of Agriculture, Livestock and Fisheries, 2016)

The Seed and Plant Varieties Act Cap 326 was enacted in 1972 and revised in 1979. The act states the procedures for seed registration, field inspection, lot inspection, sampling for post control plots, labeling and sealing. This was the function of Kenya Inspection Service (KISS) formed in 1972 which later changed to National Seed Quality Control Service in 1979 and is now referred to Kenya Plant Health Inspectorate Service ((KEPHIS) formed in 1997 and became operational in 1998 as the certifying organization (Kenya Law, 2016)

The drought in 1984 led the potato shortage prompted the ADC to import seed of *Arka, Cardinal*, *Pimpernel* and *Romano* varieties to meet the deficit. In addition, a cold shortage facility was established in 1985 in Molo with a capacity of 2,250 tons to correct the shortage problem (Ministry of Agriculture, Livestock and Fisheries, 2016). The joined project between KARI (now KALRO) and CIP done between 1986 and 1997 was conducted in various stations in Kenya to develop potato varieties with durable resistance to late blight, some level of tolerance to bacterial wilt and acceptable agronomic and post-harvest qualities. It resulted in the release of varieties *Tigoni* 1(for chips) and *Kenya Furaha* and *Asante* (for domestic consumption). The collaboration further culminated into to release of 7 more varieties by 2010 and *Shangi* variety was released in February 2015 (MOALF, 2016).

Kenya and Netherland government signed a bilateral agreement in 2011, which allowed the introduction of *Dutch Robjin* seed potato varieties and capacity building of KEPHIS

facilities and infrastructure by early 2015 there were 38 commercial released varieties and over 60 informal ones with farmers. The National Potato Council of Kenya (NPCK) was formed to bring together public and private stakeholders in the potato industry, whereas Agriculture and Food Authority (AFA) is enhancing regulation, development and promotion of food crops such as potato (National Potato Council of Kenya, 2023).

2.2 Empirical Literature

The farmer's socioeconomic characteristics in relation to adoption of potato production technologies, farmers' perception of potato suitability and the assessment of sustainable potato production technologies on yield were discussed in this section.

2.2.1 Farmer's socioeconomic characteristics

The discussion on age, education level, gender, membership to farmer groups of the respondents and how it influences potato production technology uptake are covered in this section.

2.2.1.1 Farmers age

Age of the farmer plays a significant role in the adoption of innovation and technology. The following are some of the studies done on how age influences adoption of innovation and technology.

Usman et al. (2021) found out that the older farmers were risk averse than young farmers with respect to weed management techniques in Pakistan. Similarly, the non-adopter farmers headed by oldest household heads were less willing to adopt integrated pest management strategies (Muriithi et al., 2020). Also, Maina et al. (2020) recorded that older

farmers, due to their farming experience than young farmers, were able to adopt new technology.

The participation of sustainable soil conservation was undertaken by the younger farmers in West Pokot County (Cherono et al., 2019). It was revealed that young farmers are also less risk averse and willing to invest in new technologies (Okello et al., 2019) and moreover, Mazodze (2016), found out that the decision to undertake conservation agriculture in Masvingo District was done by young female farmers.

Mohammed (2018) revealed that the aged farmers are risk averse and reduces the interest for long term investment in the farm. According to Belay et al. (2017), age was in line with farming experience and that it influenced information access. Indeed, Muchangi (2016) stated that farmer's characteristics, agricultural extension and technology specific factors showed that aged farmers were better in decision on technology adoption than young farmers.

However, the studies thereof used different sample size to determine how age influenced technology adoption.

2.2.1.2 Farmers education Level

This subsection discussed previous studies on how education level influences the adoption of technology in crop production.

Emerick et al. (2021) found out that educated farmers were willing to attend farmers field days to learn about new technologies and observe its performance than the illiterate farmers. The level of education as well as awareness programs influences the adoption of technology by potato farmers (Abreham et al., 2019). Also, Worku (2019) found out that there was a high probability of educated farmers adopting potato technology in Oromia

regional state Western Sewa in Southern Ethiopia. In Southern Ethiopia, educational level too influenced the adoption of improved potato technology (Feleke et al., 2019).

Msoffe et al. (2016) revealed that the educated farmers could read and understand and comprehend information on technologies and be able to make appropriate decisions than the illiterate farmers, thus can implement new farming techniques. Further, a study by Oyelude et al. (2014) found out that high level of illiteracy is a major limitation to the use of information and communication technology by farmers.

Nevertheless, the method of eliciting information of whether the farmer adopts the potato technology or not the aforementioned studies is varying. In Marakwet west Sub County, education may act as a moderator: it does not guarantee high yields by itself but it helps the farmer to better use of inputs (seed quality, fertilizer, pest control) and participate in value-chain opportunities (processing and market negotiations). Training and extension also may have to be differentiated:fr example more basic for those with only primay education; and most advanced for those with tertiary.

2.2.1.3 Gender of farmers

The previous studies on the relation between gender and technology adoption on yield are discussed in this section.

Technology adoption is a central theme in agricultural development. According to Rogers', adoption of innovation Theory (2003), adoption depends on the perceived benefits, compatibility, complexity, and observability of innovation.

The decision-making process in African society is centered on men due to sociocultural values and norms leading to men having control over access to most of important production resources (Acosta, et al., 2020).

Gender considers both men and women and their interdependent relationship within a specific social setting (Kurtiş et al., 2015). According to Mwangi et al. (2015), the relation that exists between male and female influence the access, use and priorities of the innovation uptake. Also, a study by Murage et al. (2015) stated that gender of the head of the household affects the probability of utilization and adoption of push and pulls technologies in Eastern Africa among smallholder farmers. However, Muema et al. (2018) results showed that the gender of the household head decreases the probability of using Climate Information Services in Makueni County.

In Kenya context, studies show that socioeconomic characteristics including gender significantly influence the adoption of agricultural technologies (Mwangi & Kariuki. 2015). In Marakwet west Women may be actively involved in potato production (planting, weeding, harvesting) but may have less access to productive resources (certified seed, land, mechanization) and less control over sale proceeds. However, the researchers did not consider the study area where both genders are informed on the new technologies.

2.2.1.4 Membership to farmer groups

The previous studies on the relationship between farmer groups and the uptake of potato production Technologies are covered in this section.

Ogola et al. (2021) found out that farmers group assist in collective action and learning, thus leads to farmers' preferences for Climate Smart Agricultural Practices in potato farming. Also, Kanyenji et al. (2020) revealed that being a member to an agricultural group influences the likelihood of adopting an agricultural technology. Similarly, Ketema et al. (2019) showed that membership in cooperatives and social institutions enhance the adoption of technologies at Nakuru County in Kenya. Also, at Woreda district in Ethiopia,

Abreham et al. (2019) observed that frequent visits by extension officers and being a member to cooperative positively influence the adoption of technology. However, Selahkwe et al. (2021) stated that being a member of an association had a significant negative effect to technology adoption.

Chagwiza et al. (2016) observed that agricultural cooperative membership contributes immensely to knowledge and technological transfer because of collective use of and action on technology that enhance innovation and learning by the members of the group. Indeed, Indeche et al. (2016) explained that if the network is stronger, there was a high likelihood of farmers having the chance to rip from innovation from the network. This enhances peer discussion of new ideas from the friends and neighbors of an adopter on innovation-evaluation information, which fosters sharing of experiences which prompt good decision making among farmers.

Macharia et al. (2014) explained that membership of an organization provides a valuable learning and collective bargaining opportunity for farmers where they are more likely to access diverse information and capacity building efforts such as trainings thus increasing their knowledge. However, Mwaura (2014) found out that being group members there is less likelihood to adopt inorganic fertilizers and improved seeds than non-group members. The social network enhances the flow of information and provides ways for peer learning among farmers as it enhances the use of soil fertility management technologies in Meru south district, Kenya (Kimaru-Muchai et al., 2020). In addition, farmers who have regular contacts with extension agents are in a better position to gather useful information regarding the benefits of belonging to a cooperative (Abebaw et al., 2013). However, the

results from the aforementioned studies are conflicting, thus calls for further research on this subject matter.

In the study area, there are approximately 20 Cooperative Based organization (C.B.Os) engaged in seed-multiplication, input access, training among others. What can limit their impacts is poor governance, lack of proper registration, poor infrastructure and group conflicts, hence there is need for further e research on this aspect.

