RELATIONSHIP BETWEEN SELECTED FACTORS AND THE PRACTICE OF CLIMATE-SMART AGRICULTURE AMONG SMALLHOLDER POTATO FARMERS IN GILGIL SUB-COUNTY, KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfillment of the Requirements for the Master of Science Degree in Agricultural Extension of Egerton University

EGERTON UNIVERSITY

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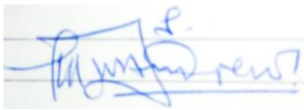
DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been submitted or presented for the award of a Diploma or Conferment of Degree in this University or any institution.

Signature:  Date: 07th November 2021

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Recommendation

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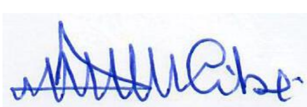
Signature:  Date 22/06/2021

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DEDICATION

This work is dedicated to the family of Mr. Bernard Mwenja Ngigi of Gilgil Sub County, Kenya, and to all people with positive motives to help others realize their dreams.

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First, my hearty thanks go to the Almighty God for His grace and mercy without which successful completion of my studies would not be possible. I wish to acknowledge MasterCard Foundation through Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for the scholarship that enabled me to further my studies. I salute Dr. Ombati M. Justus for encouraging and making me believe that timely completion of my studies was possible. I also thank all my lecturers especially Drs. Maurice Udoto, Miriam Kyule, Maina Stephen Wambugu, James Obara, and Simon Mutonga for not only believing in me but also labored tirelessly to give this work its current shape. I am indebted to my supervisors and Dr. Joel Ngeno Kipkemoi whose child-parent relationship and their invaluable input to my work eminently supported me to push harder towards the completion of my studies.

ABSTRACT

Climate-Smart Agriculture presents the potential to meet the world's increasing food demands in the face of climate variability and it promises to sustainably increase food production, potato yield inclusive. The association between information dissemination pathways and practice of Climate-Smart Agriculture practices (CSA) and the relationship between the selected factors and the practice of CSA in Gilgil Sub-County had not been studied. The purpose of this study was therefore to establish the relationship between selected factors and the practice of CSA in Gilgil Sub-County. A cross-sectional survey design was adopted for this study and targeted smallholder farmers growing potatoes in Gilgil Sub-County. The accessible population consisted of all the 10,889 potato farmers found in Morendat ward (4,287), Mbaruk / Eburu ward (6,602), and a total sample of 120 respondents was selected from these two locations within Gilgil Sub-County using a proportionate and simple random sampling approach. A structured researcher constructed questionnaire with established validity and reliability was administered to the sampled smallholder potato farmers. Data analysis was done using SPSS version 25 to run descriptive and inferential statistics. Cramer's V was used to ascertain and test the strength of the association between information dissemination pathways and practice of CSA. Binary logistic regression was used for establishing the relationship between socioeconomic and institutional factors and the practice of CSA for the rejection or acceptance of the hypotheses at a 5% level of significance. It was found that information dissemination pathways are significantly associated with the practice of CSA, and the socioeconomic and institutional factors significantly related to the practice of CSA among smallholder potato farmers in Gilgil Sub-County, Kenya. This study recommends mainstreaming of CSA information, facilitating increased output for increased farm income among the farmers, increasing access to vital resources for women farmers to enhance their capacity to adjust production methods in response to climate change and facilitating access to credit by the farmers.

TABLE OF CONTENTS

DECLARATION AND RECOMMENDATION .... **ii**

COPY RIGHT .... **iii**

DEDICATION .... **iv**

ACKNOWLEDGMENT .... **v**

ABSTRACT .... **vi**

LIST OF TABLES .... **x**

LIST OF FIGURES .... **xii**

LIST OF ABBREVIATIONS AND ACRONYMS .... **xiii**

CHAPTER ONE **1**

INTRODUCTION **1**

1.1 Background of the study 1

1.2 Statement of the Problem 4

1.3 Purpose of the Study 5

1.4 Objectives of the Study 5

1.5 Hypotheses of the Study 5

1.6 Significance of the Study 6

1.7 Scope of the Study 6

1.8 Assumption of the Study 6

1.9 Limitation of the Study 6

1.10 Definitions of Terms 7

CHAPTER TWO **9**

LITERATURE REVIEW **9**

2.1 Introduction 9

2.2 Origin and Importance of Potato Production 9

2.3 Effect of Climate Change on Potato Production 11

2.4 Evolution and Importance of Climate-Smart Agriculture 12

2.5 The CSA in Potato Production in Kenya 15

2.6 Information Dissemination Pathways and Adoption of Agricultural Technologies 17

2.7 Socioeconomic Determinants of Adoption of Agricultural Technologies 19
2.8 Institutional Determinants of Adoption of Agricultural Technologies 22
2.9 Theoretical Framework 24
2.10 Conceptual Framework 25

CHAPTER THREE 27
RESEARCH METHODOLOGY 27
3.1 Introduction 27
3.2 Research Design 27
3.3 Location of the Study 27
3.4 Target Population 27
3.5 Sampling Procedure and Sample Size 28
3.6 Instrumentation 29
3.8 Data Analysis 31

CHAPTER FOUR 33
RESULTS AND DISCUSSION 33
4.1 Introduction 33
4.2 Climate-Smart Agriculture Information Dissemination Pathways 33
4.3 Relationship between Socioeconomic Factors and Practice of Climate-Smart Agriculture 39
4.4 Relationship between Institutional Factors and Practice of Climate-Smart Agriculture 59

CHAPTER FIVE 76
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS 76
5.1 Introduction 76
5.2 Summary of Study Findings 76
5.3 Conclusions 77
5.4 Recommendations 78
5.5 Suggestions for Further Research 78

REFERENCES 79

APPENDICES 101
Appendix A: Meaning and Potential of Study CSA Practices 102
Appendix B: Questionnaire for Smallholder Potato Farmers 107
Appendix C: Location of Gilgil Sub County in Kenya 110
Appendix D: Map of Gilgil Sub County 111
APpendix E: Reliability Test Results 112
Appendix F: Research License 113
Appendix G: Socioeconomic Factors' Percentage Accuracy Classification for Likelihood Prediction 115
Appendix H: Institutional Factors' Percentage Accuracy Classification for Likelihood Prediction 116
Appendix I: The First Publication from this Thesis 117
Appendix J: Second Publication from this Thesis 118
Appendix K: Third Publication from this Thesis 119
Appendix L: Fourth Publication from this Thesis 120
Appenix M: Other Main Data Outputs 121

LIST OF TABLES

Table 1: Annual potato production, food and seed supply per country between 2014 and 2017 . 11
Table 2: Evolution of Climate-Smart Agriculture 13
Table 3: Performance of potato clones in water-stressed conditions at average precipitation of 295 mm (range from 210 to 414 mm) across three seasons and three locations between 1300 and 1700 masl in Kenya 16
Table 4: Crop rotation sequence practiced by some Kenyan potato farmers 16
Table 5: Proportion of Sample Size Per Ward 29
Table 6: Data Analysis Summary 32
Table 7: Awareness, information dissemination pathways and Practice of CSA 34
Table 8: Information dissemination pathways and practice of CSA 38
Table 9: Descriptive statistics of the smallholder potato farmers' socioeconomic factors 40
Table 10: Gender and practice of climate-smart agriculture 43
Table 11: Age and practice of climate-smart agriculture 46
Table 12: Education level and practice of climate-smart agriculture 48
Table 13: Annual farm income and practice of climate-smart agriculture 50
Table 14: Annual off-farm income and practice of climate-smart agriculture 52
Table 15: Socioeconomic factors' statistical significance analysis case processing summary 54
Table 16: Omnibus tests of model coefficients for socioeconomic factors 54
Table 17: Socioeconomic factors' model summary 55
Table 18: Percentage accuracy classification table[a] for socioeconomic factors' BLRM 55
Table 19: Hosmer and lemeshow test for socioeconomic factors' BLRM 55
Table 20: Socioeconomic variables in the binary logistic regression equation 56
Table 21: Descriptive statistics for institutional factors among smallholder potato farmers 60
Table 22: Access to credit and practice of climate-smart agriculture 65
Table 23: Training on and practice of climate-smart agriculture 66
Table 24: Non-government organization support and practice of Climate-Smart Agriculture 68
Table 25: Farmer group membership and practice of climate-smart agriculture 70
Table 26: Institutional factors' statistical significance analysis case processing summary 71
Table 27: Omnibus tests of model coefficients for institutional factors 71
Table 28: Institutional factors' model summary 72

Table 29: Percentage accuracy classification table[a] for institutional factors' model.................. 72
Table 30: Hosmer and lemeshow test for institutional factors' BLRM.. 73
Table 31: Institutional variables in the binary logistic regression equation 73

LIST OF FIGURES

Figure 1: Trends in potato yield per hectare between 2010 and 2018 in Kenya. 2

Figure 2: Potato distribution worldwide by 2018. 10

Figure 3: Stages in the technology adoption process... 24

Figure 4: Own conceptualized framework showing the interaction between the selected factors and the practice of CSA.. 26

Figure 5: Extent of practice of CSA 36

LIST OF ABBREVIATIONS AND ACRONYMS

AAA	Adaptation of African Agriculture
AGRA	Alliance for a Green Revolution in Africa
CARP+	Community Action Research Project
CaWSA-C	Climate and Water Smart Agriculture Centre
CCAFS	Climate Change, Agriculture and Food Security
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture
CIP	International Potato Centre
COP	Conference of Parties
CSA	Climate-Smart Agriculture
CSAPs	Climate-Smart Agricultural Practices
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
FARA	Forum for Agriculture Research in Africa
FGM	Farmer Group Membership
GACSA	Global Alliance for Climate-Smart Agriculture
GHI	Global Hunger Index
GoK	Government of Kenya
MICCA	Mitigation of Climate Change in Agriculture
MoALF	Ministry of Agriculture, Livestock and Fisheries
NACOSTI	National Commission for Science, Technology and Innovation
NEPAD	New Partnership for Africa's Development
NGOs	Non-Governmental Organizations
SACCO	Savings and Credit Cooperatives
SBSTA	Subsidiary Body for Scientific and Technological Advice
SDGs	Sustainable Development Goals
SNV	Netherlands Development Organization
SPSS	Statistical Package for Social Science
UNFCCC	United Nations Framework Convention on Climate Change
BLRM	Binary Logistic Regression Model

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The world's population is expected to increase by one-third by 2050 (Food and Agriculture Organization [FAO], 2014). With the expected increase in population, agriculture will have to make noticeable adjustments to produce enough food (Serdeczny *et al.*, 2017). However, this production is currently jeopardized by climate change (Aggarwal *et al.*, 2018; FAO, 2014). In case of inappropriate measures, agriculture and food systems will be at higher risk (Lipper *et al.*, 2014; Waaswa & Satognon, 2020). One of the apparent risks and effects is low agricultural productivity of the major crops (maize, wheat, cassava, potato, rice, beans) as a result of crop failure due to soil degradation coupled with prolonged dry spells (FAO, 2019). This affects the majority of African countries whose economy relies on agriculture (Olorunfemi *et al.*, 2020), leading to 48% of the population in poverty (Adhikari *et al.*, 2015).

It is known that 80% of East Africa's population is below 35 years (Dawit *et al.*, 2018). This young population is expected to contribute to the agricultural production of the region. However, the region is continuously limited by adverse weather conditions (Alliance for a Green Revolution in Africa [AGRA], 2015; Hussein, 2011; Nicholson, 2017; Omambia *et al.*, 2012; Ongoma *et al.*, 2018). These conditions lead to depletion of natural resources like soil, land, water, and ecosystems leading to the region's underperformance (Kanianska, 2016; New Partnership for Africa's Development [NEPAD], 2013; Waaswa & Satognon, 2020; Wynants *et al.*, 2019).

East Africa's climate change forecasts and Kenya, in particular, show an increase in temperatures and regular climate shocks in terms of droughts and floods. This, together with the growing population in Kenya that is expected to increase to 95 million by 2050, creates a risk of famine (Netherlands Development Organisation [SNV], 2019). Over 75% of the population is directly or indirectly employed in the agriculture sector. The sector contributes to about 26% of Kenya's Gross Domestic Product [GDP] (Bolt *et al.*, 2019). Kenya's economy will mostly be affected if appropriate precautions against climate change are not taken. According to Bolt *et al.* (2019), the productivity of potato, the second most important staple food crop in Kenya, is being lowered by climate change. Nakuru, one of the potato producing counties in Kenya has been exposed to climate variability (Frances, 2015; Mbatiah, 2015; MoALF, 2016).

Potato is both a food security crop and a crop of economic value to Nakuru farmers (Government of Kenya [GoK], 2014). Under favorable conditions in developing countries, potatoes have the potential of yielding an average of around 10 to 15 tons per hectare (NeBambi *et al.,* 2009). This is seldom realized in the Sub Saharan region which attain meager yields of 7.8 tons on average per hectare (Taiy *et al.*, 2017). Globally, potato yield is seen to decrease up to 32% in case of no climate change adaptation measures. In Kenya, potato yields have been declining between 2010 and 2018 from 22.4 to 8.6 tons per hectare as seen in Figure 1 (FAOSTAT, 2020b). Drought, floods, high temperatures and irregular rain patterns coupled with ineffective execution of adaptive strategies cause this. In Kenyan counties, besides the low yields produced per hectare, the yield is anticipated to reduce by 2 and 3 tons during long rainy seasons and optimum conditions respectively (Bolt *et al.,* 2019; Haverkort *et al.,* 2013).

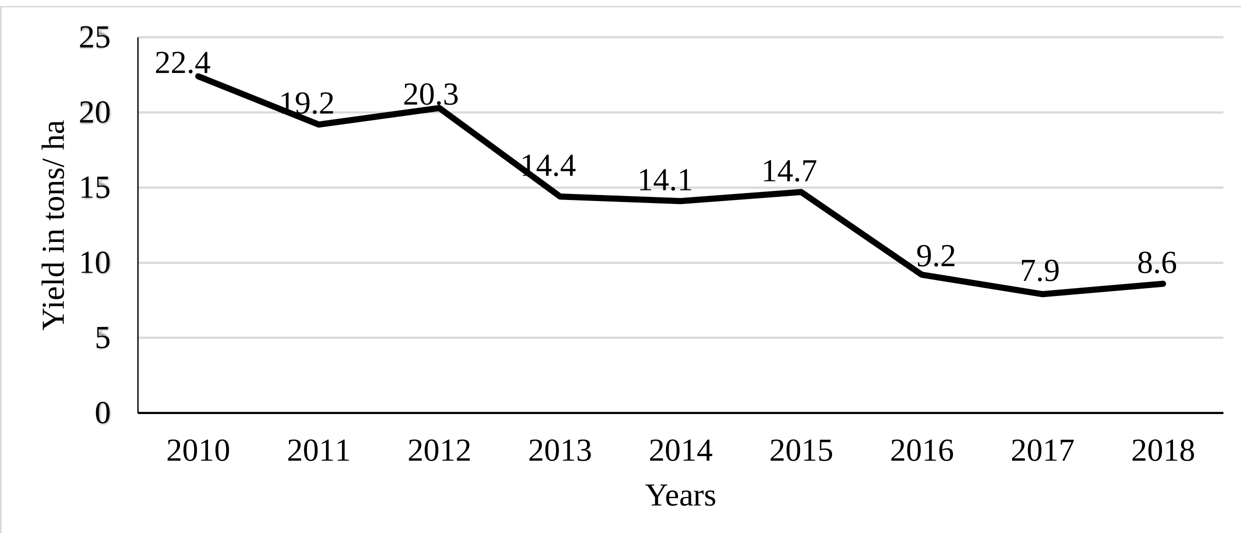

Figure 1: Trends in potato yield per hectare between 2010 and 2018 in Kenya (FAOSTAT, 2020b).

According to Totin *et al.* (2018), climate-smart agriculture (CSA) presents the potential to meet the world's food demands in the face of climate variability. The triple win effect of CSA, which are (i) increased productivity (ii) mitigation, and (iii) adaptation, are seen as the practical solution to climate change (FAO, 2010). These initiatives are likely to be more responsive to the achievement of Sustainable Development Goals (SDGs) 2 and SDG 13 that aim at increasing productivity by adapting to climate change (Rosa, 2017). Several CSA practices have been developed globally and among these include irrigation, deep-ploughing, crop rotation, mixed cropping, terracing, mulching, zero or minimum tillage and cover crops (Cramer *et al.,* 2017; Imran *et al.,* 2018; Lan *et al.,* 2018; Zahra *et al.,* 2019).

Considering its geographical location, Africa has developed and adopted context-specific CSA practices like leaving cleared weeds and biomass to mulch on prepared land, use of hybrid planting materials (Akrofi-Atitianti *et al.,* 2018), crop-livestock diversification, diversification of income-generating activities and other good agronomic practices such as mixed cropping, agroforestry and perennial plantation (Fadina & Barjolle, 2018). A good example of the benefits of CSA in East Africa is the planting of mango trees to protect the soil from physical erosion and contribute to families' nutrition (Recha *et al.,* 2016).

Like any other climate change vulnerable country, Kenya has responded to the global call to mitigate and adapt to climate change effects by launching a CSA strategy. This was designed as part of its development programs that seek to achieve food security and sustainable development at the same time (GoK, 2017). Agroforestry, the use of bunds, water harvesting, composting, improved high yielding varieties, among others, have been developed as CSA technologies (Bernier *et al.,* 2015).

Nakuru county's plan to increase potato yields to 15 tons/ha by 2022 opted for several CSA practices and among these include agroforestry, water harvesting, and planting of the short cycle and drought-tolerant potato varieties (GoK, 2018). Additionally, stakeholders working in the potato sector have come up and recommended several CSA practices with the aim of adapting potato production to the effects of climate change in Nakuru and elsewhere in the World. For example, use of potato apical rooted cuttings, irrigation, use of improved varieties among others (Kibe *et al.,* 2019; Parker *et al.,* 2019). For effectiveness, proper decisions should be made on which information dissemination channels to be used for scaling out the use of CSA practices (Faling, 2020). Faling (2020) adds that if Kenya in particular is to succeed in achieving its objective of incorporating CSA practices in its farming systems as expected by the Kenya Climate Smart Agriculture Project [KCSAP] (GoK, 2018), understanding of the farmer contexts in terms of communication channels used, institutional and socioeconomic factors is not only vital but also lays a foundation on which scaling strategies should base. Various information dissemination pathways, institutional and socioeconomic factors influence uptake of technologies differently. For example, in some localities, farmer's age may limit uptake of labor-intensive technologies, income may facilitate access to high value technologies and gender may pose barriers for women in some societies in securing recommended technologies. These combined with extension services and training on how technologies are applied, access to credit to fund technology adoption process and Non-government support services may hasten technology adoption process if available and accessible by all (Kalungu & Leal Filho, 2018). However, the reverse may hold true if these factors are not available or available but not accessible by everyone. Understanding of how these factors among others affect technology uptake especially CSA is in fact necessary and can be helpful in the context of policy, planning, and development. Cautiously derived generalizations about their relationship with the practice of CSA practices among smallholder farmers can shed light on appropriate ways for developing future planned CSA practices, policies and other climate change adaptation strategies in a way that accounts for the past failures and successes experienced by local communities and development projects (Faling, 2020). This, coupled with the fact that Gilgil Sub-County has not been studied on the factors influencing use of CSA practices despite diffusion efforts on ground, creates a research gap that prompts the need to establish the relationship between selected factors and practice of CSA by the smallholder potato farmers in Gilgil Sub County of Nakuru County, Kenya.

1.2 Statement of the Problem

Production of potato has been threatened by climate variability, characterized by low precipitation, flooding, and high temperatures, prolonged sunshine, and delayed rains leading to a decline in productivity. This has led to food insecurity challenges among the smallholder potato farmers in Nakuru County. To avert these challenges, several CSA strategies have been developed to increase potato production in the face of climate variability. However, smallholder potato farmers continue to register low yields and, in some cases, total losses. This is partly because efforts directed towards generating and promoting the practice of CSA assume that the practices could be accessed by the farmers and translated into the desired results. These have ended up being diffused to the target farmers without full understanding of their socioeconomic and institutional contexts. This coupled with inadequate knowledge on how best the CSA practices should be communicated leads to low rate of practice of CSA besides its potentials. Yet, to position the smallholder potato farmers to better adapt to the effects of climate change, these practices need to be adopted for increased and sustainable potato production. Investigation of the relationship between selected factors and practice of CSA would therefore go a long way in informing the efforts to adapt potato production to the effects of climate change. In addition, such an investigation would help to draw insights that may guide future efforts working on scaling out various CSA practices. This study, therefore, intended to narrow the knowledge gap by establishing the relationship between the selected factors and the practice of CSA by the smallholder potato farmers in Gilgil Sub-County, Kenya.

1.3 Purpose of the Study

The purpose of this study was to contribute to increased practice of CSA by providing information on the relationship between selected factors and practice of CSA in Gilgil Sub-County, Kenya.

1.4 Objectives of the Study

The following were the specific objectives of study:

i. To investigate the association between **information dissemination pathways** and practice of CSA among smallholder potato farmers in Gilgil Sub County, Kenya.

ii. To determine the relationship between **socioeconomic factors** and the practice of CSA among smallholder potato farmers in Gilgil Sub County, Kenya.

iii. To determine the relationship between **institutional factors** and the practice of CSA among smallholder potato farmers in Gilgil Sub County, Kenya.

1.5 Hypotheses of the Study

The following were the hypotheses of the study:

H_{01}: There is no statistically significant association between **information dissemination pathways** and practice of CSA among the smallholder potato farmers in Gilgil sub-County, Kenya.

H_{02}: There is no statistically significant relationship between **socioeconomic factors** and the practice of CSA among the smallholder potato farmers in Gilgil sub-County, Kenya.

H_{03}: There is no statistically significant relationship between **institutional factors** and the practice of CSA among the smallholder potato farmers in Gilgil sub-County, Kenya.

1.6 Significance of the Study

The findings of this study provide information to the Kenyan government institutions, Non-government organizations (NGOs), donors, and other organizations for a better understanding of the relationship between selected factors and practice of CSA by smallholder farmers. Findings also provide specific information on the available and widely applied CSA technologies among smallholder potato farmers that can enhance potato yields in the face of climate variability. This informs policymakers' and development workers' decisions on how best scaling out CSA practices for wide spread use among farmers can be achieved given the information on the drivers of practice of CSA that this study yielded to. Knowledge of the drivers of practice of CSA informs better strategies for fostering widespread use of CSA, which may translate into improved potato production in Gilgil Sub County, Kenya.

1.7 Scope of the Study

The study focused on the relationship between selected factors and practice of CSA by smallholder potato farmers. The study targeted the smallholder potato farmers of Gilgil Sub County and focused on selected factors that included the socioeconomic factors like farmer's age, gender, education level, and income; institutional factors that consisted of access to credit, access to training on CSA, NGO support and farmer groups; and information dissemination pathways which comprise of neighbors and friends, extension officers, and radio/ television/ phone.

1.8 Assumption of the Study

The researcher assumed that respondents would give truthful and honest responses.

1.9 Limitation of the Study

The major limitation of this study was that some farmers might have received interventions on CSA by development organizations working in the area and this could subject responses to bias. Randomly sampling the farmers but also revealing to them that the study was not linked to any of the interventions that some farmers might have received circumvented this.

1.10 Definitions of Terms

The key terms in this study were defined as follows:

Climate change refers to any change in climatic factors (rainfall, wind, sunshine, solar radiation, temperature) over time, which may be due to natural variability or as a consequence of human activities (Intergovernmental Panel on Climate Change (IPCC), 2012). This definition was adopted for this study.

Climate smart agriculture: These are agricultural management practices or technologies that sustainably lead to increased productivity, improve resilience, lower greenhouse gas emissions, and heightens the achievement of food security and development goals (FAO, 2010). In this study, CSA meant practices such as rainwater harvesting and storage, irrigation, mulching, minimal tillage, improved crop varieties, terracing, drainage management, intercropping, agroforestry, synthetic fertilizers, composting, furrow/ ridge planting, crop rotation, apical rooted cuttings (potato seedlings) and mini-tubers.

Climate variability refers to variations in the average state of climate on both spatial and temporal scales beyond that of specific weather events (Intergovernmental Panel on Climate Change (IPCC) & Edenhofer, 2014). This definition was adopted for this study.

Determinants: These are factors or causal elements that lead a given phenomenon to happen or directly influence a given decision (Merriam-Webster, 2020). In this study, determinants meant **selected factors** that affect the practice of CSA and they included socio-economic factors, institutional factors and information dissemination pathways.

Information dissemination pathways: These are means or channels through which CSA practices/ technologies are communicated to the farmers (Van den Broeck & Dercon, 2011). In this study, information dissemination pathways encompassed neighbors and friends, extension officers and media (radio/ television/ phone).

Institutional factors are related to the control measures developed by communities to moderate/ govern the people. Some of these control measures are formal e.g. legal standards while the rest are informal (Warsaw, 2013). In this study, institutional factors constituted access to credit, access to training on CSA and NGO support.

Practice is when one decides to fully use a technology that is perceived as the best option available. It entails the farmer learning the new knowledge and putting it into use. It includes purchasing of the tools and equipment necessary to execute the technology (Rogers, 2003).

This definition was adopted for this study. Therefore, **Practice of CSA** is the use of a given CSA technology. In this study, it was be measured by the percentage of farmers practicing CSA and the extent to which they practice.

Selected factors - The action or a situation of choosing or the state of being chosen (Merriam-Webster, 2020). In this study, selected factors meant information dissemination pathways, socio-economic and institutional factors.

Smallholder farmers: These are farmers who farm on less than 2 hectares (5 acres) of land (FAO, 2015). This definition was adopted for this study.

Socioeconomic factors are both the social and economic aspects that manage/ run/ govern or control the management/ operation of a farm/ agricultural unit (Genov, n.d.). In this study, socio-economic factors included age of the farmer, gender of the farmer, education level of the farmer and off-farm income/ farmers' income.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter gives an idea of the origin and importance of potato production; it reviews the effects of climate change on potato production. It describes CSA as a solution to climate change and the factors that affect the practice of CSA by smallholder farmers. The chapter also explains the theoretical model that informs the study, and it identifies knowledge gaps in the existing knowledge products concerning the proposed study topic.

2.2 Origin and Importance of Potato Production

The potato originated from the Andean regions of Bolivia and Peru. It was introduced into Spain from South America in the mid-sixteenth century. From Spain, it was introduced to nearby countries and was being cultivated moderately in many European regions. By the seventeenth century, the potato was then distributed beyond Europe into India and China and by the eighteenth century to Japan (Lim, 2016). It became so extensively spread around the globe and essential and was introduced in Africa by Christian missionaries at the end of the 17th century through the establishment of small plantations (International Plant Biotechnology Outreach [IPBO], 2019). Its tubers were swiftly adopted in many diets. They became part of the feeding habits of the urban and rural populations. Today, over 158 countries grow potatoes worldwide, and Kenya is among these. Asia and Europe produced more potatoes between 2007 and 2017, with 71% of the world’s production total (Figure 2). This is because it is produced as both food and cash crop in these regions (FAOSTAT, 2020a).

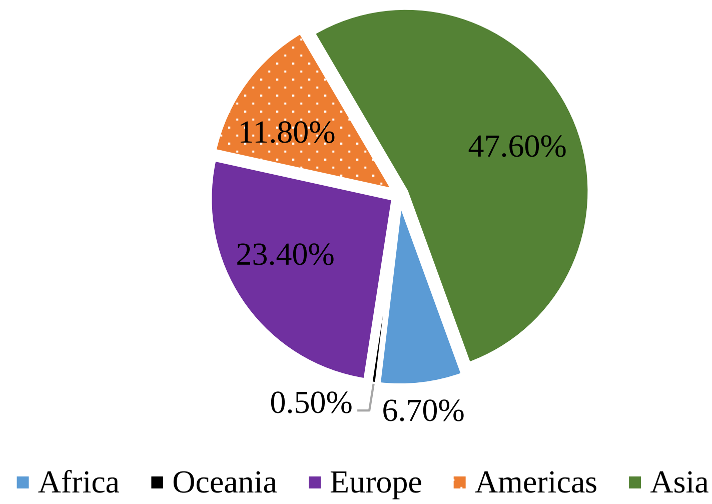

Figure 2: Potato distribution worldwide by 2018 (FAOSTAT, 2020a).

Potato production now ranks the third world food crop due to its contribution to the alleviation of food insecurity in the world and gaining more importance in sub-Saharan Africa (IPBO, 2019). The growing number of potato consumers, interest in potato use as feed for the livestock industry, the need for processed potato products that lead to higher demands of the potato by the food industries, fuel the increasing demand for potato in Africa. Potato exportation potential is another factor that increases potato demand. A typical example in Africa is Egypt (Table 1) that increases its production to satisfy herself, sell to her neighbors, and the European food market (FAO, 2008). African countries have various needs for the potato, for example, utilized as food, seed, and or feed. The potato is a very versatile food crop and can be used in multivariate ways. It is eaten and cooked in different ways, such as boiling, steaming, deep-frying, and roasting (Lim, 2016). It supplied an average of 1.75 million tons of food per year between 2014 and 2017 to the Kenyan population. According to FAOSTAT (2019), Kenya is the highest potato consumer compared to Rwanda, Ethiopia, and Uganda, as seen in Table 1.

Table 1: Annual potato production, food and seed supply per country between 2014 and 2017

Countries	Parameter	Years			
		2014	2015	2016	2017
Egypt	Food (1000 tons)	3228	3200	3450	3539
	Food supply (kcal/capita/day)	73	71	75	75
	Production (1000 tons)	4611	4955	4113	4325
	Seed (1000 tons)	490	538	298	313
Ethiopia	Food (1000 tons)	617	647	672	706
	Food supply (kcal/capita/day)	11	12	12	12
	Production (1000 tons)	922	1040	921	933
	Seed (1000 tons)	51	53	51	51
Kenya	Food (1000 tons)	1632	1767	1793	1834
	Food supply (kcal/capita/day)	68	72	71	71
	Production (1000 tons)	1626	1963	1336	1520
	Seed (1000 tons)	75	91	65	74
Rwanda	Food (1000 tons)	1079	1069	1095	1118
	Food supply (kcal/capita/day)	191	184	184	183
	Production (1000 tons)	719	743	751	846
	Seed (1000 tons)	42	44	0	50
Uganda	Food (1000 tons)	158	140	169	179
	Food supply (kcal/capita/day)	8	7	8	8
	Production (1000 tons)	181	177	200	250
	Seed (1000 tons)	29	24	27	29

Source: FAOSTAT (2019)

2.3 Effect of Climate Change on Potato Production

Climate variability threatens agricultural production systems and food security worldwide. It affects the crops through high temperatures, drought, flooding, and enhanced atmospheric CO_2 caused by changes in climate factors like wind, relative humidity, rainfall, and solar radiation (Aggarwal *et al.*, 2018). The effects are worse with the potato crop, which is a cool climate crop. It performs well under 20–25°C and below 20 °C for day and night, respectively. Such temperature conditions favor growth and tuberisation. Daily night temperatures of 23 °C and above limit tuber formation. Extreme temperatures lead to heat stress on crops whose warmer temperatures may accelerate the growth of certain crops like melons, grapes, and tomatoes. In the presence of this, other crops such as maize, wheat, and potatoes may experience lower yields (Aggarwal & Singh, 2010). Staple crops like potatoes and other cereal grains may become difficult to grow, thereby rendering them unavailable (Leal Filho, 2020).

Increasing temperature favors pests, diseases, and weed invasions like the soft rot and blackleg, root-knot, nematodes, and *M. persicae*. According to Londhe (2017) and Van der Waals *et al.* (2013), the development of these pests and diseases will increase with increasing temperature (by about 1.9 °C) over the next 90 years with a significant effect on potato sector. Potato requires 500–750 mm during its growing period of 3–4.5 months, and any deviation from the ideal due to less rainfall during its bulking stage reduces its productivity (Lim, 2016).

Besides this, farmers in highland areas face risks of unpredictable rainfall and rising temperatures due to climate change and variability (Parker *et al.,* 2019). This explains the reduction in yields (46%, from 15 to 7 t/ha) obtained by potato farmers in Kenya between 2016–2017. This came following a reduction from 737 to 126 mm in seasonal mean rainfall. Nakuru, the largest county under potato cultivation in Kenya, is exposed to drought, heavy rains, floods, and high temperatures with an increase of 1ºC since 1981 (MoALF, 2016). This contributes to the recurring low yields obtained by the farmers.

2.4 Evolution and Importance of Climate-Smart Agriculture

Maintaining agricultural growth and increased food supply while minimizing climate damage is key to building a resilient food production system to meet the developmental goals in affected countries (Aggarwal *et al.,* 2018). Climate-Smart Agriculture (CSA) seeks to address three challenges that include (i) improving the adaptation capacity of agricultural systems to climate change and its effects, (ii) reducing greenhouse gas emissions from agricultural systems, and (iii) ensuring local and worldwide food security. This is termed as the triple win effect of CSA (Acosta-Alba *et al.*, 2019).

Climate-Smart Agriculture differs from sustainable agriculture by preaching context-specific technologies that contribute to the triple win effect and among these include synthetic agrochemicals (Faling, 2020). On the other hand, sustainable agriculture is part of the larger concept of sustainable development with economic, social, and environmental aspects. Its principles pose restrictions on the use of some technologies like synthetic agrochemicals, judged based on their effects (Lipper & Zilberman, 2018). However, there are some practices like some conservation agriculture technologies, which fall under both CSA and sustainable agriculture. Climate-Smart Agriculture had its inception in 2009 and operationalized in 2010, several and progressive initiatives have been launched to ensure its success (Table 2).

Table 2: Evolution of CSA

2009	The term 'climate-smart agricultural development' was first used in 2009 in a FAO publication. The Global Research Alliance was launched, providing an organization and framework for cooperation and investment in research to reduce agricultural greenhouse emission.
2010	The First Global Conference on Agriculture, Food Security and Climate Change at the Hague defined CSA as actions, which 'sustainably increase productivity, enhances resilience, reduces/removes greenhouse gas emissions, and enhances achievement of national food security and development goals.' FAO 'The Mitigation of Climate Change in Agriculture' (MICCA) program is launched.
2011	The Johannesburg Communiqué – 'Africa: A Call to Action: Johannesburg, South Africa: African Ministerial Conference on Climate-Smart Agriculture – A common position' by African Agricultural Ministers. Global Science Conference on CSA: The Wageningen Statement identified scientific priorities to accelerate CSA. Conference of Parties (COP) 17 in Durban, South Africa: parties asked the United Nations Framework Convention on Climate Change (UNFCCC) Subsidiary Body for Scientific and Technological Advice (SBSTA) to explore the possibility of a formal work program on agriculture.
2012	The Second Global Conference on Agriculture, Food Security, and Climate Change – The Hanoi Communiqué.

Table 2 (continued)

2013	FAO Economics and Policy Innovations for Climate-Smart Agriculture (EPIC) program are launched. Global Alliance for Climate-Smart Agriculture (GACSA) is launched at the UN Climate Summit, New York.
2015	COP21 CSA displayed at a variety of side events and exhibitions.
2016	COP22, a series of CSA themed side-events, the launch of CSA initiatives four par 1000, a French-led soil carbon sequestration project, joined by Moroccan-led Adaptation of African Agriculture (AAA) initiative, also focused on CSA.

Source: Newell and Taylor (2018)

The study findings by Akrofi-Atitianti *et al.* (2018), revealed that CSA practitioners had increased their income by 29% compared to conventional farmers. These attributed the difference to the ability of the CSA technologies to sustain yields under climate variability. Globally, CSA, like improved agronomic practices, solar-powered irrigation, agroforestry, integrated soil and water management as well as integrated soil fertility and crop nutrient management, improved livestock breeds, high-yielding varieties, aquaculture and inclusive financing instruments and business models have been developed (Dawit *et al.*, 2018). Some of the technologies like irrigation, deep ploughing, crop rotation, mixed cropping, terracing, mulching, zero or minimum tillage, crop cover among others have been adopted by farmers in Asia, Vietnam, Australia, Central America and the Dominican Republic (Cramer *et al.*, 2017; Imran *et al.*, 2018; Lan *et al.*, 2018; Zahra *et al.*, 2019).

Africa, with its geographical location, has developed and adopted context-specific CSA practices like leaving cleared weeds and biomass to mulch on prepared lands, use of hybrid planting materials from certified sources, promoting of short period crops in Ghana (Akrofi-Atitianti *et al.*, 2018). Findings by Fadina and Barjolle (2018) indicated that farmers in Benin practice crop-livestock diversification and other CSA technologies like mulching, mixed cropping, crop rotation, organic fertilizer, use of improved varieties, agroforestry and perennial plantation (oil palm, orchard, tree species), chemical fertilizers and pesticides, and diversification of income-generating activities.

According to research conducted in the Teso North Sub-County, Busia County of Kenya showed that 56.83% of smallholder farmers are practicing CSA for effective crop and field management, farm risk reduction, and sustainable soil management practices (Wekesa *et al.*, 2018). A study by Mbow *et al.* (2014) in western Kenya indicated that agroforestry reduced food insecurity during drought and flooding by 25% due to its ability to increase crop yields and income.

2.5 The CSA in Potato Production in Kenya

To meet the potato demand, the potato production sector will need to invest in strengthening existing production areas. The access to the new potential potato production areas, new varieties that are well adapted to extremes of heat and drought weather conditions, irrigation equipment, pieces of equipment better adapted to wet soil conditions, and improved irrigation water storage facilities need to be adapted to potato production (Haverkort & Verhagen, 2008).

The study by Parker *et al.* (2019) showed that climate-smart potato varieties could improve potato productivity in various environments from sea level to high mountain conditions where potato smallholder farmers predominate. In addition to temperature regimes and solar radiation, consideration of several factors that include soil characteristics, nutrient availability, and water use efficiency is vital for the success of this CSA practice.

In Kenya, 15 climate-smart potato clones introduced and evaluated between 2013 and 2015 for water-stress tolerance under precipitation averaged 295 mm (range 210–414 mm), yielded significantly higher than the existing varieties (Table 3).

Table 3: Performance of potato clones in water-stressed conditions at average precipitation of 295 mm (range from 210 to 414 mm) across three seasons and three locations between 1300 and 1700 masl in Kenya

Cluster by % age above mean of existing varieties	Yield t/ha	Number of clones
Greater than 40%	22.9	1
Greater than 30%	20.7	5
Greater than 20%	19.4	5
Greater than 10%	18.3	4
Mean of existing varieties	15.5	

Source: Parker *et al.* (2019)

t/ha – tons per hectare; masl – meters above sea level

To adapt the potato to overcome the climate change challenges, breeding efforts by the International Potato Centre (CIP) have prioritized context-specific heat tolerance, earliness, disease tolerance, and water use efficiency (CIP, 2016). The following; Unica, Lenana, Wanjiku, Chulu, and Nyota varieties have been developed by the breeders and are used by the farmers in Kenya to reduce the risk of yield losses due to stress intolerance and late blight and viral diseases (CIP, 2016). However, for better results, these resistant varieties may be accompanied by the use of phytosanitation and cultural practices, clean fields, biological control, and disease-free tubers (Muthoni *et al.*, 2012). Crop rotation is also one of the CSA approaches that has been adopted by farmers in Kenya. Table 4 shows the different rotation sequences that the farmers have adopted.

Table 4: Crop rotation sequence as practiced by some Kenyan potato farmers

potato, maize, potato	potato, cabbage, potato
potato, maize+beans, potato	potato, maize/wheat, potato
potato, maize+bean/cabbage,potato	potato, maize+bean/wheat, potato
potato, maize/cabbage,potato	

Source: Muthoni *et al.* (2013)

Maize + beans = maize intercropped with beans; maize + beans/cabbage = maize intercropped with beans or cabbage alone; potato, maize, potato = potatoes followed by maize then potatoes in that sequence; maize/cabbage = maize or cabbage (Muthoni *et al.*, 2013).

The meaning and potential of some of the CSA practices promoted in Kenya and Nakuru County and elsewhere in the world are summarized in Appendix A.

2.6 Information Dissemination Pathways and Adoption of Agricultural Technologies

Decisions on which kind of dissemination pathway to use depend on farmers' needs, skills, and use of the information (Nyasimi *et al.*, 2017). Several households rely heavily on friends, relatives, and radio as well as their observations, especially weather information that guides their decisions on CSA strategies (Chengula & Nyambo, 2016; Nyasimi *et al.*, 2017; Van den Broeck & Dercon, 2011). Timely access to information about climate variability helps the farmers to make informed decisions about which CSA technology to adopt. Nyasimi *et al.* (2017) found out that farmers' access to information can enable them to start planning the CSA practices as the adaptation measures to the changing climate occurring now and that projected in the next 20 years to come.

It is unveiled that the desire to improve agricultural productivity motivates over 99% of the farmers in Lushoto to seek for CSA information on new and resistant varieties, irrigation techniques, and sustainable soil fertility improvement measures. In Lushoto, government extension services and farmer's own experience are the primary sources of information. The study by Franzel *et al.* (2014) in the Nile Basin in Ethiopia showed that limited access to weather information and extension services is a major hindrance to climate change adaptation by changing the planting dates.

2.6.1 Media

The different ways through which information on CSA is diffused to the farmers affect the farmers' adoption decision. Previous research by Nyasimi *et al.* (2017) in Lushoto of Tanzania, revealed that the use of video recording during pieces of training on CSA demonstration contributes to the wide distribution of the information by the farmers that attend. By the use of phones, radio, and television, this information reaches more farmers who did not participate in the training; as a result, this increases the adoption rate. Besides, schoolchildren, the potential future farmers prefer the latest information and communication technologies, more so television and mobile phones. The use of television and mobile phones in scaling up CSA practices reaches more farmers and youths as well. The effectiveness of the radio, television, and phone as dissemination pathways depends not only on their successful delivery of the information that influences farmers' decision to adopt but also on the large number of farmers that receive the information (Triomphe *et al.*, 2014). Kenya is endowed with Information and Communication Technology (ICT), radio, phones, and televisions are trendy among farmers. These enable the farmers to reach the extension agents at any time by phone, listening to radio or television programs. Listening to radio and television provides a convenience since farmers can do the listening as well doing other tasks (Manfre & Nordehn, 2013).

2.6.2 Neighbors and Friends

Understanding dissemination pathways also involves horizontal information pathways that include peer-to-peer through farmer meetings and face-to-face interactions (Burke, 1999). The majority of the households rely heavily on friends and relatives, as well as their observations mostly from their neighbors for information, particularly weather forecasting information and climate adaptation strategies in the short and long term (Chengula & Nyambo, 2016; Van den Broeck & Dercon, 2011). According to Nyasimi *et al.* (2017), this approach seems the simplest for CSA practices information diffusion, especially between members of the same family and locality. In their study in Kenya, Bernier *et al.* (2015) noted that participants (farmers) acknowledged the assistance offered by their neighbors in terms of providing them with agricultural and climate information that informed their adaptation decisions. Franzel *et al.*'s (2019) research in Malawi, Kenya, and Cameroon found out that mobilizing a few farmers for initial training on CSA practices has a multiplier effect since many organized demonstrations following the training to train fellow farmers. Kalungu *et al.* (2013) reported that in Kenya, most farmers adopted CSA technologies like improved crop varieties by imitating their neighbors.

2.6.3 Extension Officers

Extension officers ought to be the best source of new information on CSA technologies that can increase agricultural productivity and farmer's incomes. For effective extension information delivery, farmers need to be engaged in developing technologies for successful innovation process facilitation and catalyzing the adoption process (Napolitano, 2016). This drives extension officers to seek new CSA technologies that respond to the changing nature of agriculture and farmers' needs. In the past three decades, extension adapted the model of information dissemination to the farmers' need; and developing closer linkages between agricultural researchers with extension providers and extension providers with farmers to tap into local knowledge, that creates a better understanding of farmers' needs and problems plus obtaining feedback on how technologies are working (Nederlof & Pyburn, 2012). Kenyan extension officers work closely with the farmers to initiate the process of technology diffusion and facilitating experience exchange among farmers (Kalungu & Leal Filho, 2018). Through joint diffusion and experience sharing, farmers may adopt the technologies that have been implemented by others.

On the other hand, the cited literature backed up access to information as a critical aspect of CSA adoption. Conversely, this is void of facts on which kind of information and from which source that was translated into practice and to which extent. To end with, Gilgil Sub-County has not been studied on the proposed topic; neither generalizations have been made from the previous studies from other contexts, besides CSA practices being implemented in the area. This study, therefore, seeks to narrow this knowledge gap.

2.7 Socioeconomic Determinants of Adoption of Agricultural Technologies

Studies by Leal Filho *et al.* (2015) and Nyasimi *et al.* (2017) give an overview of the bottlenecks that continue to hinder the registration of the expected success regarding CSA diffusion. These emphasize that a gap still exists between full understanding of the farmers' contexts and the CSA practices that are best suited for individual farmers. The socio-economic aspects of agricultural areas determine the adaptation strategies for its dwellers (Dutta & Hazarika, 2020). Some of the socioeconomic factors like age, gender, farm size, education level, labor availability, and off-farm income/ farmers' income and their influence on CSA have been described below.

2.7.1 Level of Education of the farmer

Education is one of the critical aspects through which farmers are empowered with the necessary skills and knowledge to execute recommended technologies on their farms. The level of education plays a significant influence on the decision to practice the CSA (Kane *et al.*, 2018). Most educated farmers stand high chances of making better decisions as well as quickly adopting new technologies in farming. The higher level of education increases farming success since it positions farmers to understand and utilize technical information and thereby enabling farmers to make informed decisions in response to the increasing research findings in agriculture (International Center for Tropical Agriculture (CIAT) & World Bank, 2017). Moreover, farmers' education is correlated with production and marketing as agricultural skills. High literacy levels reduce gender parity in farming activities and it increases every individual's chances to access and critically assess new technologies, relate with extension and other technology providers, and practice proposed CSA practices (Duffy *et al.*, 2017). Conversely, it was found out that there is a negative correlation between education level and technology adoption in Wote, Kenya (Bernier *et al.*, 2015).

2.7.2 Age of the Farmer

Age is an indicator of maturity on which inference is made about a person's capability to make sound decisions in farming activities. For example farmers within the age bracket of 18-35 years [younger farmers according to Kennedy *et al.* (2011)] are mostly receptive to adopt new technologies in farming. Age has a direct influence on the household head experience in farming, and according to Kane *et al.* (2018), young and middle-aged as household heads are most productive and receptive to new technologies. Above 45 years, age is negatively correlated with the adoption of small-scale irrigation farming, and this suggests that adoption is higher among younger farmers (Mango *et al.*, 2018). On the contrary, Khatri-Chhetri *et al.*, (2017) found out that the farmers' age positively influences the choice of different CSA practices like integrated pest management, minimum tillage, site-specific integrated nutrient management, and crop insurance. This contradicts the findings by Amsler *et al.* (2017) that revealed that Kenyan youths farmers do not know how to adapt to climate change.

2.7.3 Gender of the Farmer

Gender and climate change are cross-cutting priorities for all development agencies. According to Okello *et al.* (2018), men and women may have different perceptions of making decisions on climate change adaptation. Due to differences in access to productive resources, extension services, and employment. This explains the findings by Nyasimi *et al.* (2017) in Lushoto, Tanzania, that found out about the variance in interests between men and women for CSA. Women have more preference for intercropping crops, whereas men adopt chemical fertilizer, composting, agroforestry system, and cut and carry feeding as CSA practices. The (United Nations Development Programme [UNDP], 2010) indicated that women engage more in adaptation activities due to their deep understanding of their immediate environment through their experience in managing natural resources (water, forests, biodiversity, and soil), and their active engagement in climate-sensitive work such as farming activities and fisheries.

However, the study by Duffy *et al.* (2017) indicates that some CSA practices like conservation tillage can increase the weeding frequency, an activity often performed by women in Africa south of the Sahara. Besides, social norms and structures complicate their ability to adopt some CSA technologies due to differential access to information and other resources like land due to property rights. This creates a barrier that constrains the practice of CSA. In Kenya for example, women unlike their counterpart the men, are curtailed by customs and taboos in accessing agricultural equipment and input stores, public support, finance, markets and transportation (Bernier *et al.*, 2015; Ngigi *et al.,* 2018). However, the literature states that gender limits access to resources necessary for practicing CSA; nevertheless, it does not show the kind of women that are profoundly affected. It leaves unanswered questions on whether the educated and uneducated gender (women) are affected the same way.

2.7.4 Off-farm income and Farmers' income

Since most CSA practices are associated with costs, the farmer's income and off income are important for its adoption. The willingness of the farmers to pay for CSA technologies is often influenced by the cost of the technologies (Khatri-Chhetri *et al.,* 2017). This means that high farmers' income translates into high access to CSA technologies. Therefore, smallholder farmers with low incomes due to the low yields may not have access to certain CSA technologies (Anuga *et al.,* 2019).

Low budget households may find it challenging to switch from the conventional agricultural practices to the CSA practices like agroforestry since they rely on agricultural production for their continuous income (Arslan *et al.,* 2014). High budget farmers may have more access to information, and this makes them less prone to risks. Besides, when farmers have non-farm options, they can afford to plant trees on the limited available land without compromising household food security, and they can easily meet the agronomic practices' requirements (Deressa *et al.*, 2009). On the other side, high farmers' income may suffer some CSA practices. A study by Ochieng *et al.* (2017) in rural Kenya found out that high-income farmers tend to specialize in one crop; this decreases the chances of alternating crop varieties and instead results in monoculture as opposed to crop rotation.