2.3 Irish Potato production technologies and practices

Irish potato production technologies include the use of certified disease free seed potatoes, proper spacing, soil fertility management, pest and disease control and improved storage facilities. Studies reveals that the use of quality seed alone can increase yields by 20-30% (Gildemacher et al., 2009). Using certified seed has real potential benefits in disease reduction on yield increase.

However, in East Africa in 2009, uptake was very low due to cost, limited availability,geographical/infrastructure/transport constrains, and because many farmers rely on informal systems. However, most farmers in Kenya rely on recycled seed, often infected with disease leading to low productivity (Muthoni &Nyamongo,2010). According to Atieno et al. (2023), study reveals that, while many farmers recognize that better seed (certified/disease-free) should generate higher yields or less disease, in practice adoption is low. The premium farmers are willing to pay depends heavily on whether they perceive real tangible benefits.

Other practices such as fertilizer use, integrated pest management, and mechanization remain underutilized due to limited financial capacity, poor extension services and weak market linkages. In Marakwet west sub county, the study also reveals that while some

improved technologies including certified seeds, fertilizer application, and pest and disease control-were being adopted, uptake remained partial due to high costs, limited access to inputs, and weak extension support.

2.4 Farmers Perceptions of Potato Varieties

The analysis of previous studies on the perception of potato suitability are discussed in this section.

In Kenya some of the seed varieties available are: *Kenya Mpya, Nyayo, Rudolf, Shangi, Sherekea, Golden purple* and *Tigoni*. Ooko et al. (2011) pointed out that Kenya *Mpya, Tigoni, Sherekea* and *Golden Purple* in that parliamentary law of taste could be utilized to produce crisps that are comparable to *Dutch Robjin*, an established crisping variety in the local food market shop. With the exception of *Kenya Mpya*, varieties *Sherekea, Dutch Robjin* and *Golden Purple* produced good quality French fries compared to the established chipping variety, *Tigoni*. Potatoes from the new varieties are expected to form an additional pool of raw material for processing in Kenya and should be promoted alongside the established ones to support the growing industry.

A demonstration site run by National Potato Council of Kenya (NPCK) in Elgeyo Marakwet tested three varieties: *Shangi, Markies* and *Destiny* under different input treatment programmes. *Shangi* achieved 16.8 t/acre under the "Amiran full programme" treatment, *Markies* achieved approximately 13.35 t/acre under one of the treatment and *Destiny* achieved 11.5 t/acre under another treatment. *Shangi* one of the better performing varieties under good management in this county and also better suited for the local conditions when inputs and seeds are good. The NCPK "Potato Variety Catalogue 2019"

lists Kenya Mavuno as suitable for high altitudes of 1800-2800 m, including Elgeyo Marakwet.

Previous studies show that attributes considered in ranking a potato cultivar by farmers are high yield potential, late blight resistance, taste, maturity period, market demand, bacterial wilt resistance, tuber size, and drought tolerance in that order (Kaguongo, et al., 2012). Tuber quality characteristics such as skin colour, tuber size, tuber shape and time to maturity are often key factors in cultivar acceptability based on local consumer preferences and criteria for potato processing (McArthur, 1989). In view of the studies aforementioned, farmers and consumers of Potatoes have different eating habits and preference, thus affects their perceptions.

Farmers perceptions play a key role in variety selection and adoption. Traits such as yield potential, maturity period, disease resistance, cooking quality, and market demand influence farmers preferences (Kaguongo et al.,2008). In Marakwet west Sub County and other highland regions, varieties such as *shangi, Asante,* and *Dutch Robjin* are widely grown due to their fast maturity and marketability, though they may be more susceptible to late blight. In the study area, variety suitability is strongly tied to management; certified seed, proper agronomic practices (fertilizer, pests/disease control), good storage, etc. Without those, even a good variety may underperform.

2.5 Sustainable Potato Production Practices and Yield Impacts

The analyses of previous studies on the sustainable potato technologies on production are discussed in this section.

Good Agricultural Practices (GAP) involve the farmer management practices in the farm during production and post-harvest activities in view of facilitating high yield as well as

ensuring cost minimization and environmental conservation. This is realized by means of minimum tillage, hand weeding and leaving crop residue in the field to enhance the conservation of natural resources (FAO, 2008). In potato production, studies found out that the GAPs applied well led to pest and disease control and enhance in soil fertility and immensely led to increase in potato yield (Okello, et al., 2016). The GAPs used in potato production include the use of fungicides to control bacterial blight (Champoseau et al., 2011), use of Certified Potato Seed (Okello, et al., 2016), Integrated Pest Management [IPM] (Champoseau et al., 2011), crop rotation (Larkin et al., 2011) and fertilizer application (Zebarth et al., 2009).

Indeed, Good Agricultural Practices (GAPs) such as integrated pest, weed and disease management, soil and water conservation as well as fertilizer management leads to sustainable production of potato, thus improve the livelihood of farmers (Kassie et al., 2013). Also, the choice of high yielding variety, late blight resistance, taste and short maturity period, market, tuber size and bacterial wilt resistance as well as drought resistance are some of the factors considered by farmers in potato variety (Kaguongo, et al., 2008)

However, lack of certified seeds has led to potato farmers to planting tubers from the previous harvest or obtained from markets and neighbours (Muthoni, 2011). Technologies such as seed plot techniques; positive seed selection and productions of mini-tubers have been used to produce certified and quality potato seeds (Kinyua, et al., 2011). In view of increasing production of potatoes, the climate change, adaptation practices and technologies used by farmers should be prioritized. This is through awareness on its

impact households and how to cope with the effect of climate change (Mustafa et al., 2019).

Cropping system and irrigation significantly affect most potato crop parameters associated with growth and yield. All crop rotations enhanced tuber yield compared to the non-rotation. The disease suppressive, green manures, and cover crops produced the highest yields under irrigation. Irrigation led to high tuber yields in all cropping systems (Larkin, 2011). Additionally, the potato production in United States and other potato growing areas is characterized by short rotation, extensive tillage, minimal crop residue returns and less crop diversity, sometimes affecting soil health and crop productivity in the long run (Grandy et al., 2002). With increase in rotation from two to three years in potato production, it has been reported to increase yield (Wright et al., 2017).

There was a significant effect on tuber yield and quality and improvement in soil properties and health when cover crops and green manures applied (N'Dayegamiye et al., 2017), changes in the rate of compost or Farmyard manure application (Ninh et al., 2015) and a smaller number of tillage (Carter et al., 2001). Moreover, most farmers disposed of pesticide containers well and this was influenced by extension training's. However, farmers did not practice safety precautions when handling, mixing and spraying agrochemical and they were not wearing protective clothing (Kurui et al., 2014). It was found out that a great deal of food and products were not at the disposal of the final consumer because of post-harvest losses experienced during harvesting, handling, transporting, storage, processing, packaging and distribution. This has contributed to reduced food crops availability and income generated by selling of these products leading to food insecurity (FAO, 2010).

The reduction of harvesting loss leads to improve in income, guarantee food security and reduction of storage loss (Hakan, 2012). Additionally, the reduction of post-harvest loss by 50%, food availability would increase by 20% without increasing the size of land for cultivation in view of increasing production (Ayandiji et al., 2011). Transportation is one of the causes of post-harvest loss as there is time lag between the farm and the market. The traders used vehicles and hand pulled-carts, either with closed or open backs. In the market the potatoes were exposed to the vagaries of nature. These include sunlight, which caused greening, which increases the risk of consumer exposure to glycol alkaloids. Creating awareness among traders on the appropriate post-harvest handling of potatoes to protect consumer health and reduce economic losses (Musita et al. (2019) should enhance emphasis. Moreover, Kaguongo et al. (2014) reported that about 75% of the potatoes are damaged or undergoes greening in most markets in Kenya.

Selling to local traders than to other alternative was more efficient market chains (Kyomugisha et al., 2018). Indeed, Laibuni (2014) reported that Potato markets are oligopolistic in nature, meaning few market participants in the form of rural brokers, urban brokers and transporters possess the market power. The existence of brokers who are the link between wholesalers and retailers, acts as the barriers to trade. The brokers and transporter determine the market prices. Besides, inadequate market information, lack of storage and other physical infrastructure affects the functioning of markets (Trostle, 2008). Also, Consumer demand, farm supply and the food marketing system determined the prices (Barrett (2009).

In the research thereof, the sustainable technologies in the potato value chain varies from one place to another, thus this study, investigated it in the context of Potato farmers in Marakwet west constituency.