2.8 Institutional Determinants of Adoption of Agricultural Technologies

According to Okello *et al.* (2018), institutional factors influence both the state and local level institutions like the market, land tenure system, Non-Government Organizations (NGOs), credit institutions, and information access, which all have the potential to directly or indirectly influence the adoption and use of CSA practices.

2.8.1 Non-Government Organization Support

Non-Governmental Organizations (NGOs) are private institutions, either profit or non-profit making bodies. Their presence and support to farming communities influence farmers' decision to adopt CSA technologies (Anuga *et al.*, 2019). The author adds that NGOs tend to provide farmers with handouts but also with CSA technologies like drought-resistant and high-yielding varieties for compensation against the shock. In the absence of these NGOs, farmers become more vulnerable to the terrifying effects of climate change. However, in Kenya, men are the primary beneficiaries of the NGO CSA projects, and this is attributed to their ability to attend agricultural-based seminars and workshops (Kalungu & Leal Filho, 2018).

2.8.2 Access to Credit

The adoption of CSA comes with a cost in terms of buying technologies like the drought-tolerant varieties and irrigation equipment. Besides, most of the farmers have low incomes; therefore, access to credit may directly and greatly influence the practice of CSA (Lipper, 2017). In turn, access to credit can increase CSA related income-generating investments, influence farmers' role in social networks, builds the ability to deal with shocks of climate events and strengthens farmers' resilience level (Asfaw *et al.*, 2012). The CGIAR's research program on Climate Change, Agriculture and Food Security (CCAFS) in East Africa affirms access to credit as one of the strong pillars that foster scaling out CSA practices in Kenya (CGIAR, 2015). On the other hand, access to credit and NGO support is accredited as significant accelerators of CSA adoption. This is so ambiguous in the sense that it did portray the bottlenecks that constrain farmers from credit access and NGO support. In addition, it did not clarify on which kind of credit and which amount that the farmers in question have/ fail to access concerning the CSA technology costs.

2.8.3 Access to Training on CSA

Farmers' training on CSA topics such as soil-water management, minimum tillage, and crop diversification influences the farmers' adoption of such technologies. Directing CSA pieces of training not only to the farmers but also to extension agents working with farmers to promote CSA breaks the adoption barriers. It creates enabling CSA adoption conditions (Aryal, Rahut, *et al.*, 2018). The effectiveness of the farmers' training on climate risk management depends more on the focus on the training period. Well planned and focused trainings increase the chances of adoption of climate risk management practices like CSA (Nkonya *et al.*, 2018). Bolt *et al.* (2019) adds that giving potato farmers in Kenya training on the benefits and costs of crop insurance as a CSA practice provides them with the details of what is required and increases the chances of adoption. Providing smallholder farmers with the knowledge on the use of technologies and why they should be used through training acts as an incentive for their adoption (Kalungu & Leal Filho, 2018). Conversely, access to training on CSA is said to enable farmers to familiarize themselves with CSA practices. That this translates into adoption; however, this is empty of knowledge on how long the training should have lasted to enhance farmers' skills on CSA.

2.8.4 Farmer Groups

The local institutions play an essential role in the practice of CSA since they constitute of local members who come together and pool resources that may be necessary to access and adopt a given CSA technology. It eases access to the resources that are within and outside the community (Aggarwal & Singh, 2010; Teklewold *et al.*, 2012). Van Rijn *et al.* (2012) suggest that links of trust and intra-community cooperation can lead to withdrawal behavior, which makes individuals less likely to adopt and seek new agricultural innovations. For example, actions like planting a drought-resistant crop at the individual level do not require much of institution coordination. However, findings by Okello *et al.* (2018) present evidence on the importance of collective action in facilitating the adoption of CSA technologies. It facilitates risk pooling and enable people to build assets that help them in withstanding climate change shocks.

2.9 Theoretical Framework

This research was based on Rogers M. Everett's theory of diffusion and adoption of technologies. Unlike other theories of technology adoption like rural household behavior under market failure by de Janvry and Sadoulet (2006) and induced innovation theory by Binswanger *et al.* (1978) that acknowledge the innovation to being part of the economic system, Rogers (2003) explains how several factors interact to influence technology adoption. Rogers (2003) points out socio-economic factors and the information dissemination pathways and identifies the key features that exacerbate

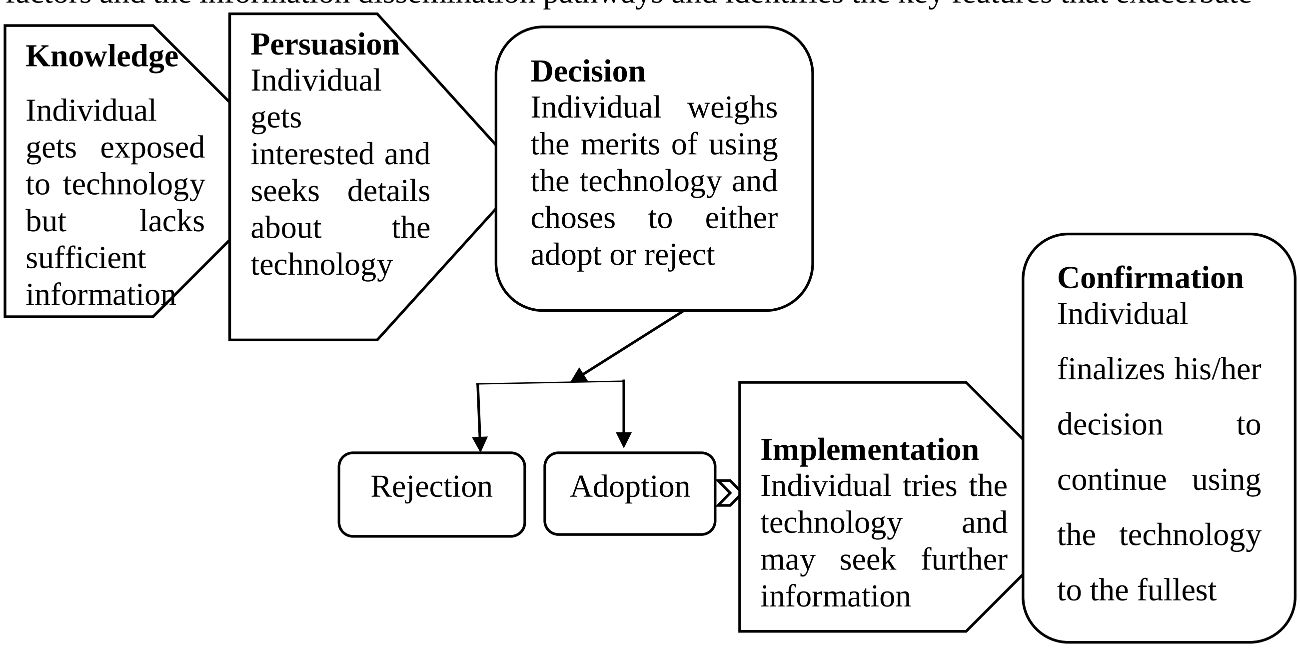

Figure 3: Stages in the technology adoption process

Source: Rogers (1995).

the rate of adoption. The features are combined in the perceived relative advantage of the technology, compatibility, ease of use/trial-ability, complexity, and how it is communicated However, this theory fails to point out that communities are discrete and that the effect of these factors may vary from one community to another. This study sought to establish the relationship between selected factors and practice of CSA. Rogers (2003) states that technology adoption decision follows five steps (Figure 3), and these steps chronologically follow one another in a time-ordered way. Individuals who learn first about the technology before others are found to have exposure to mass media and more channels of interpersonal communication, have more education that is formal, and are of high social status, have more access to change agents and exercise high levels of social participation in their communities (Rogers, 2003). Therefore, the inception of this study was premised on the ideas put forward by this theory to prompt develop an understanding of how CSA have been diffused and practiced by the smallholder potato farmers in Gilgil Sub-County, Nakuru County, Kenya.

2.10 Conceptual Framework

According to the theoretical framework (Figure 3), it was believed that for the farmers to adopt and practice a new technology, they should be provided with the appropriate information regarding the technology. The choice of a particular CSAP by the farmer was partly influenced by the farmer's understanding of its underlying benefits and how it was practiced. The study investigated the association between information dissemination pathways and practice of CSA and they consisted of neighbors and friends, extension officers, and radio/ television/ phone. The socioeconomic and institutional factors were hypothesized to have a relationship with the practice of CSA technologies (Figure 4).

The CSA that are well adapted for the communities under the study include drainage management; agroforestry; use of synthetic fertilizers; composting, ridge planting; crop rotation; improved crop varieties; intercropping; irrigation; minimal tillage; mulching; rainwater harvesting and storage; and terracing. These were considered for this study based on the Kenya CSA strategy (GoK, 2017), the Kenya CSA implementation framework (GoK, 2018), and on an interview with the local potato farmers' group leaders in Gilgil Sub-County about the CSA practices being fostered among farmers. Mainly due to the climate risk profile of the area (MoALF, 2016), that has invited these CSA as interventions.

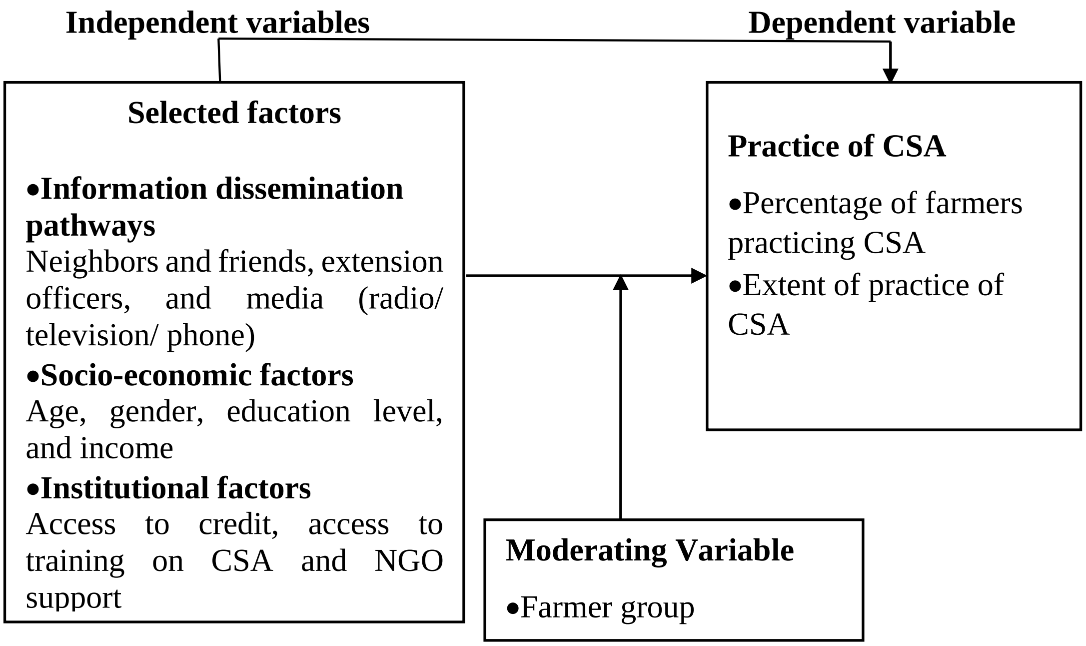

Figure 4: Own conceptualized framework showing the interaction between the selected factors and the practice of CSA

Belonging to farmer groups may influence the practice of CSA in the area of study and, therefore, was treated as a moderating variable in this study. Because, farmers who belong to farmer groups may easily pool resources to access CSAPs which an individual farmer may not afford. Random sampling controlled its influence, whereby farmers belonging to groups and those who do not were randomly sampled. The moderator variable was also included among the study variables.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter covers the research design, the study area, and population sampling procedures that were followed in obtaining the required sample size. It also explains the procedure followed in data collection that entails the research instruments, describes the pilot study, states how the validity and reliability of the instruments was ensured and, data collection, and data analysis procedure.

3.2 Research Design

The study adopted a cross-sectional survey design to collect data from the study population. Such a design enables the collection of data on the population at a particular point in time. While using this design, the respondents are allowed to describe existing phenomena without any intervention. This design allows comparison of literate/illiterate, youth/aged, and male/female among other categories without manipulating the independent variable (Mugenda & Mugenda, 2003). Practice of CSA was the dependent variable in the proposed study, and the independent variables included socioeconomic factors, institutional factors, and information dissemination pathways.

3.3 Location of the Study

The study was conducted in Gilgil Sub-County of Nakuru County, Kenya. Gilgil is subdivided into five wards, namely; Gilgil, Elementaita, Malewa West, Mbaruk / Eburu, and Morendat wards (Appendix D & E). Gilgil Sub-County covers an area of 1,348.43 square kilometers, with a total population of 171,839 (Rampa & Knaepen, 2019). The study area is located at coordinates 36°10′0″E 0°40′0″S and 35°30′0″E 1°0′0S″ in agro-ecological zone III of Kenya. It is known for its annual rainfall of between 500 and 870 mm with maize, beans, and potatoes as the significant crops covering 86.4% of the arable land area (Rampa & Knaepen, 2019).

3.4 Target Population

The study targeted smallholder potato farmers in Gilgil Sub-County. According to the 2019 agricultural census, there are 15,359 smallholder farmers actively engaged in potato production in Gilgil Sub-County (MoALF, 2019). These formed the study target population. The accessible population consisted of all the 10,889 potato farmers found in Morendat ward (4,287) and Mbaruk / Eburu ward [6,602] (Gilgil Sub-County, 2019).

3.5 Sampling Procedure and Sample Size

Gilgil Sub-County was purposively considered for this study because of its susceptibility to the effects of climate change (MoALF, 2016). This has attracted several interventions; for example, by SNV, Climate, and Water Smart Agriculture Centre (CaWSA-C) project under Community Action Research Project (CARP+) and the Kenyan government through the Sub County and Ward extension officers to foster CSA practices to cushion the area against the shock. The Kenyan government implements the CSA practices in the study area under its CSA implementation framework. The SNV has fostered the practice of CSA among the smallholder potato farmers in the study area. Besides, farmers in the study area are actively engaged in potato growing.

Out of the five wards in Gilgil Sub-County, Mbaruk / Eburu and Morendat were purposively selected because they compose of the most significant number of potato farmers in the Sub-County. Additionally, these two form the major farming communities in the Sub-county unlike other wards like Gilgil ward, which is a town with rocky soils that results into low farming activities (Rampa & Knaepen, 2019). Also, because Mbaruk / Eburu is the largest ward in Gilgil Sub-County (Appendix E).

The sample size was calculated basing on the coefficient of variation formula suggested by Nassiuma (2000). For the proposed study, a 21% coefficient of variation and 0.02 standard error was used to compute the sample size using Nassiuma (2000) equation (see equation below). These parameters were chosen assuming the lower coefficient of variation and standard error to minimize variability and error in the sample. Besides, in consideration of the fact that the maximum coefficient of variation is 30% and above, which is not justified and a low coefficient of variation leads to a small sample size, which may not be suitable for the survey research.

$$n = \frac{NC^2}{C^2 + (N-1)e^2}$$

Where

n= sample

N=population

C= Coefficient of variation

e= standard error

$$n = \frac{10889 \times (21\%)^2}{(21\%)^2 + (10889-1)0.02^2}$$

$$n = 109$$

Since n value is above 100 which is the minimum recommended sample size for survey studies, it was considered appropriate to give the required level of accuracy (Kathuri & Pals, 1993).

To cater for non-responses, attrition and for the purposes of representative sample, the researcher revised the sample size to 120 by adding 10% of 109. The wards and Sub-County extension officers helped in coming up with the list of all the potato smallholder farmers in the study area. Proportionate random sampling was used in determining the number of respondents for the purposively sampled wards (Table 5), and simple random sampling was be used in obtaining the actual respondents from the wards.

Table 5: Proportion of Sample Size Per Ward

Ward	Number of Potato Farmers	Proportion	Sample size
Mbaruk / Eburu	6,602	60.63	73
Morendat	4,287	39.37	47
Total	**10,889**	**100**	**120**

3.6 Instrumentation

The researcher collected primary data using a structured researcher administered questionnaire (Appendix A). It was administered to the sampled potato smallholder farmers in Mbaruk / Eburu and Morendat wards of Gilgil Sub-County. The questionnaire was used for data collection because it is easy to administer, and it makes scoring and analysis of the data realistic. Besides, responses to items captured in the questionnaire are consistent across the respondents (Creswell, 2012). The questionnaire items were developed based on the study objectives. Part A of the questionnaire was used to collect information on the socioeconomic factors. While part B aimed at capturing information on the institutional factors, C and D captured information on the information dissemination pathways and the practice of CSA respectively.

3.6.1 Validity

The validity of a questionnaire means its ability to measure what it is meant to measure. It does establish the aspects of face validity, which involves experts looking at the questions in the questionnaire and approving that they are a valid measure of the idea that is being investigated just on its face (Bolarinwa, 2015). In addition, content validity ensures that the instrument captures all aspects of the study. Experts from the Department of Agricultural Education and Extension validated the questionnaire. Recommendations given were used to improve the instrument.

3.6.2 Reliability

The ability of an instrument to yield the same results repeatedly is referred to as reliability (Edmonds & Kennedy, 2017). Thus, reliability measures the consistency of the instrument. This study's questionnaire reliability was ascertained by conducting a pilot study using 30 potato farmers in Mauche Ward of Njoro Sub-County within Nakuru County. The potato farmers in Mauche with related socioeconomic features (on which other features depend) to those of the target population were considered for the pilot study. Mauche was chosen for the pilot because it is also exposed to the effects of climate change (MoALF, 2016) and with farmers who are actively engaged in potato production like the study area. The reliability coefficient was estimated using Cronbach Alpha Scale to being 0.805 (Appendix E). The questionnaire was regarded as reliable since it realized a reliability coefficient of above 0.70 (Fraenkel *et al.*, 2000). Some adjustments in the instrument questions were made based on the pilot study findings.

3.7 Data Collection Procedure

The researcher obtained a clearance letter from the Graduate School of Egerton University and this was used to apply for a research permit at National Commission for Science, Technology, and Innovation (NACOSTI). The research permit (Appendix F) was then presented to the authorities that allowed the collection of data from Gilgil Sub-County. From the list of smallholder potato farmers, a sample was drawn following the earlier stated procedure. Thereafter, visits to the sampled potato farmers were arranged with the assistance of the chairperson Gilgil Sub-County Smallholder Farmers' Association. The researcher administered the questionnaires himself, with the assistance of a translator, to overcome the problem of language barrier.

3.8 Data Analyses

The data were organized and coded in consideration of both the independent and dependent variables in line with the study questions and hypotheses, and keyed into the IBM Statistical Package for Social Sciences (SPSS) version 25. Cramer's V was used to ascertain and test the strength of the association between information dissemination pathways and practice of CSA, and difference in their use by male and female farmers. Binary logistic regression was used for establishing the relationship between socioeconomic and institutional factors, and the practice of CSA for the rejection or acceptance of the hypotheses at a 5% level of significance.

The logistic regression model for socioeconomic factors was indicated below.

$$y_1 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

X_1 = Age of the farmer, X_2 = Gender of the farmer, X_3 = Education level of the farmer, and X_4 = Off-farm income/ farmers' income

Model Specification for Institutional Factors

$$y_2 = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_3 X_4 + \varepsilon$$

X_1 = Access to credit, X_2 = Access to training on CSA, X_3 = NGO support, and X_4 = Farmer groups

Table 6: Data Analysis Summary

Research Questions and Hypotheses	Independent variable	Dependent variable	Method of analysis
H_{01}: There is no statistically significant association between information dissemination pathways and practice of CSA among the smallholder potato farmers in Gilgil sub-County, Kenya	Information dissemination pathways	Practice of CSA	Percentages and frequencies and Cramer's V
H_{02} There is no statistically significant relationship between socioeconomic factors and the practice of CSA among the smallholder potato farmers in Gilgil sub-County, Kenya	Socioeconomic factors	Practice of CSA	Percentages and frequencies and Binary logistic regression
H_{03} There is no statistically significant relationship between institutional factors and the practice of CSA among the smallholder potato farmers in Gilgil sub-County, Kenya	Institutional factors	Practice of CSA	Percentages and frequencies and Binary logistic regression

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents results and discussions of the findings from the data analyzed regarding research objectives and hypotheses as specified in Chapter One. The aspects analyzed and discussed include establishing the association between information dissemination pathways and practice of CSA, the relationship between selected socioeconomic and institutional factors, and the practice of CSA among smallholder potato farmers in Gilgil Sub-County, Kenya.

4.2 Climate-Smart Agriculture Information Dissemination Pathways

The first objective of the study was stated as:

To investigate the association between information dissemination pathways and practice of CSA among smallholder potato farmers in Gilgil Sub County, Kenya.

The respondents for this study were 120 smallholder potato farmers in Gilgil Sub County. The findings of the information dissemination pathways were as follows:

4.2.1 Information dissemination pathways and Practice of CSA

Table 7 shows the descriptive statistics for the awareness level, information sources, and practice of CSA. These show the potato farmers who were aware plus their source of information and those who practice CSA. Importantly, the data disaggregates awareness of CSA to specific CSA practices and the same with overall practice of CSA. The results indicated that 97.5% of the smallholder potato farmers were aware of rainwater harvesting and this was the CSAP with the leading percentage of awareness followed by intercropping and use of synthetic fertilizers both at 95%, and crop rotation (94.2%). Of the 97.5% potato farmers who were aware of rainwater harvesting and storage, 35.9% learned about it from the media (telephone/radio/television), 38.5% from the neighbors and friends while 25.6% from extension officers. Additionally, 83.3% of the farmers who were aware of rainwater harvesting put it into practice.

Table 7: Awareness, information dissemination pathways and Practice of CSA

Climate-Smart Agriculture Practices	Smallholder potato farmers (N=120)									
	Aware		Media		N/F		Ext Off		Practice of CSA	
	F	%	F	%	F	%	F	%	F	%
Rainwater harvesting and storage	117	97.5	42	35.9	45	38.5	30	25.6	100	83.3
Irrigation	95	79.2	26	27.4	39	41.1	30	31.6	38	31.7
Mulching	104	86.7	25	24.0	36	34.6	43	41.3	77	64.2
Minimal tillage	99	82.5	27	27.3	31	31.3	41	41.4	87	72.5
Improved crop varieties	97	80.8	40	41.2	20	20.6	37	38.1	71	59.2
Terracing	105	87.5	30	28.6	29	27.6	46	43.8	90	75.0
Drainage management	105	87.5	22	21.0	33	31.4	50	47.6	85	70.8
Intercropping	114	95	24	21.0	49	43.0	41	36.0	107	89.2
Agroforestry	107	89.2	25	23.4	31	29.0	51	47.7	102	85.0
Synthetic fertilizers	114	95.0	38	33.3	26	22.8	50	43.9	114	95.0
Composting	102	85.0	28	27.5	37	36.3	37	36.3	91	75.8
Furrow/ ridge planting	96	80.0	29	30.2	26	27.1	41	42.7	89	74.2
Crop rotation	113	94.2	27	23.9	33	29.2	53	46.9	100	83.3
Apical rooted cuttings (potato seedlings)	27	22.5	3	14.3	1	3.6	23	82.1	9	7.5
Mini-tubers	7	5.8	2	28.6	1	14.3	4	57.1	2	1.7

F – Frequency; % - Percent; N/F – Neighbours and friends; Ext Off – Extension officers

Similarly, 33.3%, 22.8%, and 43.9% of the potato farmers who were aware of synthetic fertilizer use heard from media, neighbors, and friends, and extension officers respectively. Unlike rainwater harvesting, 95% of the farmers who reported being aware of synthetic fertilizers, were found practicing. Like the latter, intercropping registered a relatively big percentage (89.2%) of farmers who reported about its practice out of the 95% who were aware. Moreover, 21%, 43%, and 36% of the potato farmers sourced information on intercropping from media, neighbors, and friends, and extension officers respectively.

Another category of the CSAPs to be relatively known by the smallholder potato farmers comprised of mulching, terracing, drainage management, agroforestry, and composting, and on average, 87.18% of the farmers were aware of these CSAPs. Averagely, the largest percentage (42.3%) of smallholder potato farmers get information on this category of CSA from extension officers, 32.5% from neighbors and friends, and the least percentage (25.3%) from media. However, an average of 71.5% practice these CSAPs. This is a slightly lower percentage compared to those (87.18%) who indicated that they were aware of these CSAPs. While the category of minimal tillage, improved crop varieties, and furrow/ ridge planting ranked third in being known by the farmers, and on average 81.1% of the smallholder potato farmers were aware of their existence. The results further revealed an average of 32.9% of the potato farmers were enlightened about this category of CSA from media, 26.3% from neighbors and friends, while the largest percentage (40.7%) of the potato farmers learned about these from extension officers. Notably, only an average of 68.6% of the potato farmers practiced this category of CSA.