2.6 Conceptual Framework

The conceptual framework shows how independent variables relate to dependent variables; where potato varieties, marketing channels, knowledge and potato management affect the yield. Hence better solution to the challenges increases potato production in terms of quality and quantity. Technology as an independent variable is to enhance continuous production through irrigation, use of certified seed, control of pest, diseases, and crop rotation. Also it can significantly improve potato production by increasing yields, improving quality, reducing losses, and making production more efficient and sustainable. Intervening variables on the other hand shows how extension officers could improve the potato production through providing education on new technologies to the potato farmers. Government production policy as an intervening variable are strategies and regulations that directly influence how crops like potatoes are grown. These polices enable production depending on how it is designed and implemented. The key production policy objectives are: to increase yield per hectares, expand use of certified seed, promote clean seed systems, and to support sustainable land use among others. (Figure 2)

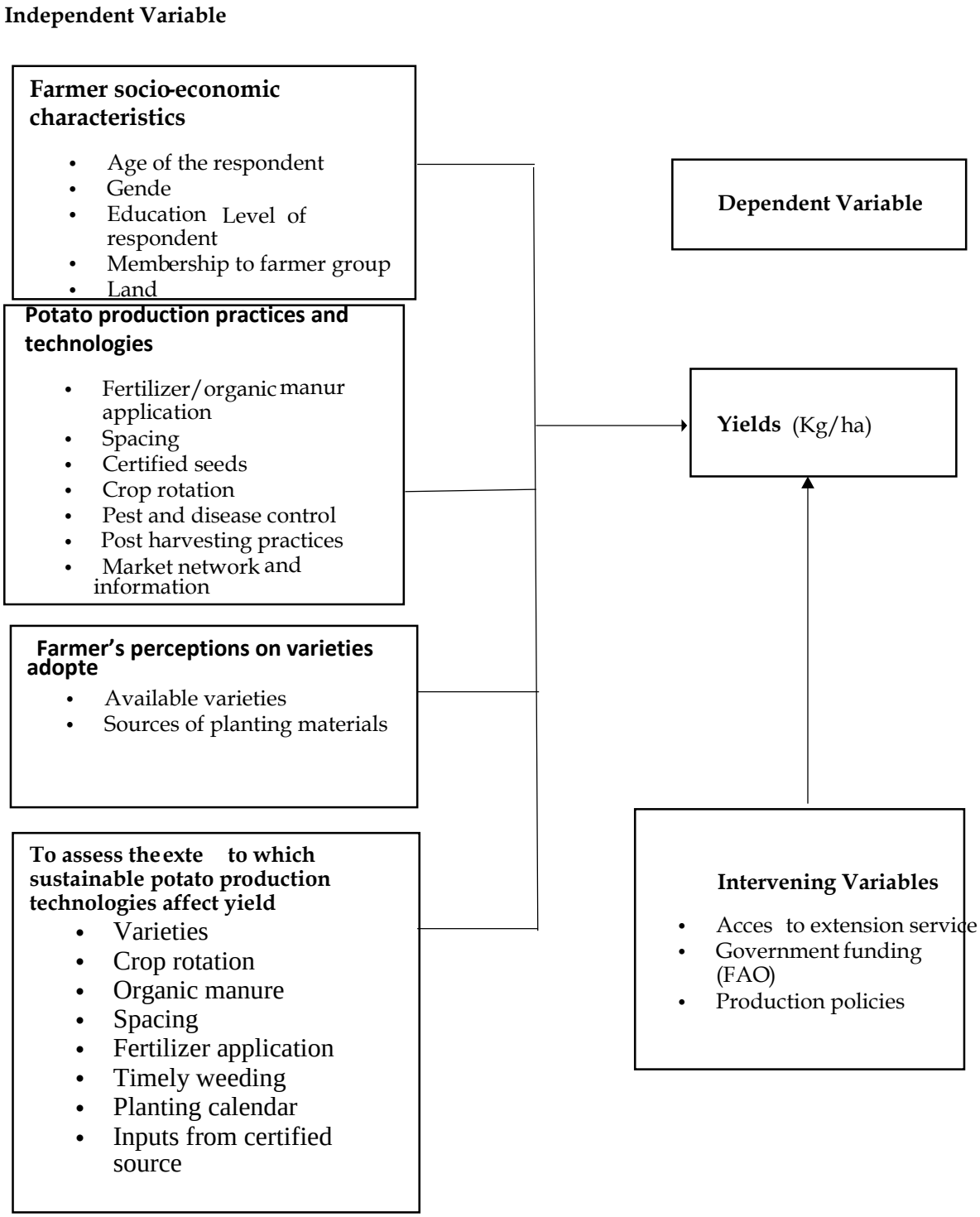

Figure 2: Conceptual Framework (Author, 2022)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter deals with the methodology of the study which is divided into the following sections; Research design, target population, sample size and sampling procedure, Study area, data collection instruments and procedures and data analysis methods.

3.2 Research Design

The study employed a descriptive study design. The study was undertaken for purposes of ascertaining and describing the potato production practices and technologies among farmers. Brief explanation was done to the farmers on the study area and assurance of confidentiality, and consent. Questionnaire consisted of a section on socioeconomic characteristics of the farmer and a another section on a detailed survey of the study. Questionnaires were administered to randomly selected 173 farmers in the study area. All the questionnaires were filled by the selected farmers and it took around 20 minutes for each to fill.

3.3 Study Location

Marakwet west sub-county is located in Elgeyo Marakwet County, Rift Valley. It borders West Pokot county to the North, Baringo County to the East, South East and South, Uasin Gishu County to the South West and West and Trans Nzoia County to the North (Figure. 3) (County Government of Elgeyo Marakwet, 2013)

The Highlands receive between 1200mm and 1500mm per annum, while the Escarpment and the Kerio Valley receive rainfall ranging between 1000mm to 1400mm per annum. In altitude, the Highland plateau rises from an altitude of 2700 meters above sea level on the Metkei Ridges in the South to 3350 meters above sea level on the Cherang'any Hills to the North. Temperatures range from a minimum of 14 °C to a maximum of 24 °C. Rainfall ranges annually from 400 to 1,400 mm. (County Government of Elgeyo Marakwet, 2013).

The area of study was selected because it is one of the major producers of Potato in Kenya as the ecological condition is suitable for potato production. The study area also serves as the major source of employment and livelihood to most potato farmers in the region.

Finally, the study area was accessible to the researcher.

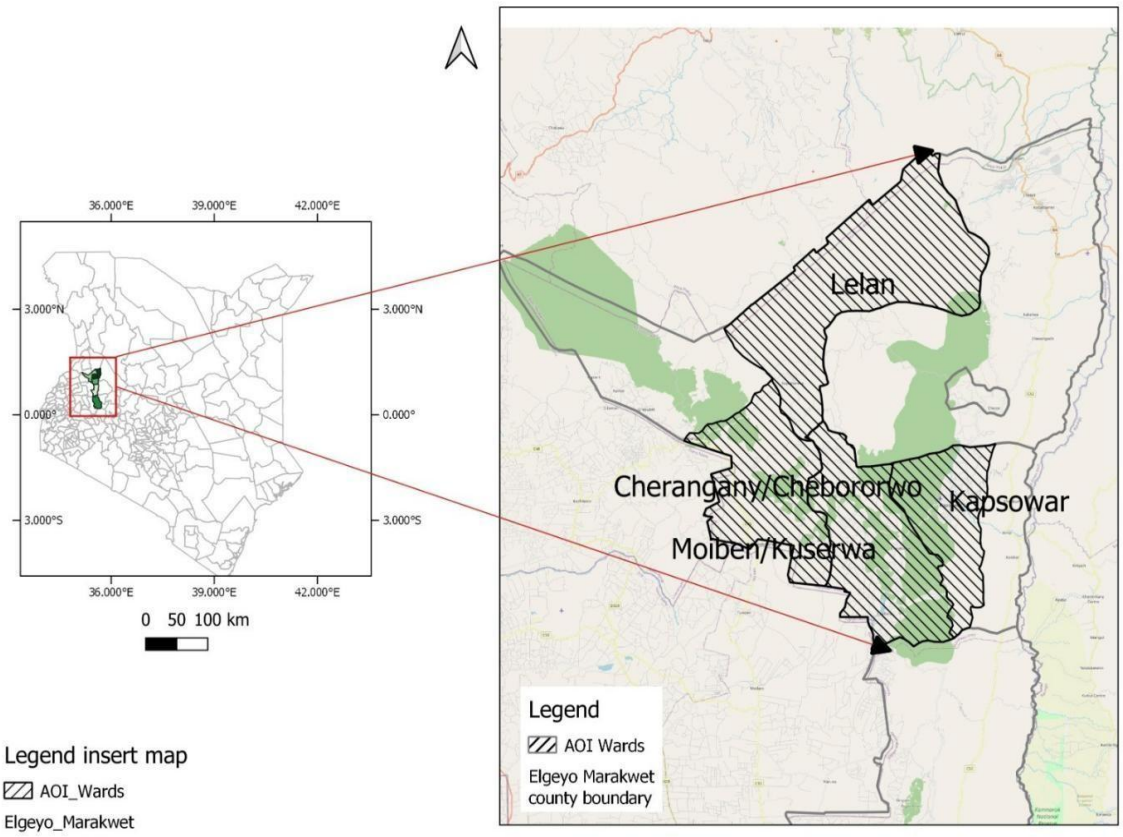

Figure 3: Map of the study area

3.4 Target Population

The target population were the Irish potato farmers from Marakwet west Sub county and specifically from the four potato growing wards namely, Chebororwo/Cherang'any, Moiben/ Kuserwo, Lelan and, Kapsowar wards.

In Elgeyo Marakwet Country, the area under Irish potato cultivation is 23,000 hectares with an average yield of 15 tons/ha and the optimal yield is 40 tons/ha. (Ministry of Agriculture, (2023).

The study targeted 305 active farmers for the purposes of the study from the four Irish Potato growing zones (Table 3). Ministry of Agriculture, (2023), Elgeyo Marakwet County.

Table 3: Target population and sample size

Sub county	Sampled Wards	Target population per sampled wards (N)	Sample size (n)
Marakwet west	Cherang'any/Cheborорwa	70	40
	Lelan	93	53
	Moiben/Kuserwo	74	42
	Kapsowar	67	38
Total		305	173

Source (Author, 2022)

The study therefore ended with a sample size of **173** farmers.

3.5 Sampling Procedure

Marakwet west Sub County is divided into six wards, namely Cheborорwa/ cherang'any, Lelan, Moiben/Kuserwo, Sengwer, Kapsowar and Arror. Purposive sampling technique was employed in selecting four wards, namely Cheborорwa/ cherang'any, Lelan, Moiben/Kuserwo and Kapsowar ward. Three of these wards are high potato-producing

zone and one of the ward is lowly producing zone as per the county records. Also, a simple random sampling was used to select the villages and the farmers for the study.

3.6 Sample Size

Since its often impractical or impossible to study the entire population, samples are selected to draw conclusion about the whole group. A properly sized and well-chosen samples allows results to be applied to the whole population. To obtain information about population of interest and to draw inference about the population, researchers use samples, (Lind et al., 2023).

According to Taro Yamane (1967), to get the desired sample, the following formula was applied.

$$n = \frac{N}{1 + N.e^2}$$

Where :

n = Sample Size

N is target population Size

e is the marginal error (0.05)

From the formula, n=**173** sample population of Marakwet West sub county

The sample size of **173** was for the four wards of Marakwet west, namely Chebororwa/ cherang'any, Lelan, Moiben/Kuserwo, and Kapsowar ward. (Table 3).

3.7 Data Sources

Both primary and secondary data were collected for the study. Secondary data was gotten from desk survey by analyzing materials, publication and relevant information sources

from Country institutions dealing with potatoes or those having credible data like the National Potato Council of Kenya (NCPK), KARI Tigoni, the Horticultural Crops Development Authority (HCDA), Ministry of Agriculture, Food and Agriculture Organization (FAO) of the United Nations (UN).

3.8 Data Collection

The researcher collected the data since it was the most convenient way to take when using questionnaires and interview schedules as the data collection instrument. Before collecting the data, the researcher obtained permit from the Sub County Crops Officer and National Commission for Science, Technology and Innovation (NACOSTI) before data collection and an introductory letter from the University. Also ethical principles were considered by the researcher where the farmers were briefed about the purpose of the study, what kind of questions will be asked, the time taken to fill the questionnaire, that participation is voluntary and they may even withdraw at any time without penalty.

Data was collected between 1st May to 5th July 2022. Simple random sampling was used to select the **173** potato farmers from the four wards. Before the data collection commenced, enumerators were trained in order for them to be familiar with the questionnaire and an overview of what was expected from the farmers so as to reduce measurement errors. Also data collection tools were pretested in one of the village outside the study are first so as to enable the researcher revise unclear questions. The farmers were interviewed and questionnaires administered to them. The questionnaire consisted of two sections; Section on socioeconomic characteristics of the farmer, and another section on the specific objectives which was a detailed survey. In the detailed survey section, information was gathered through direct entries, choice options or selection of respondent

assessment on a 5point Likert type scale. In the Likert scale, it was structured in a way that each scale could be filled as per the way the farmers' opinion on a technology in question.

In each questionnaire, each farmer took about 20 minutes to fill the questionnaire and where the farmer was unable to answer a research assistant was there to help.

3.9 Methods of Data analysis and Presentation

Descriptive and Multiple linear regression analysis are presented in this section.

3.9.1 Descriptive analysis

Descriptive analysis was done by use of Microsoft excel and Statistical Package for Social Sciences (SPSS). The frequencies and percentages were presented in tables, pie charts and bar graphs.

3.9.2 Multiple linear regression

The multiple linear regressions showed the relationship between the dependent and independent variables. Here, the dependent variable is the yield in bags while the independent variables are the gender, education; training on agricultural extension, technology, visit by agricultural extension agents, technology implementation and source of planting materials. Other independent variables include following recommended planting calendar, access of farm input form certified sources, and famers practices such as spacing, timely weeding among others.

Below is the multiple linear regressions model for the study.

$$Y=b_0+b_1x_1+b\ldots b_kx_k+e_i$$

Where:

Y=potato yield (number of bags)

b_0= intercept

b1, b_2, bk are co-effients of the variables

x_1, x_2, x_k independent variables

e_i is the error term

CHAPTER FOUR

RESULTS AND DISCUSSIONS

The results on the socioeconomic characteristics of the farmers, farmers' practices in potato production, farmers' perception on varieties adopted in the areas and the assessment of sustainable potato production technologies on yield among smallholder farmers are discussed in this section.

4.1 To determine socio-economic characteristics of potato farmers

The gender, age, education level, farmers group, farming experience, land size were the social- economic characteristics of the potato farmers presented in this section.

4.1.1 Gender of the respondent

The proportions of gender of the respondents presented inform of frequencies and percentages figure 4.

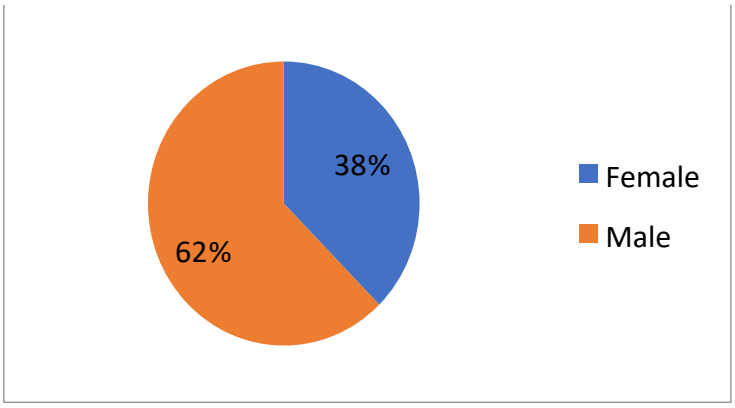

Figure 4: Gender of the respondent

Source: Author (2023)

Male farmers dominated potato production at 62 %. Female farmers accounted for approximately 38% of all farmers surveyed. The fact that male headed the households denotes the ultimate decision of potato production is a male responsibility. This means that the male farmers did the technological decision of the potato production. Manishimwe et al. (2019) found similar results in Rwanda. Also, Mwanja et al. (2016) found that there was a high probability of male farmers adopting potato technology than female farmers in South Western Uganda.

4.1.2 Age of the respondent

The potato farmers' age information is presented in figure 5.