Furthermore, 79.2% of the farmers were aware of irrigation, and the least known CSAPs were apical rooted cuttings [potato seedlings] (22.5%) and minitubers (5.8%). Around 27.4% of the farmers who were aware of irrigation obtained information from media, 41.1% from neighbors and friends, and 31.6% from extension officers. Out of those who were aware, 31.7% practiced irrigation. Potato seedlings were the second last CSAPs to be known by the farmers, and from those who indicated they knew about it, 14.3% got information from media, 3.6% from neighbors and friends, and 82.1% from extension officers, while only 7.5% were found practicing. Findings further portray that overall, 77.9% of the surveyed potato farmers were aware of the CSAPs investigated in this study. On average, most farmers moderately (47.2%) practiced the CSA, 38.5% indicated they were practicing but at a lower extent and only 14.3% were highly practicing the CSA (Fig 5).

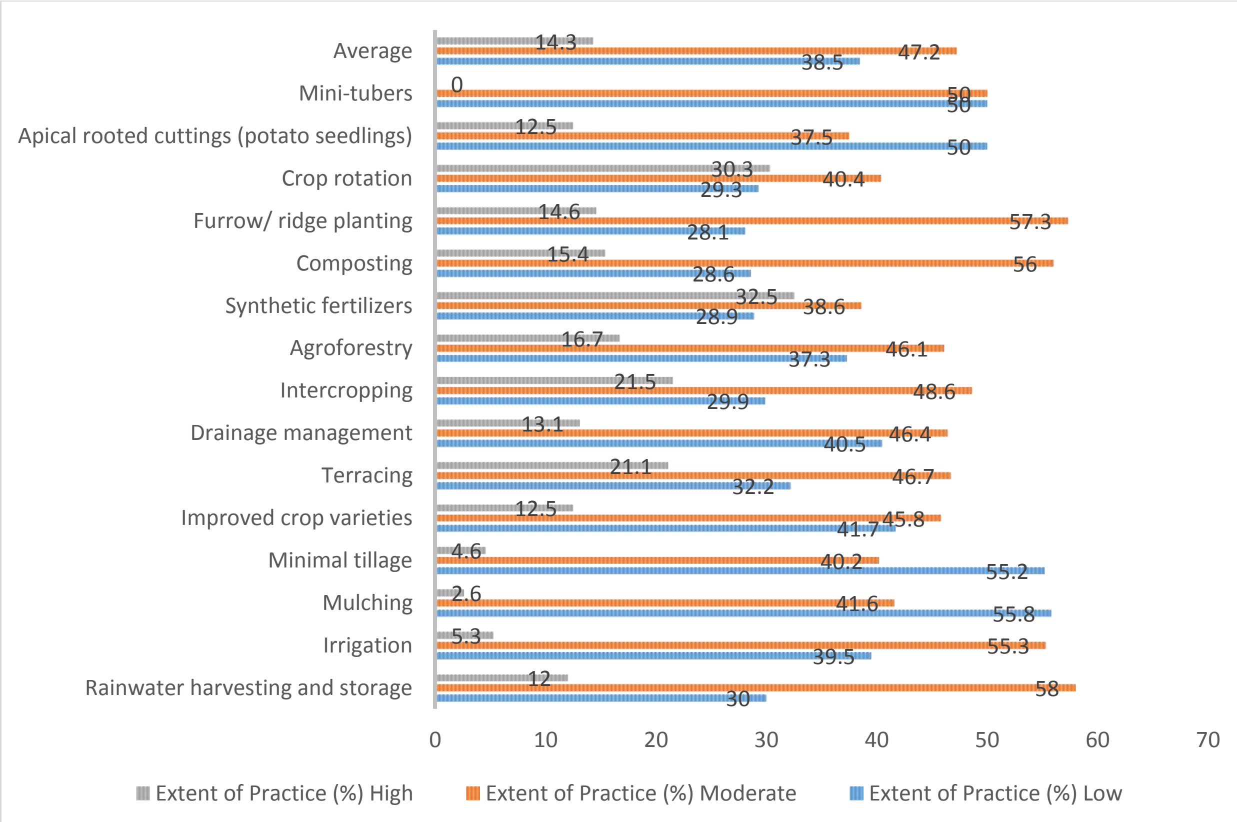

Figure 5: Extent of practice of CSA

At least every CSAPs had farmers reporting practicing it at a low, moderate, and high rate except for minitubers which were only practiced at a low and moderate extent. The widespread use and high percentages of practice of most CSAPs especially those with a high rate of awareness might be explained by the fact that information raises possibilities of practice. This agrees with the findings by García de Jalón *et al.* (2015) in their study on barriers to adoption of climate change adaptation strategies who asserted that higher knowledge may further support farmers' decision to use a given CSAP. This is because information helps the farmers gain a full understanding of a given technology, and therefore they may be willing to try it out (Deressa *et al.*, 2009; Gebrehiwot & van der Veen, 2013). On the contrary, CSAPs like irrigation attracted a high percentage of awareness yet with low percentage of farmers practicing them. For this case, factors beyond awareness come into play. For example, such CSA may require heavy capital investment, which may not readily be available or accessed by some farmers. Similarly, cultural bias on some CSAPs may curtail their widespread use. This assertion commensurate Nyasimi *et al.*'s (2017) findings that revealed cultural constraints as bottlenecks to the practice of CSA. Yet, facilitating the practice of such CSA may deter crop losses and increase agricultural output per area by enabling dry season production and eventually reduce over-reliance on rain-fed agriculture (Gebrehiwot & van der Veen, 2013; Orindi & Eriksen, 2005).

Another possible reason for the high percentage in the practice of most CSAPs is the undulating topography nature of Gilgil Sub County. This contention is in tandem with findings from previous studies (Bryan *et al.,* 2013; Nkonya *et al.,* 2015; Nkuba *et al.,* 2020), which stated that some farmers' adaptation strategies are influenced by the nature/ slope of their land. Additionally, given the nature of their terrain which is steep plus being exposed to the effects of climate change (Rampa & Knaepen, 2019), farmers from the study area are forced to seek information to guide their decisions in preventing further loss of soils, retain water, sustain and increase yields. This claim is supported by Bryan *et al.* (2009) and Nkuba *et al.* (2020) who concluded that area agro-ecological situations influence the choice of the adaptation strategies, hence the CSA practiced by the framers. On the contrary, some CSAPs like potato seedlings and minitubers recorded low awareness and practice. These practices seem to be new in the area, and according to literature (Rogers, 1995, 2003; Rogers & Ban, 1963), farmers are always skeptical to take up new technologies unless they gain a full understanding of them. Also, another cause of low use of traditionally dressed farming practices into CSA like mulching and improved crop varieties might be associated with the information sources used to communicate these. For example, televisions, telephones, and radios (media) may not fully orient the farmers to get the full knowledge required to execute a given CSAP. This is in line with findings by Arimi (2014) who found that the farmers were found half-baked regarding the practice of adaptation strategies like the growth of biennial root and tuber crops, yet they received information from media. The reasoning behind this is that these tend to give general information (Comoé & Siegrist, 2015).

4.2.2 Information dissemination pathways and practice of CSA

This section presents findings on the first hypothesis of the study, stated as:

> H_{O1}: *There is no statistically significant association exist between information dissemination pathways and practice of CSA*

Analysis of the information dissemination pathways and practice of CSA affirmed that there is a strong association between information sources and practice of CSA at a 5% level of significance

($\chi2 = 100.12139$, df = 2, $p < 0.05$, Cramer's V = 1.0) among the smallholder potato farmers (Table 8).

Table 8: Information dissemination pathways and practice of CSA

Awareness and Practice of CSA	Percentage of smallholder potato farmers		
	Media	Neighbors and friends	Extension Officers
Aware (n=93)	27.2	28.7	44.1
Practice (n=77)	26.8	27.9	45.3

Around 44.1% of the 93 potato farmers who were aware of CSA get information from the extension officers, while 28.7% and 27.2% get information from neighbors and friends, and media respectively. Similarly, 45.3% of the farmers who practiced CSA sourced information from extension officers, 27.9% and 26.8 from media, and neighbors and friends respectively.

Overall, extension officers emerged with the highest percentage as an information source and this may partly explain high percentages of CSA practice among farmers with high awareness. Because, according to Alam (2015) and Mandleni and Anim (2011), extension officers create satisfactory awareness of climate-smart farming practices. Though on the contrary, inappropriate extension services smoother efforts tailored to foster CSA (Alam, 2015). In addition, neighbors and friends scoring second notable information and CSA practice source could be because first learning farmers and early technology adopters in the communities devote their land and garden for fellow farmers to observe and imitate successful technologies. This allegation is consistent with the results of other studies which showed that farmers with experienced and progressing neighbors were more likely to devote more land to try out new agricultural technologies (Abbas *et al.,* 2003). Additionally, Kalungu and Leal Filho (2018) found farmers imitating cultivation of improved plant varieties and other practices from successful neighbors.

While media scoring the least CSA awareness and practice source might be linked to the farmers' busy schedules in the fields since they have to cascade around the undulating tenure. This makes them very tired at the end of the day to the extent that they may not have the zeal to sit and listen to the radio and or watch television. Also, most parts of the study area are not electrified and this could explain the low use of television as a media component. However, these results contradict study findings from other places where farmers reported media as the chief information source on climate change adaptation (Kalungu & Leal Filho, 2018; Nzeadibe & African Technology Policy Studies Network, 2011).

4.3 Relationship between Socioeconomic Factors and Practice of Climate-Smart Agriculture

The second objective of the study was:

> *To determine the relationship between socioeconomic factors and the practice of climate-smart agriculture among smallholder potato farmers in Gilgil Sub County, Kenya*

Table 9 shows the selected socioeconomic factors whose relationship with the practice of CSA was deemed important for investigation among smallholder potato farmers in Gilgil Sub County, Kenya

Table 9: Descriptive statistics of the smallholder potato farmers' socioeconomic factors

Socioeconomic factor	F	%
Gender of the respondent		
Male	72	60
Female	48	40
Age bracket		
18 – 35	36	30
36 – 50	45	37.5
51 – 65	30	25
66 years and above	9	7.5
Education level		
Did not go to school	6	5
Primary	61	50.8
Secondary	40	33.3
Post-secondary	10	8.3
University	3	2.5
Annual farm income		
< KES 10,000	37	30.8
KES 10,001- KES 25,000	45	37.5
KES 25,001- KES 35,000	18	15
> KES 35,000	20	16.7
Annual off-farm income		
< KES 10,000	28	23.3
KES 10,001- KES 25,000	41	34.2
KES 25,001- KES 35,000	21	17.5
> KES 35,000	30	25

KES – Kenyan Shillings

Table 9 reveals that 60% of the respondents were males and 40% females, 30% were between 18 and 35 years, 37.5% were between 36 and 50 years, 25% between 51 and 65 years, and 7.5% were 66 years and above. It further portrays that 5% of the respondents did not go to school, 50.8%

attained primary education, 33.3% secondary education, 8.3% post-secondary, and 2.5% had a university education. About 30.8% earned an annual farm income of less than KES 10,000, 37.5% earned between KES 10,001 and KES 25,000, 15% between KES 25,001 and KES 35,000 while 16.7% earned over KES 35,000. Unlike annual farm income, 23.3% of the respondents earned an annual off-farm income of less than KES 10,000, 34.2% earned between KES 10,001 and KES 25,000, 17.5% earned between KES 25,001 and KES 35,000 whereas 25% earned over KES 35,000.

Having a high percentage of male smallholder potato farmers may imply that more CSA could be practiced since men tend to own and have access to most production resources like land. Yet most of the CSAPs considered for this study may require having a land tenure (Arslan *et al.*, 2014), for example agroforestry. Following Kennedy *et al.*'s (2011) categorization of farmers into young, adults, and elderly of age ≤ 35, 36–64, and ≥65 respectively, this means that studied farmers were most likely to embrace the practice of CSA for adapting to climate change effects while improving productivity. This is because according to Arimi (2014) most productive African farmers are adults of age ranges 40 to 50.

The trend of education among the respondents shows that most (50.8% and 33.3%) smallholder potato farmers had primary and secondary education respectively, a sign of low practice of CSA. This is on the basis that learned farmers are more inclined to engage in other secondary enterprises like salaried employment and owning a business that may narrow their chances of being available for agriculture and also, increases their livelihood options and thus less likely to worry about the effects of climate change (Awotide *et al.*, 2016). However, Arimi (2014) and Ayelagbe (2012) refute this submission and further claim that high literacy levels incapacitate farmers to seek and utilize the information that may exacerbate the wide acceptance of CSA.

On average, the respondents reported low incomes (both annual farm and off-farm incomes) where most (30.8% and 37.5%) earned less than KES 10,000, and between KES 10,001 and KES 25,000 respectively for annual farm income. Similarly, the 23.3% and 34.2% that earned an annual farm income of less than KES 10,000, and between KES 10,001 and KES 25,000 respectively are still high compared to the lower percentage of 16.7% and 25% who earned both annual farm and off-farm income of above KES 35,000 respectively. This may deter the practice of some CSAPs like terracing, irrigation, and drainage management that require more labor and considerable investment in purchasing the required installation materials. For example, a study conducted in the North-Western Highlands of Ethiopia by Moges and Taye (2017) found that though terracing was used to lessen the soil erosion caused by the water runoff due to the nature of the slope, farmers lamented that its establishment plus that of drainage channels was associated with high costs by demanding a reasonable labor force. This contention is consistent with Shikuku *et al.* (2017) who asserted that high-income farmers may be in a position to afford irrigation equipment and the required labor force. On the contrary, a study by Gibreel (2013) disclosed that farmers with less income were most likely to adopt agroforestry.

4.3.1 Gender and the Practice of Climate-Smart Agriculture

Results on gender and practice of CSA are presented in Table 10 in form of percentages and frequencies.

Table 10: Gender and practice of climate-smart agriculture

Climate-smart agricultural practices	Smallholder farmers (N=120)			
	Female (n=48)		Male (n=72)	
	F	%	F	%
Rainwater harvesting and storage	39	81.3	63	87.5
Irrigation	17	35.4	18	25.0
Mulching	33	68.8	42	58.3
Minimal tillage	37	77.0	48	66.7
Improved crop varieties	29	60.4	42	58.3
Terracing	36	75.0	54	75.0
Drainage management	36	75.0	47	65.3
Intercropping	45	93.8	60	83.3
Agroforestry	42	87.5	59	81.9
Synthetic fertilizers	46	95.8	68	94.4
Composting	41	85.4	43	59.7
Furrow/ ridge planting	37	77.0	50	69.4
Crop rotation	42	87.5	56	77.8
Apical rooted cuttings (potato seedlings)	4	8.3	5	6.9
Mini-tubers	1	2.0	2	2.8

An average of 67.3% of the 48 female smallholder potato farmers and 60.8% of the 72 male smallholder potato farmers practice CSA respectively. The most practiced CSAPs by the female farmers was the use of synthetic fertilizers and intercropping with an average score of 94.8%. This was followed by 85.4% for rainwater harvesting and storage, agroforestry, composting, and crop rotation. Relatively practiced CSAPs by women included minimal tillage, terracing, drainage management, and furrow/ ridge planting with an average score of 76.0%. While mulching and improved crop varieties scored an average of 64.6%, other CSAPs (irrigation, potato seedlings, and minitubers) scored below average (35.4%, 8.3%, and 2.0% respectively). On the other hand, the most practiced CSA among male smallholder potato farmers was the use of synthetic fertilizers (94.4%) followed by rainwater harvesting and storage, intercropping, and agroforestry with an average of 84.2% of smallholder male farmers practicing them. Around 76.4% of male farmers practiced terracing and crop rotation, 67.1% practiced minimum tillage, drainage management, and furrow/ ridge planting and 58.3% practiced mulching and improved crop varieties. Whereas irrigation, potato seedlings, and mini-tubers were practiced by 25.0%, 6.9%, and 2.8% respectively.

Overall, female farmers practiced more CSA than males and this contradicts findings from previous studies (Bayard *et al.*, 2007; Deressa *et al.*, 2009, 2011; Hassan & Nhemachena, 2008) where male farmers practiced more CSA than females as a strategy to ameliorate the effects of climate change. High use of synthetic fertilizers and intercropping by women may be explained by the fact that women are major food producers (Nhemachena & Hassan, 2007) and these CSAPs tend to yield results in the shortest time possible. For example, urea as a synthetic fertilizer releases nutrients easily and intercropping allows them to have a variety of crops for both food and nutritional security.

Contrarily, slightly low use of synthetic fertilizers and intercropping by men compared to women could be due to men's risk averseness that may make them hesitant in venturing in short-term CSAPs. This claim is in line with findings by Asfaw and Admassie (2004) who found that males are inclined to being risk-averse and reluctant in adapting to climate change by obtaining new practices and changing their farming methods. The high practice of rainwater harvesting by men than women may be because of the cost associated with the initial installation of rainwater harvesting equipment. This is because, in Africa, men own productive resources that generate household income (Bedeke *et al.*, 2019) and this may limit women in accessing CSAPs that require high initial installation costs. Additionally, rainwater harvesting and storage may necessitate the digging of water pans and this is a labor-intensive activity that most women may not welcome.

However, the high percentage in the overall use of most CSAPs other than rainwater harvesting, potato seedlings, and minitubers by women can be because of being conservative to change from traditionally known practices. Because most of the CSAPs where women ranked high are traditionally known practices that were branded into climate-smart agriculture ('old wine in new bottles'). This contention is empirically supported by Tenge *et al.* (2004) who found that women farmers are not liable to change the farming methods to which they are used. Limited access to information may be responsible for the low practice of potato seedlings and minitubers by women compared to men. These being new CSAPs among potato farmers, access and utilization of information inform early adopters' decisions. This assertion is consistent with that of Di Falco (2014) who asserted that male farmers are expected to embrace new crop varieties as opposed to their counterparts which due to cultural norms have inadequate access to information.

4.3.2 Farmer's Age and Practice of Climate-Smart Agriculture

Table 11 presents results on smallholder potato farmers' age and practice of CSA in form of percentages and frequencies. Averagely, 61.8% of the farmers within the age bracket of 18-35 years [younger farmers according to Kennedy *et al.* (2011)] practiced the CSA with 86.6% practicing rainwater harvesting and storage, intercropping, use of synthetic fertilizers, and crop rotation. Agroforestry and furrow/ ridge planting were practiced by 75.0%, mulching, minimum tillage, terracing, drainage management, and compositing by 67.8%, and improved crop varieties by 58.3%. While irrigation was practiced by 33.3% and no farmer within this age category practiced potato seedlings and minitubers.

According to Kennedy *et al.* (2011), farmers within the age category of 36 to 65 years are regarded as adult farmers and the most practiced CSAPs by the adult farmers included rainwater harvesting and storage, mulching, minimal tillage, terracing, drainage management, intercropping, agroforestry, synthetic fertilizers, composting, furrow/ ridge planting and crop rotation. These were practiced by over 70% of the adult farmers; this was followed by intercropping which was practiced by over 50%. Irrigation was the second last CSA practiced by the adult farmers and practiced by over 30% while potato seedlings and minitubers were practiced by over 8.0% of the adult smallholder potato farmers and these were the least practiced CSAPs. On the other hand, over 78% of the old farmers practiced most of the CSAPs except for irrigation, which was practiced by 33.3%, mulching (44.4%), potato seedlings (11.1%), and minitubers, which was practiced by none.

Table 11: Age and practice of climate-smart agriculture

Climate-smart agricultural practices	Smallholder potato farmers (N=120)							
	18 – 35 (n=36)		36 – 50 (n=45)		51 – 65 (n=30)		66 years and above (n=9)	
	F	%	F	%	F	%	F	%
Rainwater harvesting and storage	30	83.3	36	80.0	26	86.7	8	88.9
Irrigation	12	33.3	13	28.9	10	33.3	3	33.3
Mulching	24	66.7	32	71.1	17	56.7	4	44.4
Minimal tillage	25	69.4	37	82.2	20	66.7	5	55.6
Improved crop varieties	21	58.3	28	62.2	16	53.3	6	66.7
Terracing	24	66.7	35	77.8	24	80.0	7	77.8
Drainage management	25	69.4	34	75.6	20	66.7	6	66.7
Intercropping	32	88.9	42	93.3	26	86.7	7	77.8
Agroforestry	27	75.0	39	86.7	27	90.0	9	100.0
Synthetic fertilizers	32	88.9	43	95.6	30	100.0	9	100.0
Composting	24	66.7	38	84.4	22	73.3	7	77.8
Furrow/ ridge planting	27	75.0	32	71.1	22	73.3	8	88.9
Crop rotation	31	86.1	40	88.9	23	76.7	6	66.7
Apical rooted cuttings (potato seedlings)	0	0.0	05	11.1	3	10.0	1	11.1
Mini-tubers	0	0.0	02	4.4	0	0.0	0	0.0

Based on the findings, there is no big difference in the CSAPs practiced by young farmers, adults, and old farmers except for potato seedlings and minitubers, which were not practiced at all by the young farmers yet practiced by the adult farmers, and minitubers practiced by the old farmers. Non-practice of potato seedlings and minitubers by the young smallholder potato farmers could be because of their inability to access land and other production resources controlled by the adults and old farmers. This claim is in line with Gumucio *et al.* (2020) who found that young farmers are constrained to act on some CSAPs and other climate change adaptation strategies due to lack of control on land. The overall high practice of CSA across all age categories of smallholder potato farmers could be associated with; young farmers are always perpetrated not only to acting towards climate change for adaption but also aesthetic value. This contention is supported by previous studies (Davis *et al.,* 2011; Fransson & Gärling, 1999; Marenya & Barrett, 2007; Michel-Guillou & Moser, 2006) where young farmers were regarded to have immense environmental committal. While adult and older farmers have experience and would not wish to succumb to food shortages, this drives them to practice CSA as an adaptive strategy. This agrees with Zahidul Islam *et al.* (2012) who purported that adult and older farmers are experienced and readily embrace new practices.

4.3.3 Education Level and Practice of Climate-Smart Agriculture

Table 12 displays the frequencies and percentages of smallholder potato farmers practicing CSA. The majority (an average of over 60%) of the farmers across all education categories practiced CSA with some CSAPs embraced by 100% of the farmers who did not go to school, those who attained secondary, post-secondary, and university education. Similarly, certain CSAPs were practiced by over 95.1% of the farmers with primary education.

However, a disparity in the practice of some CSAPs existed, to start with, only 50% of the farmers who did not go to school and those that attained post-secondary education practiced mulching. This is a slightly lower percentage compared to over 65% of the farmers with primary, secondary, and university education who practiced mulching. Additionally, the smallholder potato farmers with university education practiced improved crop varieties and agroforestry below average (33.3%). Still, though above average, improved crop varieties were practiced by 59% and 57.5% of the farmers with primary and secondary education respectively. Yet, generally, the overall trend shows that over 60% of the farmers across all education categories put this into practice. Except for farmers with a university education of which 66.7% practiced irrigation, its practice among the rest of the farmers within other education categories was below average.

Nevertheless, the farmers with primary and post-secondary education practiced all potato seedlings and minitubers, though at a low percentage of 8.2% and 1.6%, and 10% and 10% respectively. Unlike the potato farmers with university education who practiced neither potato seedlings nor minitubers, at least those who did not go to school and those with secondary education at a percentage of 16.7% and 5.0% respectively practiced minitubers.

Table 12: Education level and practice of climate-smart agriculture

Climate-smart agricultural practices	Smallholder potato farmers (N=120)									
	Did not go to School (n = 6)		Primary (n = 61)		Secondary (n = 40)		Post-Secondary (n = 10)		University (n = 3)	
	F	%	F	%	F	%	F	%	F	%
Rainwater harvesting and storage	5	83.3	46	75.4	37	92.5	9	90.0	3	100.0
Irrigation	1	16.7	18	29.5	15	37.5	2	20.0	2	66.7
Mulching	3	50.0	41	67.2	26	65.0	5	50.0	2	66.7
Minimal tillage	4	66.7	42	68.9	28	70.0	10	100.0	3	100.0
Improved crop varieties	4	66.7	36	59.0	23	57.5	7	70.0	1	33.3
Terracing	4	66.7	45	73.8	30	75.0	8	80.0	3	100.0
Drainage management	5	83.3	44	72.1	26	65.0	8	80.0	2	66.7
Intercropping	6	100.0	57	93.4	33	82.5	8	80.0	3	100.0
Agroforestry	6	100.0	53	86.9	36	90.0	6	60.0	1	33.3
Synthetic fertilizers	6	100.0	58	95.1	40	100.0	8	80.0	2	66.7
Composting	5	83.3	45	73.8	31	77.5	8	80.0	2	66.7
Furrow/ ridge planting	4	66.7	42	68.9	32	80.0	8	80.0	3	100.0
Crop rotation	5	83.3	51	83.6	33	82.5	8	80.0	3	100.0
Apical rooted cuttings (potato seedlings)	1	16.7	5	8.2	2	5.0	1	10.0	0	0.0
Mini-tubers	0	0.0	1	1.6	0	0.0	1	10.0	0	0.0

Generally, the high rate of the practice of CSA across all education categories could be because agriculture is the major source of income in the study area (Rampa & Knaepen, 2019), coupled with recurrent changes in the weather, all farmers regardless of their education levels are being forced to take measures to protect their primary income source. Mulching received an average score especially among farmers who did not go to school and those with post-secondary education; this can be associated with the high demand for mulches in the area where other factors like income

come into play. Farmers with low income may not afford to source mulches from far places or even may instead be tempted to sell theirs to meet overarching family needs.