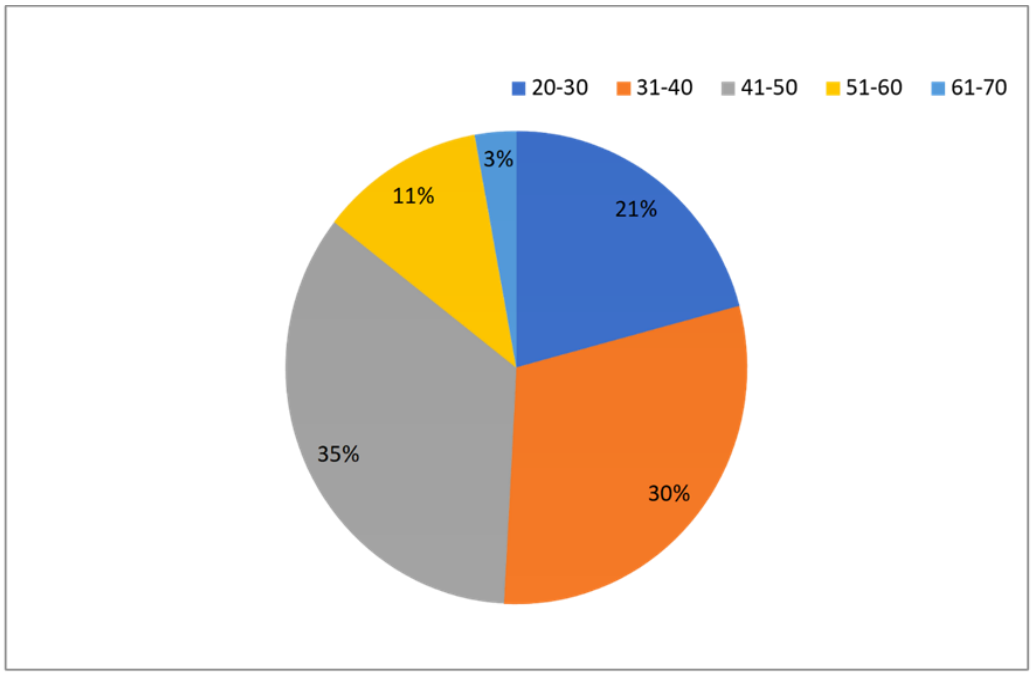

Figure 5: Age of the respondent

Source: Author (2023)

Potato producers ranged in age from 41 to 50 (34.7%). The aging population of 61-70 (2.9%) years of age were the least number of the producers of potato. The 31-40, 20-30

and 51-60 age groups comprised 30%, 21% and 12% of all farmers respectively (Fig 5). This suggests that middle-aged farmers dominate potato production. Youths were actively engaging in potato production in Marakwet west since they are endowed with skills and energy to produce the quality and quantity potatoes. Mengui et al. (2019) stated that age was the determining fact of technical efficiency among potato farmers.

4.1.3 Education level of the Farmers

The respondents' level of education has been divided into four categories and each category is represented by corresponding frequency and percentages as shown in figure 6.

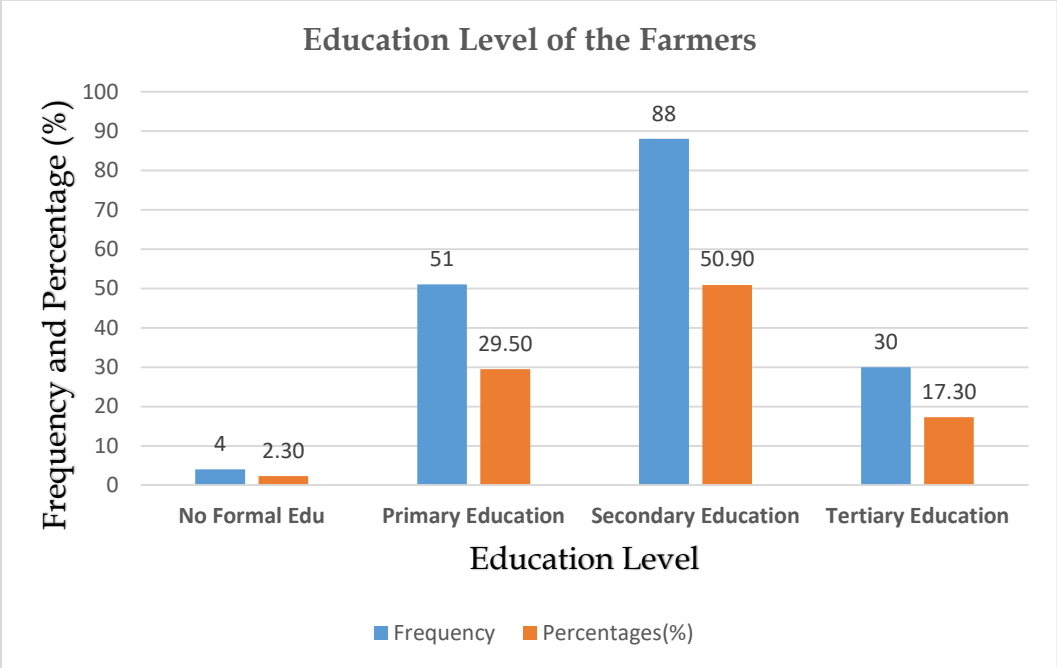

Figure 6: Education level of the farmers.

Source: Author 2023

The majority of the farmers attained the secondary level of education (51%). Those that had attained primary level of education, tertiary level of education and with no formal education were about 30%, 17% and 2% of the total number of farmers, respectively. This means that farmers had an adequate level of education to apply potato technology farmer determines the productivity of potatoes. Hence, the study found out that the farmers had the sufficient level education to comprehend and execute the potatoes production technologies. Worku (2019) concurs with it that education level of the farmers increases the probability of the adoption of potato technology Oromia regional state Western Sewa in Southern Ethiopia.

4.1.4 Farmers group

The responses from the smallholder potato farmers' affiliation to a farmer group have been presented in Table 4.

Table 4: Farmers group

Farmers group	Frequency	Percentage (%)
Yes	156	90.17
No	17	9.83
Total	173	100

Source: Author (2023)

The farmers were members of the farmers' groups. This promoted sharing of potatoes technologies in view of producing quality and quantity produce. Similarly, Ketema et al. (2016) reported that farmers belonging to cooperatives

and social institutions foster the adoption of technologies in Nakuru County in Kenya.

4.1.5 Farming experience

The different levels of farming experience of the respondents and its respective frequencies and percentages have been presented in figure 7

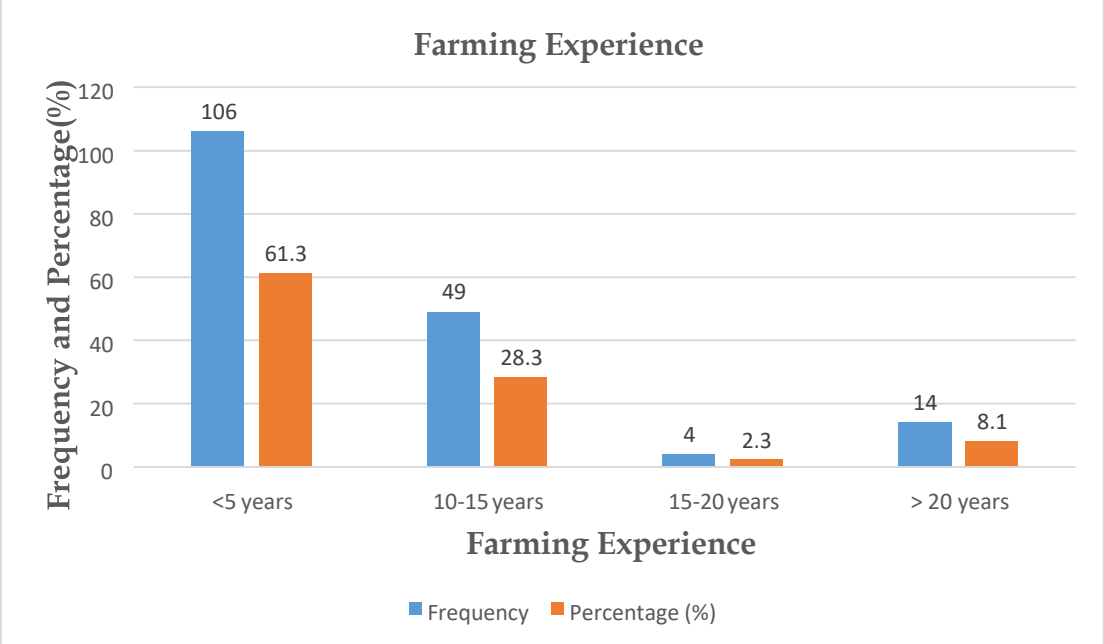

Figure 7. **Farming experience**

Farming experience is integral to the productivity of the potato. The majority of the farmers had <5 years (61%) in the production of potato. Farmers aged 5-10, over 20, and 10-15 were found at approximately 28%, 8% and 2% of the total number of farmers respectively. Farmers' agricultural experience has sufficed to ensure good potato production. Farmers experience plays a significant role in potato production. The farmers had enough experience to execute potato production. Farmer's experience was one of the

significant determinants of technical efficiency among potato farmers (Mengui et al., 2019). Besides, farmers' experience in potato production had positive effects on the adoption of new technologies (Selahkwe et al., 2021).