Low levels of practice of improved crop varieties and agroforestry, and no practice of potato seedlings and mini-tubers by the smallholder potato farmers with university education could be because these have other alternative sources of livelihood. Thus, the use of yield-enhancing varieties and agroforestry for diversification as well as adapting to climate change is not a priority. This claim contradicts with Leake and Adam (2015) who found that farmers with more years of formal education have a higher likelihood of allotting a notable proportion of their farming land to improved crop varieties. Further, Dang *et al.* (2019) added that education enables farmers to locate relevant information and inspires the acceptance of modern technologies like improved crop varieties. But again, for some practices like irrigation, a high percentage of practice among farmers with university education may mean that these can afford to meet the high cost of equipment required to install an irrigation system or buy types of equipment like watering cans. This accrues to their being able of finding salaried employment. This agrees with Kabubo-Mariara and Mulwa (2019) who noticed that learned farmers had other sources of income.

4.3.4 Annual Farm Income and Practice of Climate-Smart Agriculture

From Table 13, smallholder potato farmers with an annual farm income of KES 10,000 – KES 25,000, and above KES 35,000 practiced all the CSA investigated in this study. With all the CSAPs being practiced by over 65% and 62.2% except for irrigation (40.0% and 35.0%), potato seedlings (13.3% and 10.0%), and mini-tubers (2.2% and 5.0%) respectively among farmers of this category.

The other farmers with high percentages of practice of CSA were KES 25,001 – KES 35,000 annual farm income category. Like the latter, except for the minitubers, these practiced all the CSAPs with an overall average of 66.7%. However, mulching and minimum tillage were averagely practiced followed by irrigation and potato seedlings that were practiced by only 16.7% and 5.6% respectively of the potato smallholder farmers within this income category. On the contrary, an average of 57.7% of the smallholder potato farmers with an annual farm income of less than KES 10,000 practiced the CSA. Unlike the other annual farm income category farmers, for this category, two CSAPs (irrigation and improved crop varieties) were practiced below average and two (potato seedlings and mini-tubers) were not practiced at all.

Table 13: Annual farm income and practice of climate-smart agriculture

Climate-smart agricultural practices	Smallholder potato farmers (N=120)							
	<KES 10,000 (n= 37)		KES 10,000 – KES 25,000 (n= 45)		KES 25,001 – KES 35,000 (n= 18)		>KES 35,000 (n= 20)	
	F	%	F	%	F	%	F	%
Rainwater harvesting and storage	27	73.0	37	82.2	16	88.9	20	100.0
Irrigation	10	27.0	18	40.0	3	16.7	7	35.0
Mulching	27	73.0	28	62.2	9	50.0	13	65.0
Minimal tillage	20	54.1	34	75.6	15	83.3	18	90.0
Improved crop varieties	18	48.6	29	64.4	10	55.6	14	70.0
Terracing	24	64.9	34	75.6	15	83.3	17	85.0
Drainage management	24	64.9	31	68.9	13	72.2	17	85.0
Intercropping	34	91.9	41	91.1	15	83.3	17	85.0
Agroforestry	29	78.4	41	91.1	15	83.3	17	85.0
Synthetic fertilizers	34	91.9	43	95.6	18	100.0	20	100.0
Composting	23	62.2	34	75.6	16	88.9	18	90.0
Furrow/ ridge planting	24	64.9	32	71.1	17	94.4	16	80.0
Crop rotation	26	70.3	38	84.4	17	94.4	19	95.0
Apical rooted cuttings (potato seedlings)	0	0.0	6	13.3	1	5.6	2	10.0
Mini-tubers	0	0.0	1	2.2	0	0.0	1	5.0

As observed, at least every category of smallholder potato farmers practiced some CSA to a considerable level besides the differences in the percentages. Reason(s) for this could be that most farmers are poor with a keen eye on agriculture, which they have to cushion against the effects of climate change using the returns obtained from their harvests. This claim is supported by Alam (2015) who found that for poor farmers whose survival depends on farming, the costs of lengthened droughts are enormous and therefore, adaptation is required to reduce these disasters. Additionally, the non-practice of potato seedlings and minitubers by farmers within the income category of less than KES 10,000 can be explained by the high cost of acquiring and establishing these CSAPs. This is in line with previous studies (Ajayi, 2002; Ajayi & Solomon, 2011) that found minimal levels of uptake of practices that needed more monetary input.

While the overall high percentage of practice of CSA among farmers with more annual farm income can be caused by their desire to increase the number of crops produced. This is because as farmers get more income from their farms, they always think of increasing production, and an increase in farmland results in more CSAPs a farmer has to go for. This argument is consistent with Awotide *et al.* (2016) who argued that the more land farmers devote for crop production, the more the need that arises for adaptation strategies like the use of synthetic fertilizers, improved crop varieties, herbicides for minimum tillage, etc. A low percentage in the practice of irrigation across all annual farm income categories could be due to limited access to water sources in the area.

4.3.4 Annual Off-farm Income and Practice of Climate-Smart Agriculture

Table 14 revealed that other than potato seedlings and minitubers, synthetic fertilizer was the highly practiced CSAP by the smallholder potato farmers with the annual off-farm income category of KES 10,000 - KES 25,000, KES 25,001 - KES 35,000, and above KES 35,000. It also shows that this was the least practiced CSAP by the smallholder potato farmers within an annual off-farm income category of less than KES 10,000.

Surprisingly, irrigation was highly practiced (39.3%) by farmers within the low annual off-farm income category (less than KES 10,000) followed by farmers within KES 25,001 - KES 35,000 (33.3%), KES 10,000 - KES 25,000 (29.3%), and lastly by high annual off-income category (26.7%). Averagely, this was the third last practiced CSAP following potato seedlings and minitubers for annual off-farm income categories of above KES 10,000, and the fourth last for annual off-farm income categories of less than KES 10,000. The rest of the CSAPs were practiced by over 61% of the farmers within the annual farm income categories of less than KES 10,000, KES 10,000 - KES 25,000 and above KES 35,000, and over 76.2% for the KES 25,001 - KES 35,000 category except the two (mulching and improved crop varieties).

Table 14: Annual off-farm income and practice of climate-smart agriculture

Climate-smart agricultural practices	Smallholder potato farmers (N=120)							
	<KES 10,000 (n=28)		KES 10,000 - KES 25,000 (n=41)		KES 25,001 - KES 35,000 (n=21)		>KES 35,000 (n=30)	
	F	%	F	%	F	%	F	%
Rainwater harvesting and storage	23	82.1	31	75.6	20	95.2	26	86.7
Irrigation	11	39.3	12	29.3	7	33.3	8	26.7
Mulching	20	71.4	29	70.7	12	57.1	16	53.3
Minimal tillage	18	64.3	30	73.2	16	76.2	23	76.7
Improved crop varieties	16	57.1	25	61.0	12	57.1	18	60.0
Terracing	18	64.3	30	73.2	18	85.7	24	80.0
Drainage management	19	67.9	27	65.9	18	85.7	21	70.0
Intercropping	28	100.0	35	85.4	18	85.7	26	86.7
Agroforestry	23	82.1	34	82.9	18	85.7	27	90.0
Synthetic fertilizers	2	7.1	40	97.6	21	100.0	29	96.7
Composting	20	71.4	28	68.3	19	90.5	24	80.0
Furrow/ ridge planting	20	71.4	28	68.3	18	85.7	23	76.7
Crop rotation	21	75.0	34	82.9	20	95.2	25	83.3
Apical rooted cuttings (potato seedlings)	0	0.0	3	7.3	1	4.8	5	16.7
Mini-tubers	0	0.0	1	2.4	0	0.0	1	3.3

Unlike the earlier stated and other CSAPs, mulching was averagely practiced by 57.1% and 53.3% of smallholder potato farmers within the off-farm income category of KES 25,001 - KES 35,000 and above KES 35,000 respectively. Additionally, improved crop varieties were practiced by 57.1% of the smallholder potato farmers within the off-farm income categories of less than KES 10,000 and KES 25,001 - KES 35,000. Though least practiced, 16.7% and 3.3% within the off-farm income category of above KES 35,000 practiced potato seedlings and minitubers followed by 7.3% and 2.4%, 4.8% and 0.0% by KES 10,000 - KES 25,000 and KES 25,001 - KES 35,000 categories respectively. None of the smallholder potato farmers within the annual off-farm income category of less than KES 10,000 practiced potato seedlings and minitubers.

As noted, a high percentage of practice of irrigation among farmers within the off-farm income category of less than KES 10,000 could be explained by the fact that such 'poor' farmers are always trying all possible means to uplift themselves from poverty. Therefore, these may find hardships in acquiring sophisticated irrigation equipment but maneuver with the locally available resources like digging water pans and diverting runoff to the water collection points in their farms. This contention is in line with Awotide *et al.* (2016) who found that income-constrained farmers in Nigeria were intensifying production to stabilize their finances, and it contradicts Alam (2015) who found the progressive practice of irrigation with an increase in income among farmers.

On the other hand, the low practice of synthetic fertilizers and non-practice of potato seedlings and minitubers by the farmers that fall within this category could be due to the high costs of these CSAPs. Unlike irrigation where they can harvest rainwater, these CSAPs cannot be accessed without money. This explains the high practice of intercropping and agroforestry among this category because these increase the fertility of the soil that they would meet by adding synthetic fertilizers. This attestation is consistent with previous studies that found the increased practice of intercropping among farmers who were constrained in accessing synthetic fertilizers (Wainaina *et al.,* 2016). The practice of almost all CSAPs by farmers within the annual farm income category above KES 10,000 could be because these can meet the associated costs especially for potato seedlings and minitubers. This declaration is empirically backed up by previous studies (Deressa *et al.,* 2009; Gebrehiwot & van der Veen, 2013; Knowler & Bradshaw, 2007; Solano *et al.,* 2000; Zakaria *et al.,* 2020) and an assertion by Mujeyi *et al.* (2020) where farmers with high off-farm income were inclined to embrace CSA and other climate change adaptation strategies than their counterparts.

Test of Hypothesis H_{O1}

Objective two was translated into the following hypothesis:

H01: There is no statistically significant relationship between socioeconomic factors and the practice of CSA among smallholder potato farmers in Gilgil Sub–County, Kenya

The hypothesis was tested using binary logistic regression, and an analysis of socioeconomic factors as independent variables against the practice of CSA was statistically significant (Table 16). This was conducted by including all cases from which data was collected in the statistical significance analysis, see Table 15.

Table 15: Socioeconomic factors' statistical significance analysis case processing summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	120	100.0
	Missing Cases	0	0.0
	Total	120	100.0
Total		120	100.0

a. If weight is in effect, see classification table for the total number of cases.

Table 16 discloses that the relationship between socioeconomic factors and practice of CSA was statistically significant at a 5% level of significance ($\chi2 = 17.966$, df = 5, $p < 0.05$).

Table 16: Omnibus tests of model coefficients for socioeconomic factors

		Chi-square	df	P-value
Step 1	Step	17.966	5	0.003
	Block	17.966	5	0.003
	Model	17.966	5	0.003

This implies that a relationship existed between socioeconomic factors and the practice of CSA. Therefore, the null hypothesis is rejected. This deduction is in line with past studies' findings where socioeconomic factors were responsible for the uptake of agricultural technologies including CSA like improved crop varieties (Awotide *et al.*, 2016; Debebe *et al.*, 2015; Simtowe *et al.*, 2016). Additionally, between 13.9% (Cox & Snell R Square) and 20.6% (Nagelkerke R Square) of the variance in the practice of CSA is explained by the socioeconomic factors (Table 17).

Table 17: Socioeconomic factors' model summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	116.995[a]	0.139	0.206

a. Estimation terminated at iteration number 5 because parameter estimates changed by less than .001.

Such a variance continues to show how relevant the socioeconomic factors are in the practice of CSA and how well they relate. In addition, the socioeconomic factors' Binary Logistic Regression Model (BLRM) yielded a percentage accuracy classification (PAC) of 76.7% (Table 18).

Table 18: Percentage accuracy classification table[a] for socioeconomic factors' BLRM

Observed			Predicted		
			Practice of CSA		Percentage Correct
			.00	1.00	
Step 1	Practice of CSA	.00	7	23	23.3
		1.00	5	85	94.4
	Overall Percentage				76.7

a. The cut value is .500

This means that the explanatory variables in the socioeconomic factors' model accurately predict the practice of CSA by the smallholder potato farmers by 76.7% (also, see Appendix G). Implying that 76.7% of the times we predict smallholder potato farmers to practice CSA is correct. On the other hand, a goodness of fit test results attested that the model used was fit for the socioeconomic factors. This is affirmed by the insignificant values ($\chi 2 = 4.471$, df = 8, $p > 0.05$) which support the model (Table 19). This, therefore, presents insufficient evidence to claim that the model does not fit the data adequately.

Table 19: Hosmer and lemeshow test for socioeconomic factors' BLRM

Step	*Chi*-square	df	P-value
1	4.471	8	.812

This implies that the socioeconomic factor's BLRM is responsible for the unseen traits across smallholder potato farmers' resolutions to practice CSA. Further, results of the socioeconomic

BLRM revealed that the relationship between the explanatory variables and practice of CSA among smallholder potato farmers vary considerably (Table 20).

Table 20: Socioeconomic variables in the binary logistic regression equation

Socioeconomic variables		B	S.E.	Wald	df	P-value	Exp(B)
Step 1[a]	Age bracket	-0.290	0.268	1.175	1	0.278	0.748
	Gender of the respondent	-1.257	0.486	6.701	1	0.010	0.284
	Education level	-0.226	0.318	0.507	1	0.476	0.797
	Annual farm income	0.924	0.319	8.402	1	0.004	2.520
	Annual off-farm income	-0.021	0.256	0.007	1	0.936	0.980
	Constant	1.076	1.114	0.933	1	0.334	2.932

a. Variable(s) entered on step 1: Age bracket, Gender of the respondent, Education level, Annual farm income, Annual off-farm income.

The findings in Table 20 show that within the 5 hypothesized explanatory socioeconomic variables contained in the model, only 2 were affirmed to have a significant relationship with the practice of CSA. Among these included gender and annual farm income, however, explanations for the relationship portrayed by all variables are as follows. At the outset, note that an odds ratio less than 1 indicates a negative relationship.

Age

The binary logistic regression analysis results showed that farmer's age insignificantly relates with the practice of CSA. Additionally, the age's odd ratio shows that an increase in the farmers' age diminished their likelihood of practicing CSA by 74.8% compared to the young farmers. This could be explained by their being less open to new opinions and less willing to take risks related to new practices (Alavalapati *et al.*, 1995; Rogers, 1995, 2003). According to past studies, unwillingness to take risks is ranked among the major bottlenecks that curtail the uptake of new agricultural technologies (Awotide *et al.*, 2016; Dercon & Christiaensen, 2007; Deressa *et al.*, 2009; Reilly *et al.*, 2003). This finding is consistent with Kaliba *et al.* (2000) who declared farmer'**s** age to either enhance or reduce the possibility of embracing new practices. They further argued that as a farmer advances in age, the degree of risk averseness raises or drops based on the level of their self-confidence. Also, Dang *et al.* (2019) asserted that the more aged a farmer is, the more unwilling to accept the change they are. That it becomes hard for aged farmers to embrace technological modifications in their farming systems.

Gender

The findings show that the variable of gender is statistically significant but negative at a 5% significance level (Wald $\chi 2 = 6.701$, df = 1, $p < 0.05$). As observed, female smallholder potato farmers were likely to practice CSA more than male farmers by 28.4%. This could be because women are responsible for most of the farming activities especially in Africa, which inclines them to adapt to climate change and avoid damage being caused to their household food security. This contention is in line with several studies that have alleged that female farmers are more inclined to embrace adaptation strategies like CSA given their much responsibilities in farming that indoctrinate them with greater knowledge and expertise on numerous farm management practices (Nhemachena & Hassan, 2007; Silvestri *et al.*, 201). Additionally, it could be possible that males are likely to deny the presence and consequences of climate change (García de Jalón *et al.*, 2015), and this makes them skeptical in embracing the CSA as an adaptive strategy. Contrarily, numerous studies (Asfaw & Admassie, 2004; Deressa *et al.*, 2009) have found that male farmers were more likely to take up adaptation strategies and other agricultural technologies than females. Reasons rotate around women being less exposed to climate change adaptation strategies, being culturally designated for domestic pursuits, and having restricted access to crucial resources like finances, labor force, and land which oftentimes undermines their capacity to venture into labor-demanding farm enterprises (Akudugu *et al.*, 2012).

Education

An insignificant relationship between education and practice of CSA existed. Results show that an increase in the farmers' education level reduced their possibilities of practicing CSA by 79.7% compared to farmers with less or no education. This could be justified by the reality that educated farmers have varied sources of livelihood and therefore worry less about the effects of climate change. This finding is consistent with that of Kabubo-Mariara (2008) who found a negative relationship between education and uptake of adaptation strategies among livestock farmers in Kenya. On the contrary, other studies have found that farmers with no or less education are less knowledgeable of the possible and existing options (Evangelista *et al.,* 2013; García de Jalón *et al.,* 2013; Islam *et al.,* 2013) and that they show a likelihood of ignoring adapting agriculture to the climate change effects. This finding also contradicts those of Ahmed (2015) and Roy *et al.* (2015) who found a positive and significant relationship between farmer's education level and execution of CSA, and other climate change adaptation strategies. These asserted that educated farmers readily understand information and consequently adopt refined technologies more comfortably than illiterate farmers.

Annual farm income

Annual farm income positively relates with the practice of CSA at 5% significance level (Wald $\chi 2 = 8.402$, df = 1, $p < 0.05$). Results reveal that for every unit increase in annual farm income, the chance of practicing the CSA increases by 2.52 times more than for the farmers with low annual farm income. This could be because increasing the size of land consecrated to CSA such as planting of improved crop varieties necessitates extra money to acquire the required inputs like herbicides, improved seeds, fertilizer and to meet labor costs (Alam, 2015; Coulibaly *et al.,* 2015). These findings resonate with other studies (Ayanlade *et al.*, 2017; Mpandeli & Maponya, 2013) that found increased investment in agrochemicals, growing of more than one crop and quality seeds of improved varieties. Plus assertions by Deressa *et al.* (2009) that increased farm income eminently increased the likelihood of adapting to climate change by practicing soil conservation measures, altering planting dates, and diversifying crop varieties. Nevertheless, these findings are disputed by Danso-Abbeam *et al.* (2017) who found the low practice of maize varieties as a CSAP among farmers with high farm income. This was attributed to the reality that farmers who garnered more income from the previous seasons' harvests could diversify their income into different agricultural or non-agricultural ventures.

Annual off-farm income

Results indicated an insignificant relationship between annual off-farm income and the practice of CSA. Results further show that every unit increase in annual off-farm income decreases the farmers' likelihood of practicing CSA by 98% compared to farmers with low annual off-farm income. This could be justified by the reality that indulging in off-farm vocations usually disinclines farmers from committing themselves to farm work. Because off-farm revenue tends to trigger many off-farm activities. Similar results were found by many other studies (Awotide *et al.*, 2016; Gebrehiwot & van der Veen, 2013; Mihiretu *et al.*, 2019; Nkuba *et al.*, 2020) and reasons for the insignificance rippled around non-farm ventures decreasing the possibility of practicing some adaptation strategies that needed time and commitment yet with long-term returns. However, inconsistency was observed between this study's findings and those of other researchers (Amaza *et al.*, 2006; Diiro, 2013; Mmbando & Baiyegunhi, 2016) who found that income from non-farm pursuits coaxes acceptance of CSAPs like improved crop varieties by enabling farmers to raise capital and meet costs related to new agricultural practices.

4.4 Relationship between Institutional Factors and Practice of Climate-Smart Agriculture

The third objective of the study was stated as:

> *To determine the relationship between institutional factors and the practice of climate-smart agriculture among smallholder potato farmers in Gilgil Sub County, Kenya*

Table 21 shows the selected institutional factors whose relationship with the practice of CSA was investigated among smallholder potato farmers in Gilgil Sub County, Kenya.

Table 21: Descriptive statistics for institutional factors among smallholder potato farmers

Institutional factors	F	%
Access to credit		
No	68	56.7
Yes	52	43.3
Sources of credit		
SACCOs	36	69.2
Private money lenders	3	5.8
Relatives and friends	7	13.5
Banks	6	11.5
Amount of credit accessed annually		
< KES 10,000	16	30.8
KES 10,001- KES 25,000	23	44.2
KES 25,001- KES 35,000	5	9.6
> KES 35,000	8	15.4
Trained on CSA		
No	82	68.3

Table 21 (continued)

Yes	38	31.7
Time when first training on CSA was attended		
Last season	22	57.9
One year ago	13	34.2
Two years ago	3	7.9
Three years ago and above		
Number of trainings on CSA attended		
One	13	34.2
Two	13	34.2
Three	6	15.8
Four and above	6	15.8

Table 21 (continued)

Source of training on CSA		
Ministry of Agriculture	23	60.5
Private companies	6	15.8
NGOs	9	23.7
Universities		
Access to NGO support on CSA		
No	108	90
Yes	12	10
Kind of support received from NGOs on CSA		
Extension services	7	58.3
Credit	4	33.3
Inputs	1	8.3
Farmers' group membership		
No	67	55.8
Yes	53	44.2
Receive support from farmers' group on CSA		
No	9	17
Yes	44	83
Kind of support received from farmers' group on CSA		
Eases access to extension services	38	86.4
Eases access to credit	2	4.5
Eases access to inputs	4	9.1

Around 56.7% of the interviewed smallholder potato farmers had no access to credit. Of the 43.3% who had access to credit, 69.2% accessed it from Savings and Credit Co-operatives (SACCOs), 5.8% (the least) from private moneylenders, 13.5% from relatives, and friends, and 11.5% from banks. Majority (44.2%) accessed KES 10,001- KES 25,000, followed by 30.8% (less than KES 10,000), 15.4% (above KES 35,000) and the least (9.6%) who accessed KES 25,001- KES 35,000. A relatively low number of farmers with access to credit, moreover the biggest percentage with a low amount and locally sourced may mean that farmers in the study area find difficulties in

accessing and practicing CSA. Because most CSAPs require a financial muscle to execute them as recommended. This assertion is consistent with previous findings (Deressa *et al.,* 2009; Gebrehiwot & van der Veen, 2013; Meijer *et al.,* 2015; Mihiretu *et al.,* 2019) where access to credit was appreciated to aid in adapting agriculture to the effects of climate change by facilitating access to CSAPs and other adaptation strategies. Further affirmation of this is that farmers with no access to credit might be prevented from implementing appropriate adaptive strategies because even access to the required information is dictated by available resources, especially in monetary terms (Arimi, 2014).

The majority (68.3%) of the farmers who participated in this study reported having no training on CSA, and only 31.7% had been trained. Over 57.9% of those that received training had been trained within the previous season, 34.2% within one year ago, 7.9% had received training two years ago, and non-had been exposed to training within the last three years. Additionally, out of those that had been trained on CSA, the majority had been trained once (34.2%) and twice (34.2%) and the rest thrice (15.8%), and four and above (15.8%) times. Of these, 60.5% received training from the ministry of agriculture, 15.8% from private companies, 23.7% from NGOs, and non-from universities besides their involvement in diffusing CSA in the study area.

The low percentage of trained farmers may result in a low rate of uptake of CSA among the farmers. Because training helps to expose farmers to institutions that support agricultural development and sources of inputs and credit that farmers require to effectively execute CSA (Nkuba *et al.,* 2020). For example, during training, agricultural input dealers are always invited to enable the farmers to effect what they have learned from the training by locating quality inputs. Additionally, during the training farmers access information on the weather forecast and this drives them to seek adaptation strategies like CSA (Arimi, 2014).

Having few farmers trained more than three times and above may also mean that farmers are left ill-equipped with the knowledge required to put CSA into practice, because farmers being adult learners may need to be trained over and over again to grasp the concept and get convinced. This contention agrees with Danso-Abbeam *et al.* (2017) who indicated that the amount of training was key to farmers' decision to adopt improved maize varieties. On the other hand, a large number of farmers getting training from the ministry of agriculture followed by the NGOs may mean that new practices can easily be communicated to the farmers. Since the ministry may have a hand in generating the innovations that are done by sister institutions like the research institutions (Rogers, 2003; Rogers & Ban, 1963).