4.1.6 Land size

The land size under potato production and its respective frequency and percentage is presented in figure 8

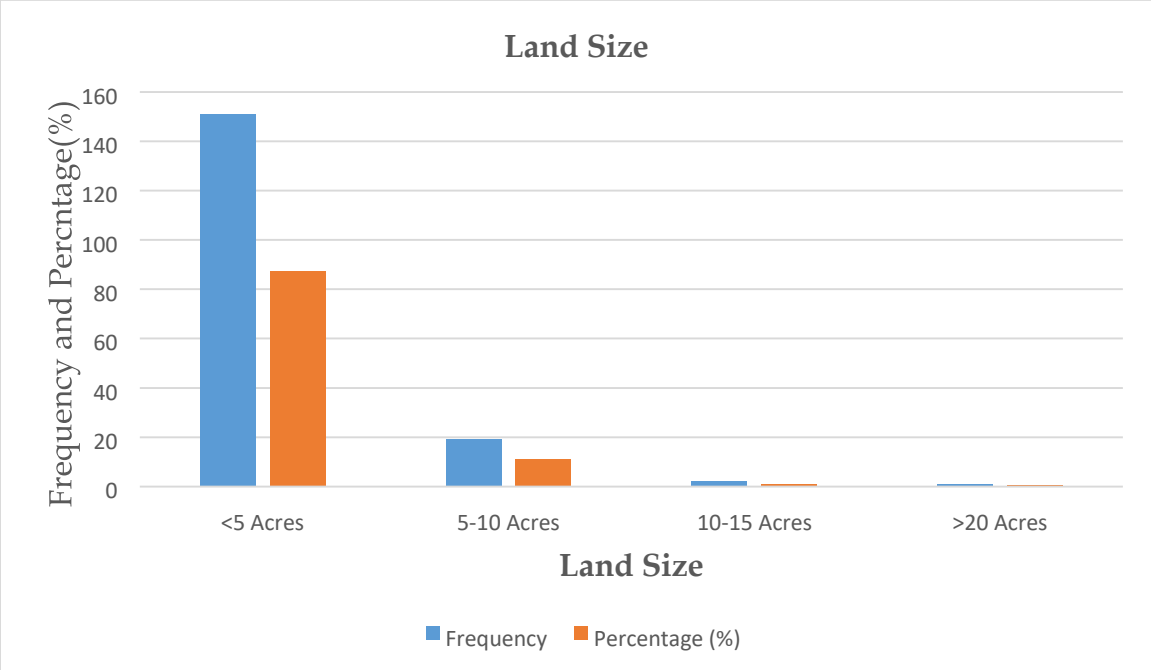

Figure 8: **Land size**

Source: Author (2023)

Most of the farmers were operating at a land size of below 5 acres (87%). The farmers were running on land size above 10 acres were about 1.2% of the entire number of farmers. This means that the smallholder farmers-controlled potato production.

Smallholder farmers with land size of less than 5 acres practiced potato production. This was as a result of land subdivisions, which was prevalent in the area due to increasing population rate. Similar results were found by Omiti et al. (2009) that smallholder farmers did Potato production in Kenya with a land size of less than 5 acres.

4.2 Potato production technologies practiced by farmers

The potato production technologies including crop rotation in the farm, use of organic manure during planting, control of pest and diseases in the farm, recommended spacing, recommended fertilizer rate during planting, safe and effective use of pesticides are discussed in table 5.

Table 5: Potato production technologies

	Potato production technologies and Percentage (%)					
Response	Crop rotation	Organic manure	Pest and disease control	Recommended Spacing	Recommended fertilizer rate	Safe and effective use of pesticides
Strongly disagree	6.4	9.8	3.5	2.9	3.5	3.5
Disagree	1.2	4.6	0.6	1.7	4	4.6
Undecided	1.2	2.3	1.7	2.3	2.9	1.7
Agree	13.9	12.7	16.2	13.3	10.4	10.4
Strongly agree	77.5	70.5	78.0	79.8	79.2	79.8
Total	100	100	100	100	100	100

4.2.1 Practice of crop rotation in the farm

About 78% of the total number of farmers strongly agreed to practice crop rotation in the farms, about 6 % of them strongly disagreed. The farmers, who agreed, disagreed and the undecided were 14%, 1.2 % and 1.2 % of the total number of farmers, respectively. This means that farmers in the region practiced Crop rotation. The farmers practiced crop rotation of potatoes with beans, maize crop. This reduces the incidences of pest and diseases build-up, especially the soil borne pest and diseases. Liu et al. (2019) revealed that the yield of potatoes increased with crop rotation, while Larkin et al. (2011) found out that, rotation increased tuber yield. Wakahiu et al. (2007) revealed that farmers practice crop rotation in Nyandarua County through planting potatoes for 3-4 seasons.

4.2.2 Use of organic manure during planting

Most of the farmers strongly agreed that they use organic manure during planting (71%). Whereas about 13% of the farmers agreed to use organic manure during planting, about 5% disagreed. Only about 5% of the farmers remained undecided on the use of organic manure during planting.

Most farmers used organic manure because of its availability and affordability by the farmers. Manure has a positive effect on the yield of potatoes. Sidhu et al. (2007) found out that the use of Farm Yard manure at 50 t ha^{-1} lead to increases in tuber yield. Also, Mengui et al. (2019) revealed that the application of manure increased technical efficiency among potato farmers.

4.2.3 Control of pest and diseases in the farm

Most of Potato farmers strongly agreed to control pest and diseases in their farms (78%).

The farmers, who agreed, strongly disagreed, undecided and disagreed were about 16%, 4%, 2% and 1% of the total farmers respectively. This shows that farmers controlled pest and disease in order to increase the quality and quantity of potato production.

4.2.4 Recommended spacing during planting

While the majority of the farmers practiced recommended spacing during planting 93.1%, about 4.6 % of them did not practice it. Only about 2.3% of them remained undecided. This connotes that the farmers applied the recommended spacing in the growing of potatoes in their farms. There is a standard spacing recommended to farmers for planting of potatoes by the Ministry of Agriculture in Kenya that guarantees maximum yield and this is (30cm by 50cm). The fact that the farmers practiced the recommended spacing was owed to the trainings provided by the extension agents. Gebre et al. (2001) revealed that optimum yield of potatoes depends on correct spacing.

4.2.5 Recommended Fertilizer rate during planting

Farmers strongly agreed to be applying recommended fertilizer rate (79%). Only about 8% of the farmers applied fertilizers contrary to recommended rate. The farmers who agreed and the ones who remained undecided were about 11% and 3% of the total number of farmers respectively. This displays that farmers were cognizant of the need to apply the correct fertilizer regime on potato production.

The use of recommended fertilizer rate in the production of potatoes by the farmers guarantees optimum yield. (200kgs/acre). Due to the constant trainings and soil testing by both private and public extension officers did the recommended rate of fertilizer use. Both Urea and DAP fertilizers were the most utilized fertilizers by smallholders' farmers (Haile

et al., 2013). Beside, Naz et al. (2011) revealed that NPK fertilizers enhanced yield and quality of potato tubers.

4.2.6 Safe and effective use of pesticides on control of pests and diseases

Safe and effective usage of pesticides was practiced by most of the farmers (90.2%). The farmers who practiced on the contrary were 8.1%.

The undecided farmers were only 2% of the entire number of farmers. This indicates that farmers were knowledgeable on the safe and effective use of agro-chemicals.

4.3 Farmers perception on the varieties adopted in the area

Available varieties and source of planting materials is covered in this section.

4.3.1 Variety available in the region

The response of the farmers on the varieties available in the area of study is presented in this section (Table 6).