Similarly, most of the farmers (90%) never received any NGO support, and out of the 10% who received NGO support, the biggest percentage (58.3%) were supported with extension services, 33.3% with credit, and 8.3% with farm inputs. Likewise, over 55.8% of the potato farmers who participated in this study did not belong to any farmer's group. Of the 44.2% who were members of different farmers' groups, majority (83%) received support on the practice of one or more of the CSAPs from their farmers' groups. Nevertheless, 86.4% were supported through easing their access to extension services, 4.5% through easing their access to credit and 9.1% found it easy to access farm inputs through their respective farmers' groups.

The biggest percentage of farmers not receiving NGO support may mean that farmers are not exposed to enough external support that may bolster the execution of CSA. This is because NGOs tend to expose farmers to new adaptive strategies, support them with the required information, and in some cases facilitate farmer to farmer learning (Meijer *et al.,* 2015). Therefore, having a high percentage of farmers receiving extension services as NGO support among those that are supported could mean the high practice of CSA among such a category (Zhang *et al.*, 2012). On the contrary, low NGO support may create room for the farmers to look for alternatives by themselves and hence result in the increased practice of CSA. This is based on the fact that NGOs tend to create an overdependence attitude among farmers and this may make them reluctant in taking action against climate change effects (Elbehri & Lee, 2011).

In addition, the majority of the farmers not belonging to farmer groups may imply the low practice of CSA, especially those that require collective action for their execution. For example, establishing agroforestry may burden and shun away individual farmers mainly in the sourcing of the seedlings, but this can easily be done when farmers pool resources and do collective sourcing of the required planting materials. This contention is supported by previous studies (Arimi, 2014; Hunecke *et al.,* 2017; Tazeze *et al.*, 2012) which found that farmers with farmer group membership

(FGM) easily accessed information on various CSAPs and other adaptive measures, collectively worked together in adopting CSA. A typical example is a case for the lower Nyando soil and water conservation initiative where a successful farmer was found to be a group member (Gbegbelegbe *et al.*, 2018). However, having a few farmers belonging to farmer groups may be to the advantage of CSA scaling efforts, because as noted by Arslan *et al.* (2014), ties of trust and collaboration among group members can result in withdrawal behavior, which makes farmers less inclined to embrace and try new agricultural discoveries.

4.4.1 Access to Credit and Practice of Climate-Smart Agriculture

Table 22 shows that almost all CSAPs were highly practiced by over 69.2% of the farmers with access to credit. However, mulching scored low by being practiced by 59.6% followed by irrigation (28.8%), and the two (potato seedlings and minitubers) that were least practiced by only 15.4% and 3.80% farmers respectively.

On the other hand, smallholder potato farmers with no access to credit also practiced most of the CSAPs though not at the same rate as their counterparts. Over 61.0% of the farmers in this category practiced CSA with improved crop varieties being practiced by 52.9%, followed by irrigation (33.8%), potato seedlings (1.5%), and minitubers (0.0%). For some CSAPs, access to credit may affect them less or not at all, for example, the practice of irrigation being high among farmers with no access to credit. These farmers may use free options of providing water to their crops like irrigating by flooding method, which only requires labor and determination. Similar scenarios were encountered by other investigators (Pattanayak *et al.,* 2003; Silvestri *et al.,* 2012) where credit didn't seem to influence the uptake of some CSAPs.

Table 22: Access to credit and practice of climate-smart agriculture

Climate-smart agricultural practices	Smallholder potato farmers (N=120)			
	No Access (n=68)		With Access (n=52)	
	F	%	F	%
Rainwater harvesting and storage	54	79.4	46	88.5
Irrigation	23	33.8	15	28.8
Mulching	46	67.6	31	59.6
Minimal tillage	45	66.2	42	80.8
Improved crop varieties	36	52.9	35	67.3
Terracing	48	70.6	42	80.8
Drainage management	46	67.6	39	75.0
Intercropping	58	85.3	49	94.2
Agroforestry	55	80.9	47	90.4
Synthetic fertilizers	64	94.1	50	96.2
Composting	46	67.6	45	86.5
Furrow/ ridge planting	48	70.6	41	78.8
Crop rotation	52	76.5	48	92.3
Apical rooted cuttings (potato seedlings)	1	1.5	8	15.4
Mini-tubers	0	0.0	2	3.8

Contrarily, the low percentage of practice of CSA among farmers with no access to credit compared to those with access to credit can prove the contention by Teklewold *et al.* (2013) that limited access to credit stifled farmers' ability to initially take up and intensify the use of some CSA. This also explains why farmers with access to credit show a high percentage in the practice of CSA. Conversely, the low practice of mulching by farmers with access to credit could be due to differences in access to credit. Because in some areas men have more access to credit yet some practices are commonly practiced by women and this makes them unable to access resources necessary to adequately put such CSAPs into practice (Gumucio *et al.*, 2020).

4.4.2 Training on and practice of Climate-Smart Agriculture

Surprisingly, an average of 69.0% of the farmers who had been trained practiced CSA (Table 23). This is nearly similar to the response shown by the farmers with access to credit. Furthermore, an average of 62% of the farmers who were not trained also practiced CSA.

Table 23: Training on and practice of climate-smart agriculture

Climate-smart agricultural practices	Smallholder potato farmers (N=120)			
	Not Trained (n=82)		Trained (n=38)	
	F	%	F	%
Rainwater harvesting and storage	68	82.9	32	84.2
Irrigation	17	20.7	21	55.3
Mulching	47	57.3	30	78.9
Minimal tillage	57	69.5	30	78.9
Improved crop varieties	42	51.2	29	76.3
Terracing	60	73.2	30	78.9
Drainage management	55	67.1	30	78.9
Intercropping	74	90.2	33	86.8
Agroforestry	72	87.8	30	78.9
Synthetic fertilizers	79	96.3	35	92.1
Composting	61	74.4	30	78.9
Furrow/ ridge planting	63	76.8	26	68.4
Crop rotation	65	79.3	35	92.1
Apical rooted cuttings (potato seedlings)	7	8.5	2	5.3
Mini-tubers	1	1.2	1	2.6

Besides, the percentage of farmers with no training practicing CSA, in general, is not far from that exhibited by their counterparts. Because some CSAPs were highly practiced by this category. For example, intercropping (90.2%), agroforestry (87.8%), synthetic fertilizers (96.3%), furrow/ ridge planting (76.8%), and potato seedlings (8.5%) of which these were practiced by 86.8%, 78.9%, 92.1%, 68.4%, and 5.3% respectively of the farmers who had been trained on CSA. However, a noticeable difference was observed in the practice of the rest of the CSAPs where trained farmers scored high, especially in the practice of irrigation, mulching, improved crop varieties, and a minimal difference in the practice of minitubers.

Though small, a discrepancy existed in the practice of CSA between the two categories of farmers. The reason could be that trained farmers have an opportunity to see how some practices are practiced or even to witness the results of a given practice. This argument is in line with previous findings (Moges & Taye, 2017; Nkuba *et al.*, 2020) where trained farmers adapted by practicing more improved crop varieties and other adaptive strategies. Danso-Abbeam *et al.* (2017) added that farmers who participated in farm demonstrations had increased chances of allocating more land for improved maize varieties. However, a relatively higher percentage of practice of CSA by untrained farmers could mean that the training is not a panacea but other factors like social relationships in the communities come into play (Arslan *et al.*, 2014).

4.4.3 Non-government Organization Support and practice of Climate-Smart Agriculture

Averagely, a very small difference existed between the practice of CSA by the smallholder potato farmers who receive NGO support (66%) and those that did not receive [64%] (Table 24). Some CSAPs were practiced at the same rate by both farmers receiving NGO support and those that do not. Among these included terracing and compositing, all practiced by 75% of both categories with a slight difference in the practice of compositing (practiced by 75.9% of the farmers that do not receive NGO support).

Amazingly, some CSAPs were practiced by a higher percentage of farmers with no NGO support compared to their counterparts. Among these included improved crop varieties (59.3%), intercropping (89.8%), agroforestry (87.0%), synthetic fertilizers (96.3%) and furrow/ ridge planting (75.9%) compared to 58.3%, 83.3%, 66.7%, 83.3%, and 58.3% respectively practiced by the farmers receiving NGO support.

Results also show that other than the latter, a high percentage of practice of the rest of the CSAPs was recorded among farmers receiving NGO support. A prominent difference existed in the practice of irrigation where only 28.7% of the farmers with no NGO support practiced it compared to 58.3% of the farmers with NGO support. However, with a difference in practice between the two categories, potato seedlings and minitubers were practiced below average by both categories of farmers, with the lowest percentages among farmers with no NGO support.

Table 24: Non-government organization support and practice of Climate-Smart Agriculture

Climate-smart agricultural practices	Smallholder potato farmers (N=120)			
	Not Supported (n=108)		Supported (n=12)	
	F	%	F	%
Rainwater harvesting and storage	89	82.4	11	91.7
Irrigation	31	28.7	7	58.3
Mulching	68	63.0	9	75.0
Minimal tillage	78	72.2	9	75.0
Improved crop varieties	64	59.3	7	58.3
Terracing	81	75.0	9	75.0
Drainage management	76	70.4	9	75.0
Intercropping	97	89.8	10	83.3
Agroforestry	94	87.0	8	66.7
Synthetic fertilizers	104	96.3	10	83.3
Composting	82	75.9	9	75.0
Furrow/ ridge planting	82	75.9	7	58.3
Crop rotation	89	82.4	11	91.7
Apical rooted cuttings (potato seedlings)	7	6.5	2	16.7
Mini-tubers	1	0.9	1	8.3

A possible explanation for the higher percentage of practice of some CSAPs by non-NGO-supported farmers could be that NGOs may introduce non-agricultural projects, especially for women. For, example in Uganda World Vision supports women with sewing machines which tend to occupy them compromising the available time devoted to agriculture (Pouw & Elbers, 2012). This translates into low execution of some CSAPs besides receiving support from NGOs. This is because some CSAPs are majorly practiced by women for example intercropping (Arslan *et al.*, 2014). However, a slightly high percentage of the practice of some CSAPs among NGO supported farmers could be explained by the actuality that these farmers are exposed to various pieces of training, conferences and sometimes directly supplied with farm inputs that aid them in executing some CSAPs (Danso-Abbeam *et al.*, 2017; Gbegbelegbe *et al.*, 2018; Meijer *et al.*, 2015).

4.4.4 Farmer group membership (FGM) and practice of Climate-Smart Agriculture

Results in Table 25 unveil that a big percentage (92.5%) of the farmers with no FGM practiced rainwater harvesting and storage compared to the 71.7% that practiced the same and have FGM. Though practiced by a lower percentage for both categories, a slightly lower percentage (29.9%) of farmers with no FGM practiced irrigation compared to those (34.0%) with FGM. Except for potato seedlings, minitubers, and the latter, over 71.7% of the farmers with FGM practiced the rest of the CSAPs. However, this is not the case with farmers with no FGM where some CSAPs like improved crop varieties were practiced below average (46.3%), in addition to the minitubers (1.5%) and potato seedlings (4.5%) which were also practiced below average by the farmers with FGM though a bit higher than the latter at 1.9% and 11.3% respectively. Additionally, other than the latter and the former, plus mulching which was practiced by 58.2% of the farmers with no FGM, the rest of the CSAPs were practiced by over 67.2% of the farmers within this category.

A possible explanation for the high percentage of practice of some practices among smallholder potato farmers with no FGM could be due to the free-riding tendency that diminishes active participation among some members of the groups. According to Arslan *et al.* (2014), this problem poses a burden on some active members of the groups and stifles initiatives like a high percentage in the aggregate practice of some CSAPs that would be realized in its absentia. Yet some practices like rainwater harvesting are labor-intensive and for income-constrained smallholder farmers, collective efforts would be the best solution. But instead, farmers with no FGM realize their incapability and this raises their motives to extremely work hard to equalize with their counterparts, hence ending up doing even better than compromised group members (Hackman & Katz, 2010).

Table 25: Farmer group membership and practice of climate-smart agriculture

Climate-smart agricultural practices	Smallholder potato farmers (120)			
	No FGM (n=67)		Has FGM (n=53)	
	F	%	F	%
Rainwater harvesting and storage	62	92.5	38	71.7
Irrigation	20	29.9	18	34.0
Mulching	39	58.2	38	71.7
Minimal tillage	46	68.7	41	77.4
Improved crop varieties	31	46.3	40	75.5
Terracing	50	74.6	40	75.5
Drainage management	45	67.2	40	75.5
Intercropping	58	86.6	49	92.5
Agroforestry	53	79.1	49	92.5
Synthetic fertilizers	62	92.5	52	98.1
Composting	45	67.2	46	86.8
Furrow/ ridge planting	47	70.1	42	79.2
Crop rotation	54	80.6	46	86.8
Apical rooted cuttings (potato seedlings)	3	4.50	6	11.3
Mini-tubers	1	1.50	1	1.9

On the other hand, a low percentage of farmers with no FGM practicing some CSAPs especially irrigation, mulching, improved crop varieties, potato seedlings, and mini-tubers could be because of limited access to information, lack of motivation and social support required in executing these CSAPs. This is premised on the fact that farmers with FGM are supported by each other and easily access information on new technologies and adaptive measures. This assertion is in line with previous studies (Bekele & Drake, 2003; Nkegbe *et al.*, 2011; Tambo & Abdoulaye, 2012) that found members of farmer groups to have considerable access to credit, new knowledge, inputs, and more labor as a result of collective action. This might be followed by changes in on-farm-management practices due to collective learning and information spillover and thus increasing the possibility of practicing CSA, for example, group participation might allow farmers to consolidate labor (Teklewold *et al.,* 2013). This can facilitate the creation of terraces on a farmer's garden before proceeding to the subsequent farmer (Shikuku *et al.*, 2017), while credit pooled from the group members may increase the possibility of practicing CSA whose access directly require money, for example, synthetic fertilizers (Ajayi *et al.*, 2003). This also, explains the overall average of the practice of CSA among farmers with FGM being slightly high compared to that seen among their counterparts.

Test of Hypothesis H_{O2}

Objective three was translated into the following hypothesis:

> *H_{02}: There is no statistically significant relationship between institutional factors and the practice of CSA among smallholder potato farmers in Gilgil Sub–County, Kenya*

Binary logistic regression was used in testing the hypothesis, and the analysis of institutional factors as independent variables relating to the practice of CSA was statistically significant.

All the cases from which data were obtained were selected and incorporated in the statistical significance analysis (Table 26).

Table 26: Institutional factors' statistical significance analysis case processing summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	120	100.0
	Missing Cases	0	0.0
	Total	120	100.0
Total		120	100.0

a. If weight is in effect, see classification table for the total number of cases.

From Table 27, it is observed that the relationship between institutional factors and practice of CSA was statistically significant at a 5% level of significance ($\chi2 = 10.219$, df = 4, $p < 0.05$).

Table 27: Omnibus tests of model coefficients for institutional factors

		Chi-square	df	P-value
Step 1	Step	10.219	4	0.037
	Block	10.219	4	0.037
	Model	10.219	4	0.037

This signifies that a relationship existed between institutional factors and the practice of CSA. Hence, the null hypothesis is rejected. This inference is consistent with findings from previous studies (Aryal *et al.*, 2018; Diallo *et al.*, 2019; Tran *et al.*, 2020) where institutional factors were accountable for the practice of CSA. Besides, between 12.1% (Cox & Snell R Square) and 8.2% (Nagelkerke R Square) of the variance in the practice of CSA is explained by the institutional factors (Table 28).

Table 28: Institutional factors' model summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	124.741[a]	0.082	0.121

a. Estimation terminated at iteration number 5 because parameter estimates changed by less than .001.

Like the latter, such a variance shows the relevance of institutional factors to the practice of CSA and how they relate. In addition, a percentage accuracy classification (PAC) of 75.0% was yielded by the institutional factors' BLRM (Table 29).

Table 29: Percentage accuracy classification table[a] for institutional factors' model

Observed			Predicted		
			Practice of CSA		Percentage Correct
			.00	1.00	
Step 1	Practice of CSA	.00	0	30	0.0
		1.00	0	90	100.0
	Overall Percentage				75.0

a. The cut value is .500

This implies that the explanatory variables in the institutional factors' model accurately predict the practice of CSA by the smallholder potato farmers by 75.0% (also, see Appendix H). Inferring that 75.0% of the times we predict smallholder potato farmers to practice CSA is correct. That said, a goodness of fit test results declared that the model used was fit for the institutional factors. This is confirmed by the insignificant values ($\chi2 = 10.458$, df = 6, $p > 0.05$) which support the model (Table 30). This, therefore, presents insufficient evidence to challenge the model that it does not adequately fit the data.

Table 30: Hosmer and lemeshow test for institutional factors' BLRM

Step	*Chi*-square	df	P-value
1	10.458	6	.107

This indicates that the institutional factor's BLRM is liable for the invisible traits across smallholder potato farmers' decisions to practice CSA. The results of the model further showed that the relationship between the explanatory variables and practice of CSA amongst smallholder potato farmers differs considerably (Table 31).

Table 31: Institutional variables in the binary logistic regression equation

Institutional variables		B	S.E.	Wald	df	P-value	Exp(B)
Step 1[a]	Access to credit	1.072	0.504	4.524	1	0.033	2.922
	Trained on CSA	0.777	0.611	1.619	1	0.203	2.176
	Receive NGO support on CSA	-0.768	0.827	0.863	1	0.353	0.464
	Farmers' group membership	0.406	0.496	0.670	1	0.413	1.501
	Constant	0.423	0.301	1.970	1	0.160	1.526

a. Variable(s) entered on step 1: Access to credit, Trained on CSA, Receive NGO support on CSA, Farmers' group membership.

Table 31 shows that within the four hypothesized explanatory institutional variables included in the model, only one was found to have a significant relationship with the practice of CSA. This was access to credit; however, descriptions for the relationship exhibited by all variables are stated following this. To start with, it is worth noting that an odds ratio of less than one symbolizes a negative relationship.

Access to credit

There is a positive relationship between access to credit and the practice of CSA. This is statistically significant at a 5% level of significance (Wald $\chi 2 = 4.524$, df = 1, $p < 0.05$). Results tell that farmers with access to credit had 2.922 more chances of practicing CSA than those with no access to credit. This could be because access to credit empowers the farmers to meet labor costs, transport costs, and the rest of the costs related to production. Additionally, farmers with access to credit can practice more than one CSAPs because it enables them to utilize existing information and change methods of their farm management in response to the effects of climate change (Kandlikar & Risbey, 2000). This finding is consistent with several past studies (Ali & Erenstein, 2017; Awotide *et al.,* 2016; Danso-Abbeam *et al.,* 2017; Mulwa *et al.,* 2017; Piya *et al.,* 2013) that found a positive and significant relationship between access to credit, and practice of CSA and other adaptation strategies. Reasons raised by these are related to the contention stated here, they cited that access to credit is required to fund the uptake of agricultural innovations and is regularly quoted as a factor influencing varied adoption rates. Contrastingly, some studies (Aryal, Jat, *et al.*, 2018; Pattanayak *et al.,* 2003; Silvestri *et al.*, 2012) found a statistically insignificant relationship between access to credit and practice of CSA.

Training

The findings show that an insignificant relationship exists between the variable of training and practice of CSA. It is also observed that attending a training reduced the farmers' chances of practicing CSA by 2.176 times. This could be because the principal role of the development facilitators that offer training on CSA is essentially restricted to the training of farmers on the best adaptive strategies and encouraging the practice of CSA. They may not portray anything like connecting farmers to the sources of CSAPs, credit required to purchase some CSAPs, or finding for them markets for their produce that accrue from the use of CSA. This claim is supported by Davis (2009) who affirmed that bodies responsible for offering training to the farmers do it without emphasis on context-specific alternatives which are of low input cost yet provide cushion to the farmers. Bryan *et al.* (2009) added that lack of confidence in the trainers may also dissuade farmers from practicing CSA even after attending the training. On the contrary, Zakaria *et al.* (2020) found a positive and significant relationship between attending training and practice of CSA, where trained farmers were 49.8% more inclined to practice CSA compared to the untrained fellows.

NGO support

NGO support negatively relates to the practice of CSA. Results show that receiving NGO support decreased farmers' likelihood of practicing CSA by 46.4% compared to the non-NGO-supported farmers. This could be because NGO-supported farmers have scarce production resources and incapable of accessing and executing some CSAPs. This is because NGOs provide a wide range of aid to the farmers, and in most cases, the farmers who are supported are identified and selected for the aid based on having limited resources and being unable to support themselves (García de Jalón *et al.*, 2015). Similarly, Jones and Boyd (2011) found that NGOs being external institutions may have limited access to power for influencing communities' decisions especially regarding fundamental resources required by the farmers to practice CSA. However, these findings are inconsistent with Bryan *et al.* (2013) and Schmitt (2012) who found that agrarian and poor farmers adapted to climate change effects following the support received from several institutions including NGOs, and claimed that these were very influential players. Also, Baudoin (2014) and Comoé and Siegrist (2015) applauded NGOs for effectively enhancing farmers' adaptive decisions.

Farmers' group membership

The findings show that there is no statistically significant relationship between the variable of farmers' group membership and practice of CSA. It is also observed that farmers who belonged to the farmers' group were predicted to have reduced chances of practicing CSA by 1.501 times than farmers who did not belong to any farmers' group. This could be justified by the reality that social groups may yield to groups that treasure "something for nothing". This finding is in tandem with those of Bandiera and Rasul (2006) who found a negative relationship between FGM and practice of CSA. The reason given was that as a large group of farmers engages in the trial of new practices, some blend in and free ride on the efforts of their colleagues and end up picking no skills required to execute the CSAPs on their farms. As opposed to this, many studies have found a positive and significant relationship between FGM and the practice of CSA (Awotide *et al.,* 2016; Bamire *et al.,* 2002; Danso-Abbeam *et al.,* 2017; Mango *et al.,* 2017; Nkegbe *et al.,* 2011; Ojiako *et al.,* 2007). These claim that group membership intensifies informative networking that builds trust among group members and facilitates experience sharing about CSA, which creates courage among the persuaded farmers to fully practice CSA.

CHAPTER FIVE
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a summary, conclusions, and recommendations of the study, and suggestions for future research.

5.2 Summary of the Study

Climate-Smart Agriculture presents the potential to meet the world's increasing food demands in the face of climate variability and it promises to sustainably increase food production, potato yield inclusive. The association between information dissemination pathways and practice of Climate-Smart Agriculture and the relationship between the selected socioeconomic and institutional factors on the practice of CSA in Gilgil Sub-County had not been studied. The purpose of this study was therefore to investigate the association between information dissemination pathways and to establish the relationship between selected factors and the practice of CSA in Gilgil Sub-County. A cross-sectional survey design was adopted and results revealed that an association existed between information dissemination pathways and practice of CSA. The selected socioeconomic and institutional factors were found to be related to the practice of CSA.

i) Information Dissemination Pathways

It was found that around 44.1% of the 93 potato farmers who were aware of CSA get information on CSA from the extension officers, while 28.7% and 27.2% get information from neighbors and friends, and media respectively. Similarly, 45.3% of the farmers who practiced CSA sourced information from extension officers, 27.9% and 26.8 from media, and neighbors and friends respectively. On average, most farmers moderately (47.2%) practiced the CSA, 38.5% indicated they were practicing but at a lower extent and only 14.3% were highly practicing the CSA.

ii) Socioeconomic Factors

An analysis of the five hypothesized explanatory socioeconomic variables contained in the socioeconomic factors' BLR model disclosed that a relationship between socioeconomic factors and practice of CSA was statistically significant. It further revealed that only two variables had a significant relationship with the practice of CSA. Among these, included gender, which was negative and statistically significant, and annual farm income, which was positive and statistically significant.

iii) Institutional Factors

Among the four hypothesized explanatory institutional variables included in the institutional factors' BLR model, only one was found to have a significant relationship with the practice of CSA. This was access to credit, which was positive and statistically significant. Therefore, warranting access to credit is deemed to produce favorable requisites for the practice of farming methods befitted to adapting agriculture to the effects of climate change.

5.3 Conclusions

The main conclusions for this study are as follows:

i) There was a strong association between information sources and practice of CSA. Overall, extension officers emerged with the highest percentage as an information source and this may partly explain high percentages of CSA practice among farmers with high awareness. Because, extension officers create satisfactory awareness of climate-smart farming practices.

ii) There was a significant relationship between the socioeconomic factors and the practice of CSA. The binary logistic regression analysis confirmed that female smallholder potato farmers were likely to practice CSA more than male farmers by 28.4%. This could be because women are responsible for most farming activities, which inclines them to adapt to climate change and avoid damage being caused to their household food security. Additionally, a unit increase in annual farm income increased the chance of practicing the CSA by 2.52 times more than for the farmers with low annual farm income. This could be because increasing the size of land consecrated to CSA necessitates extra money to acquire the required inputs like herbicides, improved seeds, fertilizer, and to meet labor costs.

iii) The come of the binary logistic regression analysis of the institutional factors and the practice of CSA was statistically significant. Among the four hypothesized explanatory institutional variables, only access to credit was found to have a significant relationship with the practice of CSA. This could be because access to credit empowers the farmers to meet labor costs, transport costs, and the rest of the costs related to production.