Table 6: Variety available in the region

Variety	Frequency	Percentage (%)
Shangi	160	92
Tigoni	8	4.6
Kerr pink	5	2.8

Source: Author (2023)

Shangi variety was the widely grown potato variety in the region. However, farmers did not use the certified seed instead they sourced seeds from other farmers. This is explained by its adaptive capacity high yield and strong market demand (Table 6).

4.3.2 Source of planting materials

The farmers' response on the source of planting materials is presented in this section.

Table 7: Source of planting materials

Variable	Frequency	Percentage (%)
Certified seeds	1	0.6
Own seeds	72	41.6
From other farms	100	57.8
Total	173	100

Source: Author (2023)

Most of the farmers sourced potato seeds for planting from other farms (58%), while about 41 % of them utilized seeds from their own farms. Only 0.6% of farmers used certified seed during planting of potatoes. Most of the farmers stated that certified potato seed were not available to them, the other reasons given by the farmers were that certified seeds were not affordable to them, and at the same time they had no information on the certified seeds hence it was a new product to them. Njagi et al. (2018) found out that indeed farmers are constrained in accessing quality certified seeds and that Okello et al. (2016) revealed that the distance to the market, household food insecurity and asset endowment influenced the decision to use certified seeds of potatoes. If the farmers' access the certified seeds, coupled with good management practices, Hassen (2015) revealed that the yield would improve.

4.4 Perception of farmers on sustainable potato technologies

Varieties available are suitably adapted in the region, farmers following recommended planting calendar on potato yield, farmers access to farm inputs from certified sources on potato yield, farmers practice on recommended practice like spacing, fertilizer application, timely weeding among others on potato yield, farmers practice on appropriate application of post-harvest practices on potato yield, farmers access to good market network and information, farmers' information on good market price on high quality potato obtained and farmers access to good transport to the market have been covered in this section.

Table 8: Sustainable potato technologies on potato yield

Response	Perception of sustainable potato production technologies and percentage (%					
	Variety adaptation	planting calendar	Input from certified sources	Recommended crop husbandry	Safe and effective use of pesticide	Post-harvest practices
Strongly disagree	1.7	0.6	6.9	2.3	2.3	5.2
Disagree	10.4	5.8	4.0	2.9	1.2	5.2
Undecided	0.6	6.9	7.5	6.4	5.8	4.6
Agree	11.6	12.7	19.7	16.2	20.2	24.9
Strongly agree	75.7	74	61.8	72.3	70.5	60.1
Total	100	100	100	100	100	100

Source: Author (2023)

4.4.1 Varieties available are suitably adapted in the region

The majority of the farmers strongly agreed that the variety that they were planting was adapted to the region (78%). The farmers, who agreed, disagreed, strongly disagree and those who remained undecided were about 12%, 11%, 2% and 0.6% of the total number of farmers respectively (Table 8).

Shangi variety was the widely grown potato variety in the region and well adapted to the ecological conditions of the study area. Tuber quality characteristics such as skin colour, tuber size, tuber shape and time to maturity are often key factors in cultivar acceptability based on local consumer preferences and criteria for potato processing (McArthur, 1989), In addition, the improved varieties of potatoes are high yielding and resistant to late blight, even though the level of adoption by farmers is still low in most regions (Abebe et al., 2013).

4.4.2 Farmers following recommended planting calendar

With respect to the following recommended planting calendar by farmers on potato yield, most of the farmers strongly agreed on it (74%), while only 0.6% strongly disagreed. Farmers who agreed, undecided and disagreed accounted for 12.7%, 6.9% and 5.8% of the total number of farmers, respectively (Table 8).

The farmers, mostly plant before the beginning of the rainy season while others were practicing it under irrigation. Singh et al. (2020) reveals that the timely planting leads to maximum germination, good crops stand and maximum use of light and temperature leading to high yield. Also, Haile et al. (2015) found out that there was an increase in the number of stems per plant and heavier tubers with delayed planting, but in late planting,

the number of tubers was low. Potato farmers also accessed potato inputs that were necessary for potato production, these were seeds, fertilizer and agro-chemicals and this guaranteed better potato yields.

4.4.3 Farmers access to farm inputs from certified sources

Farmers who accessed to farm inputs from certified sources are 81.5 %. Only about 10.9% of them responded that they were not able to receive inputs from certified sources. Those who remained undecided were found to be 7.5% of the total number of farmers (Table 8)

4.4.4 Farmers application of recommended husbandry practices

Most of the farmers strongly agreed that they practiced recommended practices like spacing, fertilizer application, (72%). Those farmers, who agreed, undecided, disagreed and strongly disagreed were 16.2%, 6.4%, 2.9% and 2.3% of the total farmers, respectively (Table 8)

These are practices such as correct spacing, recommended fertilizer application, crop rotation and timely weeding. Correct spacing leads to better plant density and good size tubers, thus leading to good price in the market. FAO (2009) recommends soil testing before any application of fertilizer to ascertain soil characteristics, nutrient content and soil contaminants. This avoids the overuse or under-use of the fertilizer level to the potatoes, thus optimizing yield and reduces environmental pollution. In addition, timely weeding reduces weed competition for plant nutrients with the potatoes, hence better yield.

There was a significant effect on tuber yield, quality, and improvement in soil properties and health when cover crops and green manures are applied (N'Dayegamiye et al., 2017), changes in the rate of compost or Farmyard manure application (Ninh et al., 2015) and a

smaller number of tillage (Carter et al., 2001). In addition, the improved varieties of potatoes are high yielding and resistant to late blight, even though the level of adoption by farmers is still low in most regions (Abebe et al., 2013).

4.4.5 Farmers practice on safely and effective use of pesticides and fungicides

Whereas about 71% of the farmers strongly agreed that safely and effectively use of pesticides increased potato yield, about 2% of the farmers strongly disagreed with it. The farmers who agreed, remained undecided and disagreed were 20%, 6% and 1% of the total number of farmers respectively (Table 8).

Pest and disease posed great challenges to the potato Farmers they revealed that the control of the pest and disease improved the yield of the potatoes. According to FAO (2009), the management of potato blight is done better with the use of fungicides, while the insecticides are used to control the insect pest. The appropriate use and disposal of agro-chemicals was enhanced through training's done by the extension agents. This reduces environmental pollution.

4.4.6 Farmers practice on appropriate application of post-harvest practices

While farmers who strongly agreed that appropriate application of post-harvest practice influence the potato yield, only about 5 % of them strongly disagreed. The farmers who agreed, disagreed and remained undecided were about 25%, 5% and 5% of the total number of farmers (Table 8). The farmers employed post-harvesting technologies on potatoes and this helps reduce post-harvest losses. Through reduction of post-harvest

losses, farmers can improve income, guarantee food security and reduction in storage (Hakan, 2012). Additionally, the reduction of post-harvest loss by 50%, food availability would increase by 20% without increasing the size of land for cultivation in view of increasing production (Ayandiji et al., 2011).

4.5 The relationship between the dependent and independent variables

To understand the relationship between the dependent and the independent variables, multiple regression models was used as shown in table 9.

Table 9: Multiple Linear Regression Model

Model	Unstandardized Coefficients	Standardized Coefficient			Significant
	B	Std. Error	Beta		
(Constant)	-24.357	11.976		-2.034	0.044
Gender	-3.940	3.286	-0.081	-1.199	0.232
Education	2.008	2.149	0.062	0.934	0.352
Training on Agricultural Extension and technology	11.920		0.246	3.399	0.001
Visit by agricultural extension agents	8.131	3.507	0.130	1.786	0.076
Technology of Implementation	-13.769	4.552	-0.237	-3.622	0.000
Source of planting materials	16.486	3.802	0.356	5.229	0.000

Model performance parameters

R 0.559
R Squared 0.312
Significance at 5 % level
Dependent Variable: Number of Bags of potatoes harvested

Source: Author (2023)

The model is significant at 5% level. This indicates that the independent variables predict the dependent variable. The R Squared is 0.312, meaning that 31.2% of the variance in the yield of potato is explained the gender, education, training on agricultural extension

and technology, visit by agricultural extension agents, technology implementation and source of planting materials.

The gender, education, visit by agricultural extension agents were found to be insignificant, whereas training on agricultural extension and technology, technology implementation and source of planting materials were significant at 5% level.

From the study as the education level of the respondent increase by one unit, the yield of potato increases by 2 bags likewise, if the farmers were trained on agricultural technologies; the yield increases by 12 bags, and when agricultural extension officers visited the farmers, the yield increases by 8 bags. However, if the farmers failed to implement the technology, the yields decrease by 14 bags and when the farmers get the certified planting materials, the yield increases by 16 bags (Table 9).