Additionally, farmers with access to credit can practice more than one CSAPs because it enables them to utilize existing information and change methods of their farm management in response to the effects of climate change.

5.4 Recommendations

Based on the results attained from this study, the following recommendations are made.

i) The government and other CSA scaling agencies should mainstream CSA information by considering the different information sources with the potential to result in bumper uptake of specific CSAPs. This would go a long way in ameliorating climate change impacts among farmers.

ii) The CSA scaling agencies should support farmers to increase farm earnings to produce favorable requisites for the acceptance and practice of farming methods befitted to adapting agriculture to the effects of climate change. In addition, such agencies are greatly recommended to facilitate increased farm output and income among the farmers, and securing access to vital resources for women farmers is indispensable to enhance their capacity and compliance to adjust production methods in response to climate change.

iii) The government and CSA scaling agencies should facilitate farmers' access to credit since this is believed to produce promising conditions for the practice of CSA and other adaptation strategies geared towards helping farmers adapt to the effects. This is an estimable recommendation for policymakers too.

5.5 Suggestions for Further Research

Principally, this study's analysis was restricted to cross-sectional data. This constrains observation of long-term transitions and changes in farmers' decisions to practice CSA. Therefore, an investigation that allows long-term observation of transitions and changes in farmers' decisions to practice CSA should be conducted. Additionally, assessment of the farmer's perceptions on the potentials of CSA would also go a long way in informing the CSA scaling efforts' decision on which CSAPs to improve to best address the farmers' needs.

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APPENDICES

Appendix A: Meaning and Potential of Study CSA Practices

The meaning and potential of some of the CSAPs that have been scaled out in Kenya and Nakuru county

CSAPs	Meaning	Potential
Drainage management	This encompasses the removal of excess water caused by flooding from the garden through the use of water control structures like channels	Reduces risks of crop failure due to flooding that may wash away the crops, that may lead to waterlogged conditions which result in rotting of potato tubers
Agroforestry	Is the intentional planting or guarding against the removal of more than one tree within 12 months on agricultural land or from its borders and on land set aside for purposes of tree planting. It manifests through practices such as planting of fruit trees, windbreaks, live fences, planting on boarders, and execution of strip cropping	Results into sustainable land use management through soil fertility maintenance, creation of favorable microclimates like shade, and reduces moisture-related stress. It also leads to carbon sequestration, soil erosion prevention, and tree products that offer environmental services
Synthetic fertilizers	These are substances of manufactured origin that, when applied to the soil, release one or more critical nutrients needed by plants for growth and increased yields	Compensates for the declining soil fertility and mostly nitrogen deficiency, speeds up crop growth and development to counteract the effects of the short growing seasons. This results in increased productivity and reduced chances of crop failure

Composting	Refers to the collection and heaping of waste materials of either plant or animal origin such as food remains, crop residues, and or animal manure piled in a pit or any other structure to hasten decomposition and application to cropland soil afterward	Also compensates for the declining soil fertility, avoids emissions from the use of raw animal manure, improves soil carbon sequestration and increases productivity with low inputs
Ridge planting	Is the construction of continuous lines of mounded soil on which crops/ potato tubers are planted—ridges constructed along the contours of farmland help to prevent run-off of rainwater, thus controlling soil erosion	Increases on water retention to compensate for the dry spell and low rainfall, increases nutrient absorption and leads to increased productivity on compacted and sloping marginal areas
Crop rotation	Is the systematic and planned change of crop plots per season or per year to avoid the depletion of soil nutrients that may occur when the same type of crop is planted in the same area seasonally or yearly. It entails the farmer choosing to alternate crops that can replenish and or help to fix the nutrients used up by the other; this includes scenarios like planting groundnuts after maize	Compensates for the reduction in soil fertility, increases resistance to pests and diseases, soil structure improvement, contributes to carbon sequestration, prevents erosion and sustains productivity through soil exhaustion avoidance
Improved crop varieties	Is the use of genetically and phenotypically improved crop planting materials that have been bred for their traits such as increased yield, tolerance to stress (cold and heat), and disease resistance.	Ensures stress (drought, flood, and heat and cold stresses) tolerance and disease resistance; early maturing that avoids crop loss from shorter growing seasons and unreliable rains. It also results in higher

		productivity and reduces risks of crop failure
Intercropping	Refers to the planting of two different but complementary crops on the same piece of land at the same time in a mixed pattern, in rows, or done through strip intercropping	Improves nitrogen fixation and improved soil quality and reduces risks of total crop failure
Irrigation	Supplying water to crops by making use of labor-saving or increased-efficiency technology, either on a large scale such as a canal/pump system or as a smaller micro-irrigation scheme	Enables dry season production that compensates for the reduced rainfall. By making offseason production possible, it leads to increased diversification and productivity
Minimum tillage	Tillage refers to all techniques used to prepare the soil for farming. It entails the loosening by breaking of topsoil using farm implements like hoes. Minimum tillage occurs when land preparation is done by slashing of existing vegetation that allows regrowth of the vegetation followed by the application of herbicides, followed by hand planting using a planting stick. Under minimum tillage practices, residues from vegetation removal are used as mulch to cover the soil surface	Reduces resource wastage on land preparation, improves water percolation, and amount of organic matter in the soil. This results in improved soil structure and prevents soil erosion. In the long run, it leads to improved productivity through moisture retention and soil compaction and degradation prevention
Mulching	The covering of the soil surface with a layer of organic residues and allowing for eventual decomposition to smother weed growth and reduce evaporation of soil water	Reduces soil temperatures compensating for higher air temperatures, compensates for drought and reduced rainfall by improving the moisture retention capacity, reduces

		emissions from the uncovered soil surface and reduces risks of crop loss
Rainwater harvesting and storage	The collection and storage of rainwater using a rooftop harvesting into concrete tanks and plastic tanks and use of ponds that collect the runoff	It avails additional water sources during dry spells. This results in reduced crop/ animal loss when used for irrigation and watering animals leading to increased productivity
Terracing	Refers to a soil conservation measure put in place to prevent rainfall-runoff mostly on sloping land from building up and causing severe soil erosion. Terraces consist of both ridges and channels constructed in a planned and systematic way across the slope	Reduces runoff and soil loss that may occur because of water erosion. This results into reduced soil fertility loss and increased water infiltration into the soil
Apical rooted cuttings	Apical rooted cuttings are produced vegetatively. Instead of letting tissue culture plantlets to mature and yield minitubers in the screen-house, apical rooted cuttings are produced from the plantlets. After rooting, the apical rooted cuttings are grown in the field to yield seed tubers, followed by one to three consecutive generations of field multiplication	Apical rooted cuttings are more productive and shorten the time required to complete the production cycle by one season. This also avoids crop loss from shorter growing seasons and unreliable rains

Mini-tubes	Minitubers are progeny tubers of the in vitro derived plantlets. The term is due to their size as they are smaller than normal seed tubers but bigger than in vitro tubers	Minitubers result into healthier tubers because of the nonexistence of soil-borne diseases. They lead to higher quantity of tuber set per plant and they can be kept until favorable planting conditions, thus escaping harsh weather.

Source: Adapted from (Caitlin A., 2014; Khatri-Chhetri *et al.,* 2017; Mereu *et al.,* 2018; Parker *et al.*, 2019)

Note: These CSA technologies directly or indirectly lead to improved agricultural productivity, reduced GHG emission and results in enhanced resilience

Appendix B: Questionnaire for Smallholder Potato Farmers

Introduction

I am **Andrew Waaswa**, a Student of Egerton University, pursuing a Master of Science Degree in Agricultural Extension. I am carrying out a study on the relationship between selected factors and Practice of Climate-Smart Agriculture among Smallholder Potato farmers in Gilgil Sub County. You have been selected as one of the respondents in this study. I humbly request you to spare some little time for me and answer these questions below. You are requested to choose options provided and also to give your view where necessary. The information you provide will be strictly for academic purposes and will be handled with the utmost confidentiality.

Guidelines:

Please complete all the sections provided by ticking (√) *the most appropriate answer from the alternatives given.*

SECTION A: INFORMATION ON SOCIO-ECONOMIC FACTORS

1	Sub-County: Gilgil Ward____________________ Location_____________________
2	Age bracket: 18 – 35 36 – 50 51 – 65 66 years and above
3	Gender : Male Female Others, specify
4	Highest Education level attained: Did not go to school Primary Secondary Post-secondary University
5	How much do you earn per year from your farm? Less than (<) KES 10,000 KES 10,001- KES 25,000 KES 25,001- KES 35,000 > KES 35,000
6	How much do you earn from potato per year? Less than (<) KES 10,000 KES 10,001- KES 25,000 KES 25,001- KES 35,000 > KES 35,000
7	How much do you get per year on average from other sources of income? Less than (<) KES 10,000 KES 10,001- KES 25,000 KES 25,001- KES 35,000 > KES 35,000

SECTION B: INFORMATION ON INSTITUTIONAL FACTORS

8	Do you have access to credit? Yes No
9	What is/are the sources of your credit? SACCOs Private money lenders Relatives and friends Banks
10	If yes in questions 10 and 11 above, how much do you get on average per year? Less than (<) KES 10,000 KES 10,001- KES 25,000 KES 25,001- KES 35,000 > KES 35,000
11	Have you been trained on CSA? Yes No
12	How often do you attend trainings on CSA Rarely =1 Sometimes =2 Regularly =3
13	Since when have you attended the trainings on CSA? Last season One year ago Two years ago Three years ago and above
14	How many times did/ have you attended the training on CSA? Once 2 times 3 times 4 times and above
15	Who offer (s) the training? Ministry of Agriculture Private Companies NGOs Universities
16	Do you have any NGO here working on CSA? Yes No
17	If yes, in question 20 above, do you receive any support on CSA from them? Yes No
18	If yes, in question 19 above, which kind of support do you receive? Extension services Credit Inputs Others, specify
19	Are you a member of any farmers' group? Yes No
20	If yes, in question 22 above, do you receive any support from it on CSA? Yes No
21	If yes, in question 23 above, which kind of support do you receive? Access to extension services Access to credit Access to inputs Others, specify

SECTION C: INFORMATION ON INFORMATION DISSEMINATION PATHWAYS

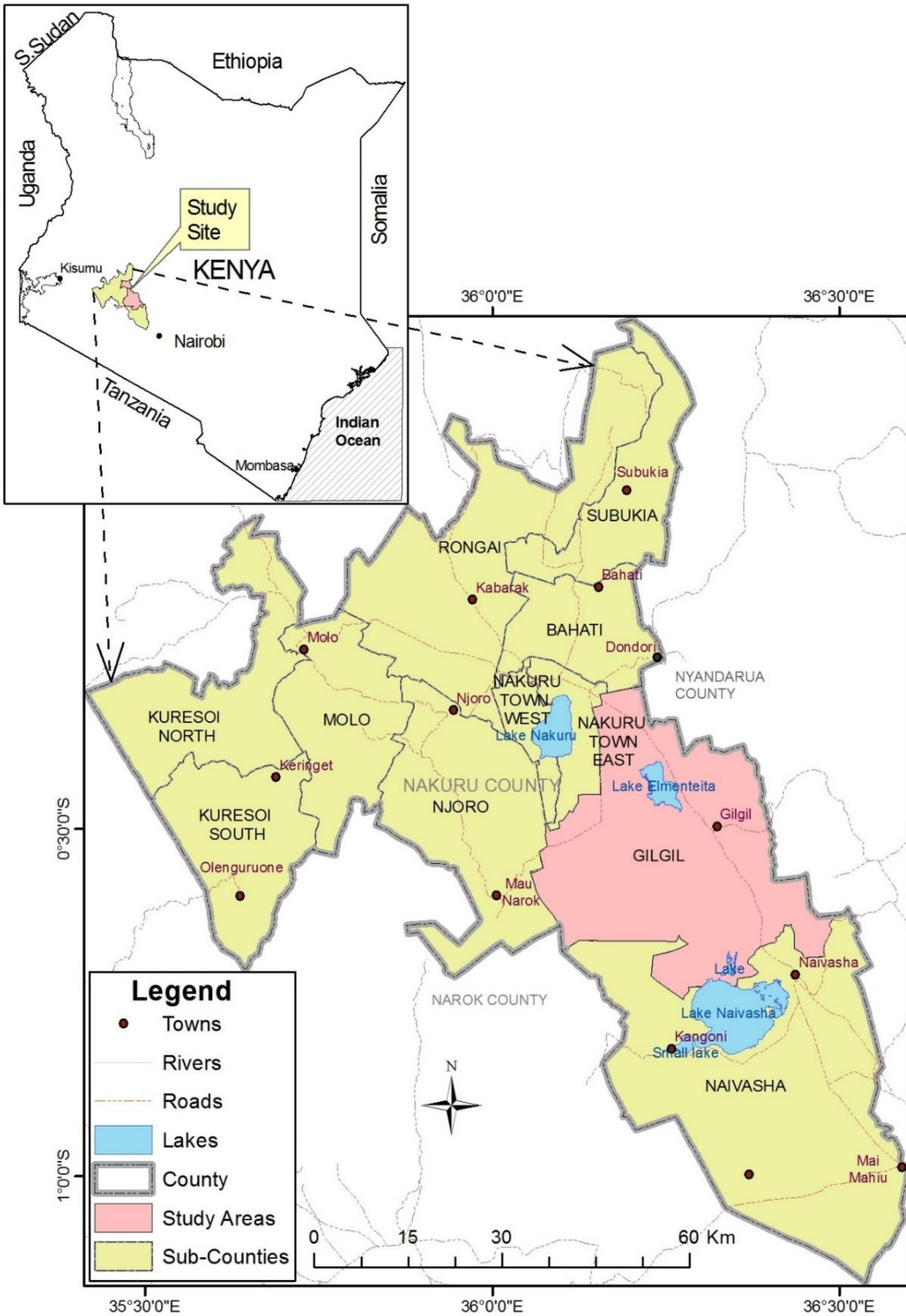
Climate Smart Agricultural practices	Are you aware of the Climate Smart Agricultural practices below? Yes = 1 No = 2	What was or is your major source of information on CSA? Radio/Television/Phone =1 Neighbors/friends =2 Extension officers =3
Rainwater harvesting and storage		
Irrigation		
Mulching		
Minimal tillage		
Improved crop varieties		
Terracing		
Drainage management		
Intercropping		
Agroforestry		
Synthetic fertilizers		
Composting		
Furrow/ ridge planting		
Crop rotation		
Apical rooted cuttings (potato seedlings)		
Mini-tubers		

SECTION D: INFORMATION ON PRACTICE OF CSA

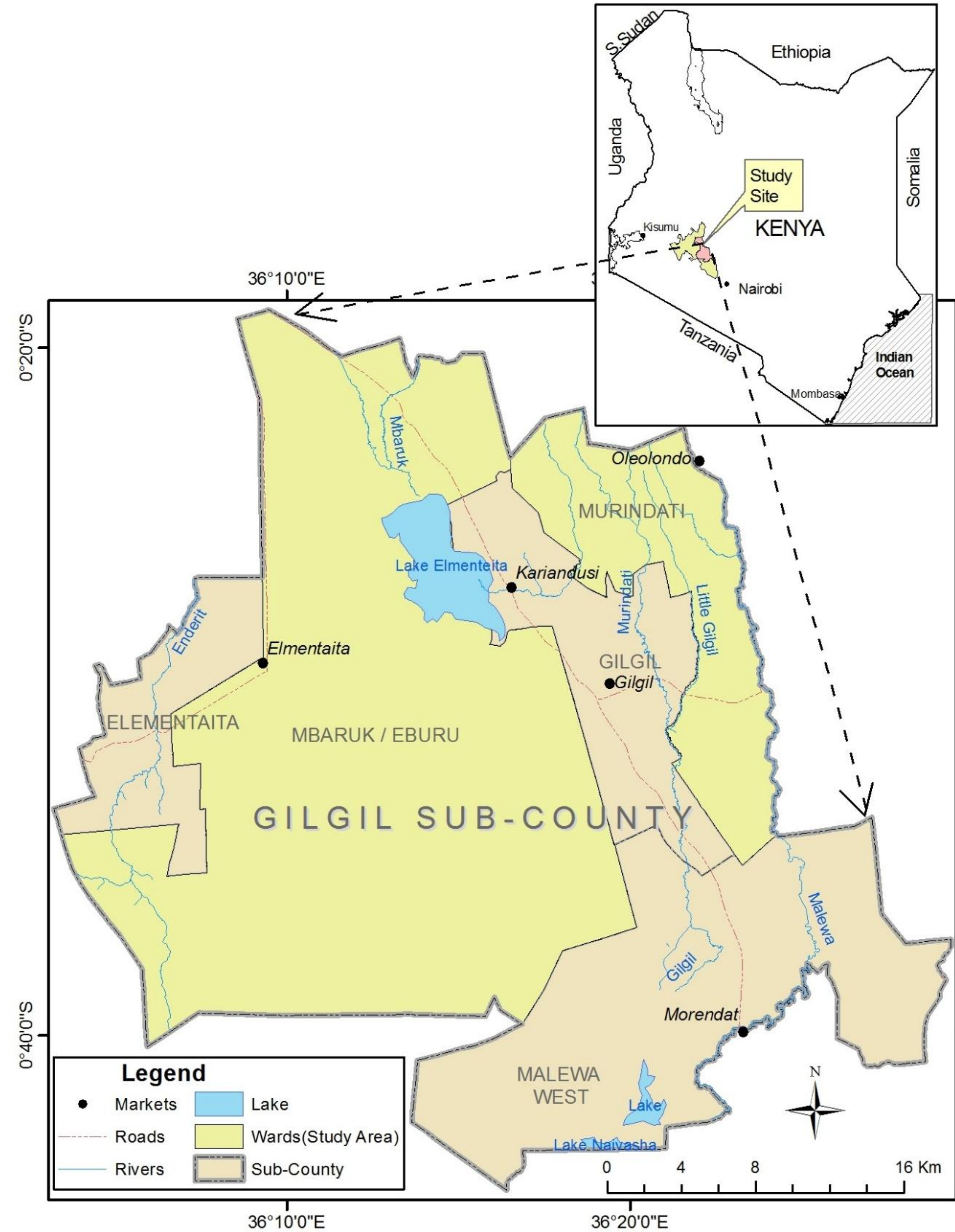
Climate Smart Agricultural practices	Do you practice the CSA below? Yes = 1 No = 0	If yes, to what extent? 1 = low 2 = moderate 3 = high
Rainwater harvesting and storage		
Irrigation		
Mulching		
Minimal tillage		
Improved crop varieties		
Terracing		
Drainage management		
Intercropping		
Agroforestry		
Synthetic fertilizers		
Composting		
Furrow/ ridge planting		
Crop rotation		
Apical rooted cuttings (potato seedlings)		
Mini-tubers		

Thank you for your time.

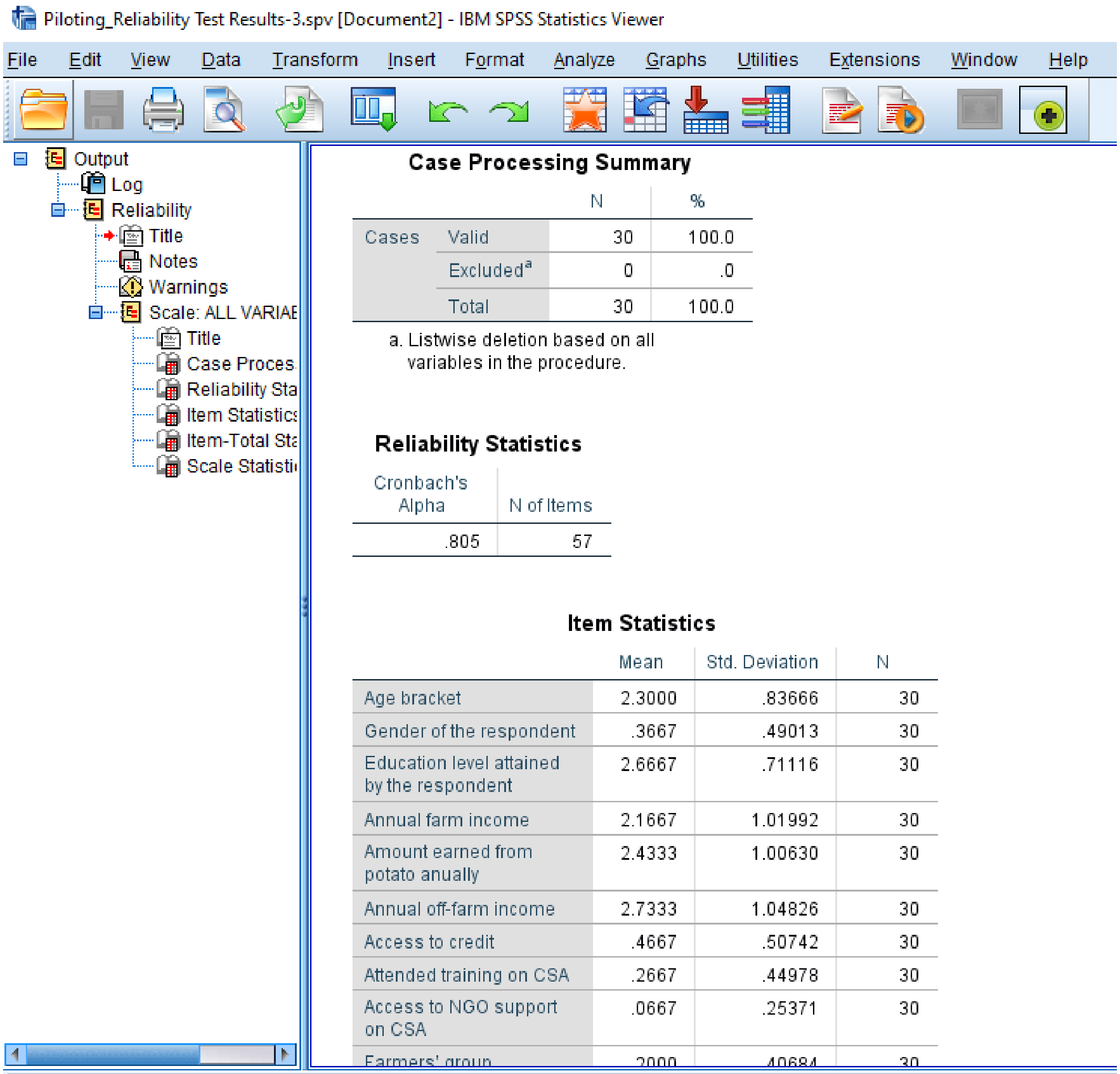
Appendix C: Location of Gilgil Sub County in Kenya



Appendix D: Map of Gilgil Sub County



Appendix E: Reliability Test Results



Case Processing Summary

		N	%
Cases	Valid	30	100.0
	Excluded[a]	0	.0
	Total	30	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.805	57

Item Statistics

	Mean	Std. Deviation	N
Age bracket	2.3000	.83666	30
Gender of the respondent	.3667	.49013	30
Education level attained by the respondent	2.6667	.71116	30
Annual farm income	2.1667	1.01992	30
Amount earned from potato anually	2.4333	1.00630	30
Annual off-farm income	2.7333	1.04826	30
Access to credit	.4667	.50742	30
Attended training on CSA	.2667	.44978	30
Access to NGO support on CSA	.0667	.25371	30
Farmers' group	.2000	.40684	30

Appendix F: Research License

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Appendix G: Socioeconomic Factors’ Percentage Accuracy Classification for Likelihood Prediction

Step number: 1

Observed Groups and Predicted Probabilities

```
      16 +                                                                                                    +
         I                                                                                                    I
         I                                                                                                    I
F        I                                                                                                    I
R     12 +                                                                                                    +
E        I                                                                                                    I
Q        I                                                                                                    I
U        I                                                                             1        1             I
E      8 +                                                                             1        1             +
N        I                                                                             1        1             I
C        I                                                                        1    1        1         1   I
Y        I                                           1                     1      1    1    11 11         1   I
       4 +                                           1             1       1     11    0    11 11         1   +
         I                                           0             1       11    11    01   11111     1 1 11  I
         I                                    1    1 0      1      01 1   1011  101    01  1111111    111 111 I
         I                             0   0  1    000      0  0   0110  11000 10001  000111101001 1111111011 I
Predicted ---------+---------+---------+---------+---------+---------+---------+---------+---------+----------
  Prob:   0       .1        .2        .3        .4        .5        .6        .7        .8        .9         1
  Group:  0000000000000000000000000000000000000000000000000011111111111111111111111111111111111111111111111111

          Predicted Probability is of Membership for 1.00
          The Cut Value is .50
          Symbols: 0 - .00
                   1 - 1.00
          Each Symbol Represents 1 Case.
```

Appendix H: Institutional Factors' Percentage Accuracy Classification for Likelihood Prediction

```
            Step number: 1

            Observed Groups and Predicted Probabilities

      80 +                                                                                                    +
         I                                                                                                    I
         I                                                                                                    I
F        I                                                                                                    I
R     60 +                                                                                                    +
E        I                                                                                                    I
Q        I                                                                                                    I
U        I                                                                                                    I
E     40 +                                                            1                                       +
N        I                                                            1                                       I
C        I                                                            1                                       I
Y        I                                                            1                                       I
      20 +                                                            1                                       +
         I                                                            0        1           1    1             I
         I                                                            0        1           1 1  1      1      I
         I                                                            0        0      1    0 1  11  1  1      I
Predicted ---------+---------+---------+---------+---------+---------+---------+---------+---------+----------
  Prob:   0        .1        .2        .3        .4        .5        .6        .7        .8        .9         1
  Group:  0000000000000000000000000000000000000000000000000011111111111111111111111111111111111111111111111111

          Predicted Probability is of Membership for 1.00
          The Cut Value is .50
          Symbols: 0 - .00
                   1 - 1.00
          Each Symbol Represents 5 Cases.
```

Appendix I: The First Publication from this Thesis

Climate-Smart agriculture and potato production in Kenya: review of the determinants of practice

Andrew Waaswa, Agnes Oywaya Nkurumwa, Anthony Mwangi Kibe & Joel Ngeno Kipkemoi

To cite this article: Andrew Waaswa, Agnes Oywaya Nkurumwa, Anthony Mwangi Kibe & Joel Ngeno Kipkemoi (2021): Climate-Smart agriculture and potato production in Kenya: review of the determinants of practice, Climate and Development, DOI: 10.1080/17565529.2021.1885336

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Published online: 21 Feb 2021.