Gender, education level, training on agricultural extension and technology, visit by agricultural extension agents, technology implementation and source of planting materials have effect on yield of potato. Tata et al. (2018) found out that gender, age and education had an effect on the utilization of the technology and on extension service delivery. The agricultural technologies such as use of fertilizer and fungicides improved potato yields (Kange et al., 2022). Other factors that were not considered by the researcher and could have created a significant impact on the yield included the marketing factors, post harvesting practices among others.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

The study evaluates the Irish potato production technologies among farmers in Marakwet west sub-county. This section discussed on the conclusions and recommendations made during the study.

5.1 Conclusions

From this study, it is revealed that; farmers possess diverse socioeconomic characteristics such as age, education level, farm size, gender, access to extension services, all of which significantly influenced adoption decision.

From this study it is concluded that male headed the households and the ultimate decisions about the potato production is a male responsibility. This means that the male farmer did the technological decision of the potato production. Besides, the farmers were smallholder farmers operating at land size of less than 5 acres. In addition, farmers were well experienced and well-educated youth and able to implement with efficiency the potato production technologies. Also, the farmers were members of farmers group and this promoted sharing of potato production technologies in view of producing quality and quantity yield.

Also from the study, improved technologies like certified seed use, fertilizer and manure application, crop rotation, control of weeds, pest and diseases in the farm among others were applied by farmers in view of improving potato production to reduce poverty and improve food security.

From the study it was concluded that training on agricultural extension technology did not reach all the farmers in the area of study. However, those who received agricultural extension training on the technology implemented the technologies on their farms. Moreover, the decision on whether to apply the technology or not was determined by the male who happened to be the household heads. Technology has allowed farmers to improve their yields, save on inputs and fight pests and diseases.

Shangi variety of potatoes was grown by farmers in the region because it matures early and it is of high yield and well adapted to the region, whereas *Tigoni, Asante* and *Kerr's Pink* were potato varieties no longer grown by the farmers. However, the farmers did not use the certified seed of *Shangi* variety instead they sourced seeds from other farmers. The reasons thereof were that the seeds were not available to them, expensive, they had no information and it was a new product to them.

Following recommended planting calendar, access of farm inputs from certified sources, farmer's practices such as spacing, fertilizer application and timely weeding, the farmers revealed that the control of the pest and disease improved the yield of the potatoes, the farmers employed post harvesting technologies including sorting and cleaning on potatoes and this help reduce post-harvest losses However, farmers were not accessing good market network and information, hence affected the production of potatoes.

5.2 Recommendations

From the study, it is recommending that the farmers should adopt improved production technologies such as certified seeds, soil fertility management practices, and integrated

pest and disease control to enhance yields. Tissue culture need to be adopted to increase the planting materials to meet the demand of potato growers.

The study also recommends that the agricultural extension agents should target both the male and female farmers when training on potato production technologies. However male farmers are the ones who own resources and therefore the ultimate decision makers but also female should access the technologies too.

In addition, farmers should be encouraged to join farmers' groups because technology is disseminated and shared every time farmers come support programs and subsidies for certified seeds, fertilizer among others should be enhanced to make technologies more accessible.

Policy framework should promote collaboration between government, private sector, research institution in affordable inputs and strengthening extension services are important in improving adoption of appropriate technologies. This would not only raise production but also contribute to food security, household income, and rural development in the sub-county.

Further research is suggested on gender and youth roles, economic viability of technologies, climate-smart practices, and value chain integration together during their groups.

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APPENDICES

Appendix I: Questionnaire

Questionnaire for potato Farmers Administrative Units

Location ……

Sub location……

Village ……

Section A: Socioeconomic characteristics of the farmers

Personal Information

Socioeconomic variables: Gender of the Household Head, Respondent's age, the level of education and membership to Farmer Groups

Background Information of the Respondent

1. Sex of the Household Head 1= Female [ ] 2=Male [ ]
2. What is your age bracket?

   i=20-30 years [ ]
   ii=31-40 years [ ]
   iii=41-50 years [ ]
   iv=51-60 years [ ]
   v= 61-70 years [ ]

3. What is your highest level of education?

   0= No formal education [ ]

   1=Primary education [ ]

   2=Secondary education [ ]

   3=Tertiary education [ ]

4. Who within your household is an ultimate decision maker in planning on farming and technology implementation?

   1= Household head [ ]

   2= Wife [ ]

   3= Children [ ]

5. Do you have access to information like attending trainings on agricultural extension services and technology development?

   1= Yes [ ]

   2= No [ ]

6. Do you have regular visits by agricultural extension agents?

   1= Yes [ ]

   2= No [ ]

7. Kindly rate the degree to which you feel about the services offered by the extension officers in the region?

Statement	**(Level of opinion)**
Excellent	
Good	
Bad	
Not sure	

8. Do you belong to any farmer group within your locality?

   0= No [ ]

   1=Yes [ ]

If yes, name these farmer group/s

1……

2……

9. What is your frequency of attending the meetings conducted by these farmers' groups?

   1= Rarely [ ] 2= Sometimes [ ] 3= Often [ ]

10. How membership / association to farmer group mentioned above, contributes to potatoes technologies uptake in your locality?

    i. Information sharing [ ]
    ii. Social capital [ ]
    iii. Collective actions [ ]
    iv. Other, specify……

11. Have you implemented the technologies 1= Yes [ ] 2=No [ ]

12. Please specify the technology that you have implemented

    i……. ii. ……..……..…….

13. How has your implementation of the adopted technology been helpful?

    i.
    ii.
    iii.

14. If no, what could be the reason?

    i. Lost interest [ ]
    ii. No access to information [ ]
    iii. Fear of taking risk [ ]

iv. Complexity of technology [ ]

v. The technology is costly [ ]

vi. Others…….. ……

15. What is your farming experience in years?

i. <5 [ ]

ii. 5-10 [ ]

iii. 10-15 [ ]

iv. >20 [ ]

16. What is the total land coverage on potato production?

i. <5 acres [ ]

ii. 5-10 acres [ ]

iii. 10-15 acres [ ]

iv. >15 acres [ ]

17) What is your average potato yield per acre per year?

……

Section B: Questionnaire on specific objectives of the study

Objective 2: Farmers practices on potato production in the area

18 (a) To what extent do you agree with the following statements regarding the practices you carry out on your farm?

Key 5: Strongly Agree, 4: Agree, 3: Undecided; 2: Disagree; 1: Strongly Disagree

Statement	5	4	3	2	1
There is training on various technologies on issues in potato farming					
Do you practice crop rotation on your farm					
Do you use organic manure during planting					
Do you control pest and diseases in your farm					
Recommended spacing during planting					
Recommended fertilizer application					
Safe and effective use of agrochemicals					

Objective 3: Farmers perception on the varieties adopted in the area

19. a) Source of planting materials

i) Certified seeds [ ]
ii) Own Seeds [ ]
iii) From other farms [ ]

b) Which varieties are available in the region

i) *Shangi* [ ]
ii)Kerr's Pink [ ]
iii)Nyayo [ ]
iv) *Asante* [ ]
v) *Tigoni* [ ]

vi) Others ……

(c) Have you ever-used certified potato seeds in your farm?

Yes [ ] No [ ]

If No, why did u not use the certified seeds?

…..…….

……

……

Objective 4. To assess the extent to which sustainable production technologies affect yield among the smallholder farmers

20. Among the varieties which ones have been accepted or rejected in the area?

	Accepted	Rejected
i) *Shangi*	[ ]	[ ]
ii) *Kerr's Pink*	[ ]	[ ]
iii) *Nyayo*	[ ]	[ ]
iv) *Asante*	[ ]	[ ]
v) *Tigoni*	[ ]	[ ]

vi) Others……

……

(b). To what extent do you agree with the following statements on the use of production technologies to improve yield?

Key 5: Strongly Agree, 4: Agree, 3: Undecided; 2: Disagree; 1: Strongly Disagree

Statement	5	4	3	2	1
The varieties available are suitably adapted to the region					
I practice crop planting recommended calendar in my farm					
I can easily access farm inputs from certified sources					
I can easily practice the recommended practices like; spacing, fertilizer application, timely weeding among others					
I can safely and effectively use pesticides					
I can appropriately apply good post harvesting practices					
I can easily access good market network and information					
My produce gets good market price because of good quality obtained					

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