Click here to see full article from publisher's website or here to see the archived copy.

Appendix J: Second Publication from this Thesis

Heliyon 7 (2021) e07873

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Research article

Communicating climate change adaptation strategies: climate-smart agriculture information dissemination pathways among smallholder potato farmers in Gilgil Sub-County, Kenya

Check for updates

Andrew Waaswa [a,*], Agnes Oywaya Nkurumwa [a], Anthony Mwangi Kibe [b], Ng'eno Joel Kipkemoi [c]

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ARTICLE INFO

Keywords:
Climate change
Climate-smart agriculture
Sustainable development
Information dissemination pathways
Gender
Adoption
Potato production
Smallholder farmers
Kenya

ABSTRACT

Proven and sustainable practices like climate-smart agricultural practices (CSAPs) need to be prioritized and promoted for uptake especially by the farmers to achieve sustainable development. These are capable of contributing to the realization of sustainable development goals through averting food and nutritional insecurity, increasing and sustaining yields that translate into increased incomes and later reduced poverty. This is because CSAPs enable farmers to adapt and mitigate climate change effects. However, due to inappropriate communication of CSAPs to the farmers, to date, some farmers still see no escape route from the frightening effects of climate change and they are currently adopting a rather fatalistic attitude. This study investigated the information dissemination pathways used by different categories of smallholder potato farmers for and practice of CSAPs. It found a difference between information sources and practice of CSAPs at a 5% level of significance ($\chi2$ = 100.12139, df = 2, $p < 0.05$, Cramer's V = 1.0), and a difference in the use of the three information dissemination pathways between men and women at a 5% level of significance ($\chi2$ = 6.05949, df = 2, $p < 0.05$, Cramer's V = 0.17406). The three information dissemination pathways included media, neighbors and friends, and extension officers. Generally, farmers were aware and practiced the CSAPs investigated in this study except for irrigation with high awareness yet with low uptake percentage and potato seedlings and minitubers both with low awareness and practice respectively. This study recommended mainstreaming of CSAPs information.

1. Introduction

The consequences of climate change on people and agricultural production have attracted global attention (Acosta et al., 2021; Amadou, 2020). Public, private, and non-profit development agencies have broadened their scope to cushion farmers against the climate change effects, more so on the smallholder farmers in Africa where the magnitude of the effect is exorbitant (Alliagbor et al., 2020; Derbile et al., 2021). Dissemination and practice of climate-smart agricultural practices (CSAPs) are principal strategies to cope with the impacts of climate change (Alliagbor et al., 2020; Waaswa et al., 2021). The practice of CSAPs portrays the potential to boost and sustain agricultural productivity and improve farmers' resilience to climate change shocks (Arslan et al., 2014; García de Jalón et al., 2017; Martey et al., 2021). The practice of CSAPs is also a fundamental remedy in alleviating poverty, food, and nutritional insecurity by improving agricultural output plus incomes of farm families beyond Africa. For example, in the Sub-Saharan, CSAPs are continuously being scaled up to adapt to climate change and increase yields (Chirambo, 2018; García de Jalón et al., 2017).

CSAPs are of a farm, international level, and of financial matters of concern (Amadu et al., 2020). They are a present strategy to reposition and modify agricultural systems to battle food and nutritional insecurity under climate change. Climate change increases the inabilities of smallholder farmers to meet their present and future needs by threatening agriculture on which they solely depend for their livelihoods (Derbile et al., 2021; Lipper et al., 2014). It reduces their resilience and copying potential by destructing agricultural food systems (Ingutia, 2021; Waaswa and Satognon, 2020). CSAP is an integrated and

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Appendix K: Third Publication from this Thesis

Discover Sustainability

Discover

Research

Understanding the socioeconomic determinants of adoption of climate-smart agricultural practices among smallholder potato farmers in Gilgil Sub-County, Kenya

Andrew Waaswa[1] · Agnes Oywaya Nkurumwa[1] · Anthony Mwangi Kibe[2] · Joel Kipkemoi Ng'eno[3]

Received: 16 June 2021 / Accepted: 15 September 2021
Published online: 21 September 2021

Abstract
Besides climate-smart agriculture's (CSA) potential to meet the world's increasing food demands in the face of climate variability through sustainably increasing food production, its acceptance among farmers is still low. This could be partly because of limited insight into the contextual underpinnings of its uptake. Therefore, the purpose of this study was to establish the relationship between selected socioeconomic factors and the adoption of CSA in Gilgil Sub-County. This study's results were attained from a binary logistic regression model, using a sample of 120 smallholder potato farmers in two wards of Gilgil Sub-County of Nakuru County, Kenya. An analysis of the five hypothesized explanatory socioeconomic variables contained in the model disclosed that a relationship between socioeconomic factors and adoption of CSAPs was statistically significant at a 5% level of significance ($\chi^2 = 17.966$, df = 5, $p < 0.05$). It further revealed that only two variables had a significant relationship with the adoption of CSAPs. Among these, included gender which was negative and statistically significant at a 5% level of significance (Wald $\chi^2 = 6.701$, df = 1, $p < 0.05$) and annual farm income, which was positive and statistically significant at a 5% level of significance (Wald $\chi^2 = 8.402$, df = 1, $p < 0.05$). Therefore, securing access to vital resources for women farmers is indispensable to enhance their capacity and compliance to adjust production methods in response to climate change. Facilitating increased farm output and income among the farmers is greatly recommended.

Keywords Agricultural productivity · Climate change · Climate change adaptation · Climate-smart agriculture · Potato production · Socioeconomic factors · Adoption

1 Introduction

Climate change dramatically affects socioeconomic and biophysical systems since these are profoundly and intricately interrelated [1–3]. Variation in any of these causes an alteration in another. In that event, distinctive consideration should be given to climate change, notably to mitigate greenhouse gas (GHG) emissions [2, 4]. By 2030, its concentration in the atmosphere is forecasted to double, which induces a notable rise in temperature globally [5–7]. Yet, an increase in GHG emissions produces severe implications for the farming sector worldwide.

Adaptation energies, especially among farmers, are interconnected in climate-smart agriculture (CSA), which utilizes the most advanced technological executions while mitigating climate change [6, 8]. Notwithstanding the possible gains

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Discover Sustainability (2021) 2:41 | https://doi.org/10.1007/s43621-021-00050-x

Springer

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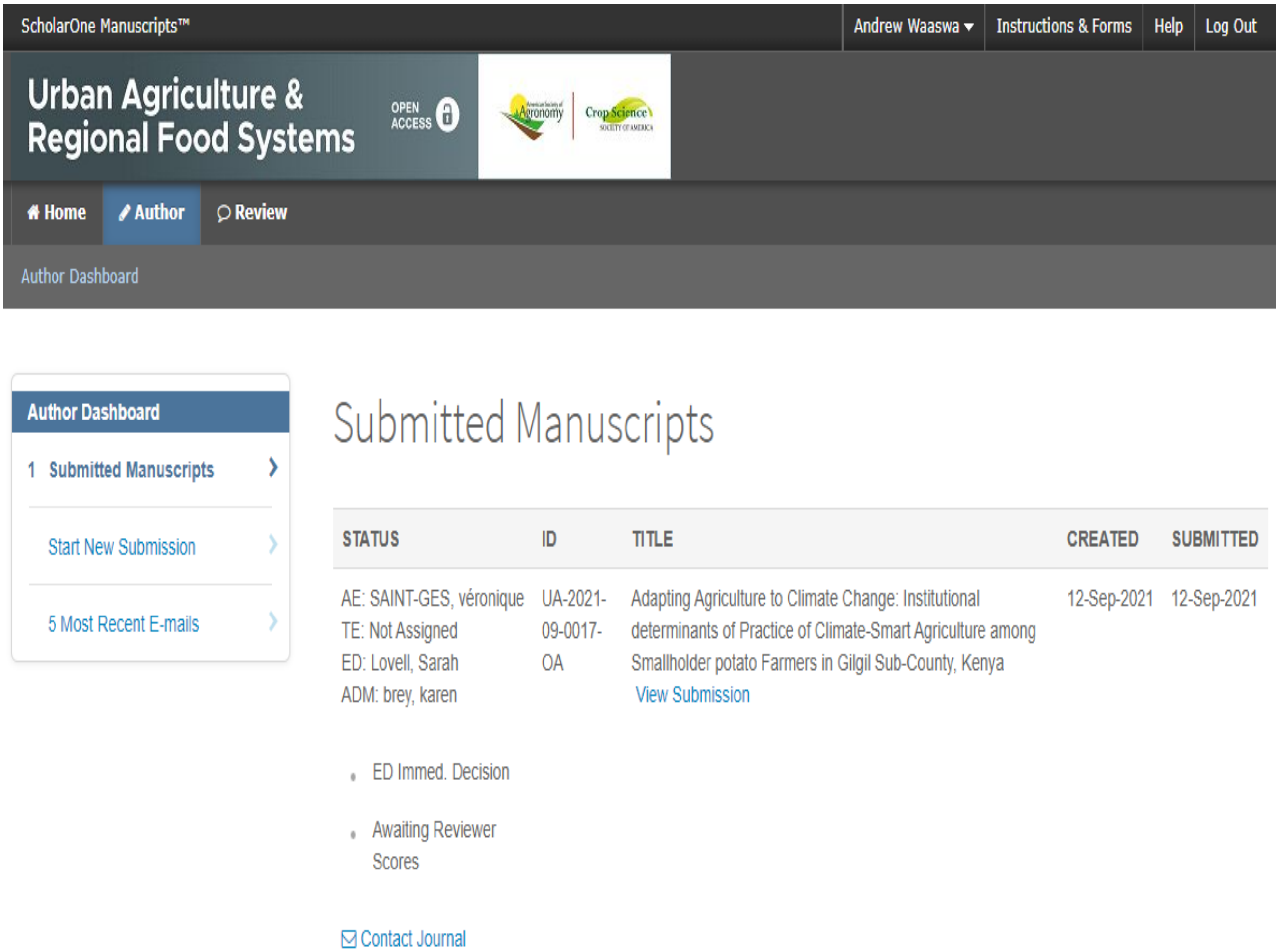
Appendix L: Fourth Publication from this Thesis



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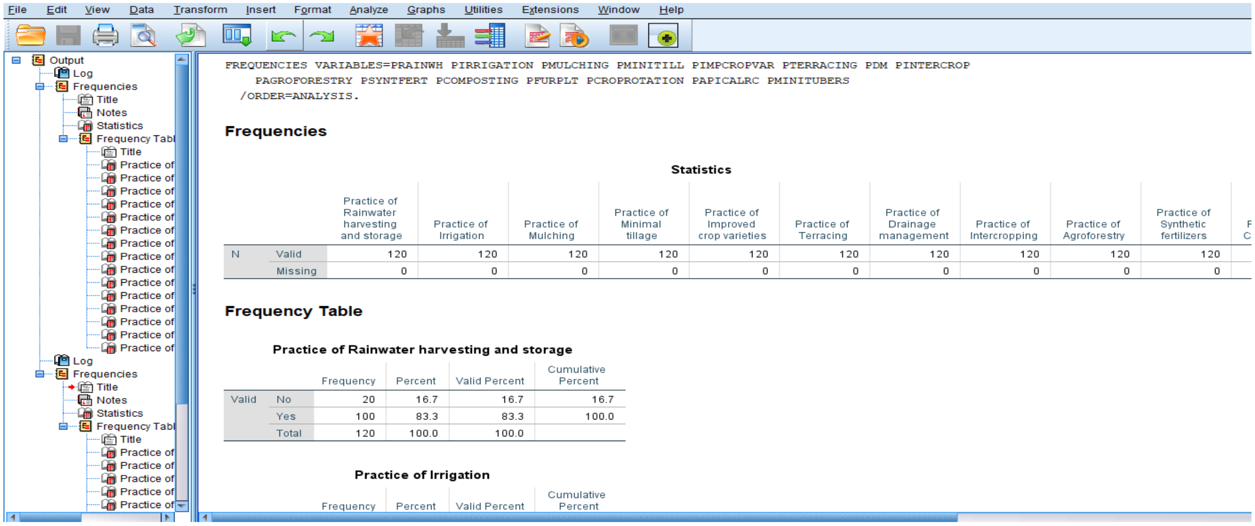
- ED Immed. Decision
- Awaiting Reviewer Scores

Contact Journal

Under review

Appendix M: Other Main Data Outputs



```
FREQUENCIES VARIABLES=PRAINWH PIRRIGATION PMULCHING PMINITILL PIMPCROPVAR PTERRACING PDM PINTERCROP
    PAGROFORESTRY PSYNTFERT PCOMPOSTING PFURPLT PCROPROTATION PAPICALRC PMINITUBERS
  /ORDER=ANALYSIS.
```

Frequencies

Statistics

		Practice of Rainwater harvesting and storage	Practice of Irrigation	Practice of Mulching	Practice of Minimal tillage	Practice of Improved crop varieties	Practice of Terracing	Practice of Drainage management	Practice of Intercropping	Practice of Agroforestry	Practice of Synthetic fertilizers
N	Valid	120	120	120	120	120	120	120	120	120	120
	Missing	0	0	0	0	0	0	0	0	0	0

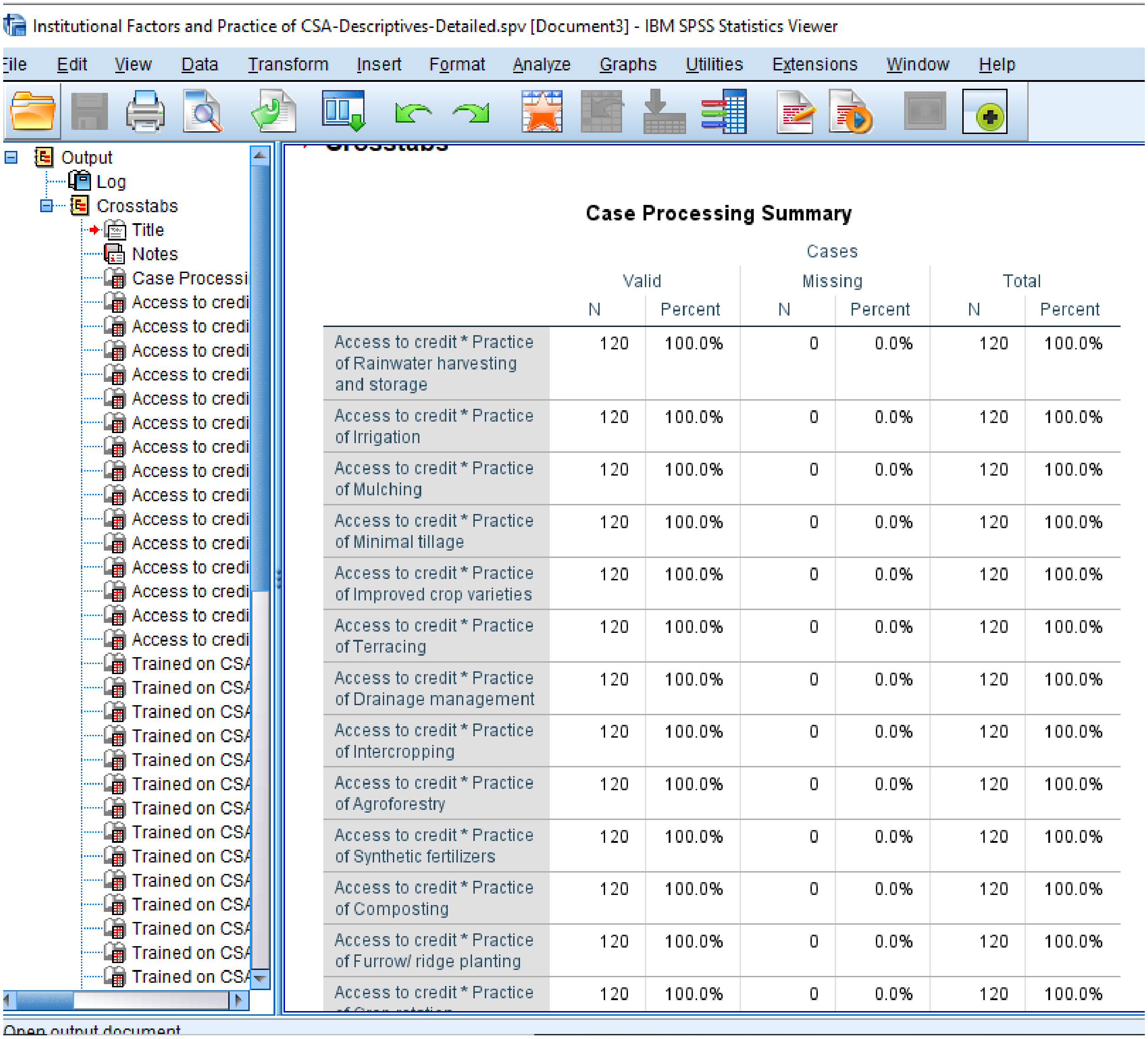
Frequency Table

Practice of Rainwater harvesting and storage

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	20	16.7	16.7	16.7
	Yes	100	83.3	83.3	100.0
	Total	120	100.0	100.0	

Practice of Irrigation

		Frequency	Percent	Valid Percent	Cumulative Percent



Institutional Factors and Practice of CSA-Descriptives-Detailed.spv [Document3] - IBM SPSS Statistics Viewer

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Access to credit * Practice of Rainwater harvesting and storage	120	100.0%	0	0.0%	120	100.0%
Access to credit * Practice of Irrigation	120	100.0%	0	0.0%	120	100.0%
Access to credit * Practice of Mulching	120	100.0%	0	0.0%	120	100.0%
Access to credit * Practice of Minimal tillage	120	100.0%	0	0.0%	120	100.0%
Access to credit * Practice of Improved crop varieties	120	100.0%	0	0.0%	120	100.0%
Access to credit * Practice of Terracing	120	100.0%	0	0.0%	120	100.0%
Access to credit * Practice of Drainage management	120	100.0%	0	0.0%	120	100.0%
Access to credit * Practice of Intercropping	120	100.0%	0	0.0%	120	100.0%
Access to credit * Practice of Agroforestry	120	100.0%	0	0.0%	120	100.0%
Access to credit * Practice of Synthetic fertilizers	120	100.0%	0	0.0%	120	100.0%
Access to credit * Practice of Composting	120	100.0%	0	0.0%	120	100.0%
Access to credit * Practice of Furrow/ ridge planting	120	100.0%	0	0.0%	120	100.0%
Access to credit * Practice	120	100.0%	0	0.0%	120	100.0%

File Edit View Data Transform Insert Format Analyze Graphs Utilities Extensions Window Help

- Output
  - Log
  - Frequencies
    - Title
    - Notes
    - Active Dataset
    - Statistics
    - Frequency Table
      - Title
      - Gender of the
      - Education lev
      - Age bracket
      - Annual farm i
      - Annual off-far

Statistics

		Gender of the respondent	Education level	Age bracket	Annual farm income	Annual off-farm income
N	Valid	120	120	120	120	120
	Missing	0	0	0	0	0
Std. Deviation		.49195	.81954	.92036	1.05051	1.10610

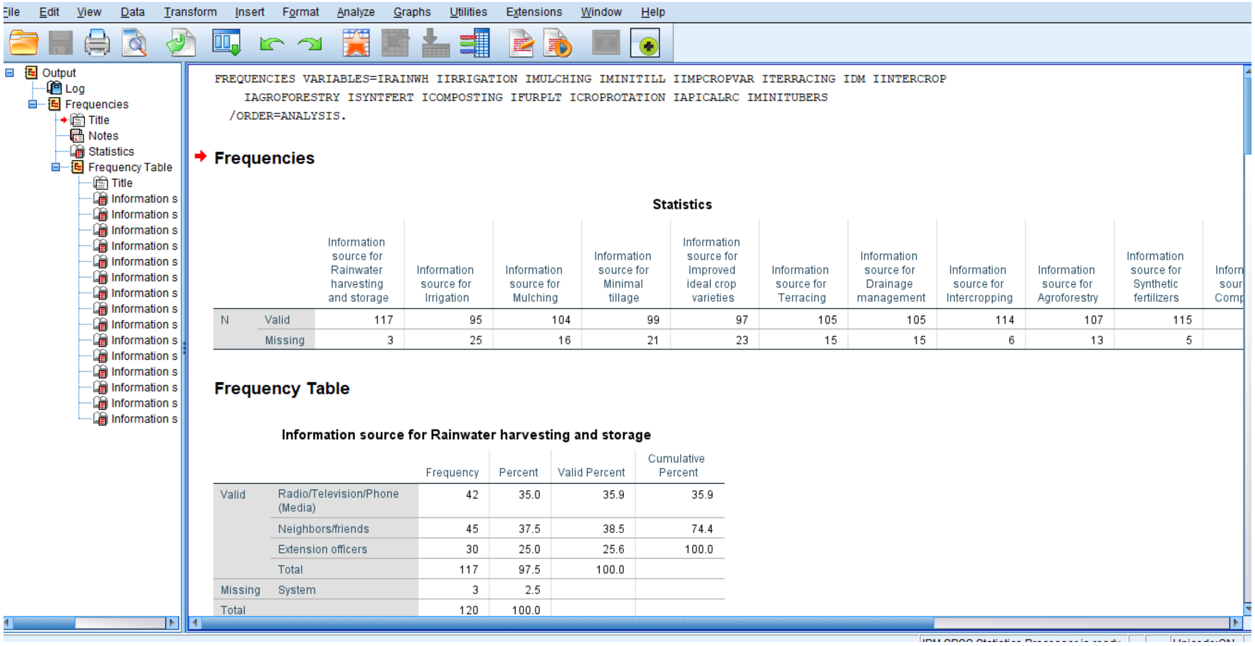
Frequency Table

Gender of the respondent

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	72	60.0	60.0	60.0
	Male	48	40.0	40.0	100.0
	Total	120	100.0	100.0	

Education level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Did not go to school	6	5.0	5.0	5.0
	Primary	61	50.8	50.8	55.8
	Secondary	40	33.3	33.3	89.2
	Post-secondary	10	8.3	8.3	97.5
	University	3	2.5	2.5	100.0
	Total	120	100.0	100.0	



```
FREQUENCIES VARIABLES=IRAINWH IIRRIGATION IMULCHING IMINITILL IIMPCROPVAR ITERRACING IDM IINTERCROP
    IAGROFORESTRY ISYNTFERT ICOMPOSTING IFURPLT ICROPROTATION IAPICALRC IMINITUBERS
  /ORDER=ANALYSIS.
```

Frequencies

Statistics

		Information source for Rainwater harvesting and storage	Information source for Irrigation	Information source for Mulching	Information source for Minimal tillage	Information source for Improved ideal crop varieties	Information source for Terracing	Information source for Drainage management	Information source for Intercropping	Information source for Agroforestry	Information source for Synthetic fertilizers	Inforn sour Comp
N	Valid	117	95	104	99	97	105	105	114	107	115	
	Missing	3	25	16	21	23	15	15	6	13	5	

Frequency Table

Information source for Rainwater harvesting and storage

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Radio/Television/Phone (Media)	42	35.0	35.9	35.9
	Neighbors/friends	45	37.5	38.5	74.4
	Extension officers	30	25.0	25.6	100.0
	Total	117	97.5	100.0	
Missing	System	3	2.5		
Total		120	100.0		