Climate Finance Instruments and Kenyan Agriculture

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Abstract

Human activities lead to the emission of carbon and carbon equivalents into the atmosphere which leads to climate change. Some of the negative impacts of climate change include increased frequency of flooding and drought. These lead to loss of soil and crucial soil nutrients which affects agricultural production leading to food insecurity, increased poverty, and may have significant impact on the quality of life. The majority of Africa's population are smallholder rain dependent farmers. Their success depends on actual rainfall (amount and distribution) whose variability is projected to increase due to climate change. As the impact of climate change is felt, the inhabitants' activities may further exacerbate land degradation through unsustainable agricultural practices. To escape from these adverse impacts requires investment. To this end, climate finance has been offering funds for investments in climate smart agricultural projects. This has the possibility of enhancing Africa's adaptive capacity, food security and economic growth.

This thesis estimates weather related yield risk in agriculture and the possible use of climate finance instruments for risk weather management. First, the global climate finance landscape was reviewed. This provided an overview of the available financing mechanisms, the sources of climate finance and the overall distribution of the finances across the various regions and sectors. It also highlighted the opportunities and challenges faced by climate finance investments as well as the innovative approaches that have been adopted to tap the available climate risk finance.

Upon establishing the current climate finance landscape and the approaches adopted for climate risk management in agriculture, this study estimated the probable risk in Kenya's agriculture as a result of weather events such as drought. To achieve this, the national annual maize yield data from 1961 to 2014 was utilised. The yield variation was calculated by comparing the actual yield with the average expected yield. First the average yield for each year was defined as a 5-year running mean of yields for the interval comprising of 2 years before and 2 years after the year under consideration (t-2 to t+2). This was then compared against the actual yield to obtain the yield variation. The results were fitted to a probability distribution and the Value at Risk (VaR) method was used to estimate the agricultural drought risk. The study finds the risk of yield loss due to drought to be high especially for the 50 and 100-year return period which was an estimated loss of approximately 24%. In the 1980's, yield losses of approximately 20% were experienced affecting over half a million people. These results provide information on drought risk and the possible associated losses which could be useful for drought risk management. This information is relevant to financial institutions when pricing financial products for farmers and to the government for estimating the financial resources required to manage the impacts of drought.

After estimating the agricultural yield risk due to weather changes, the viability of Index Based Weather Derivative as risk management tool against drought losses for maize farmers in Western Kenya was evaluated. To this end, option contract prices were estimated using the growing period rainfall and a Standardised Precipitation Evapotranspiration Index (SPEI). Burn analysis and the equilibrium pricing models were also used. The study finds that farmers would have benefitted if they had hedged against drought using option contracts. Specifically, at a strike level of 1 and 4, the positive pay-outs would have been in 41 and 18 seasons out of the 108 seasons during the period under study. Further research is recommended regarding the use of market price-based models to price SPEI based weather derivatives.

An analysis of the efficiency of Weather Derivatives (WD) in hedging against drought risk exposure by maize farmers in Kenya was undertaken. A put option with the Standard Precipitation Evapotranspiration Index (SPEI) as the underlying index was assumed to have been bought by the farmers to hedge against income variations due to drought. The study finds that the option contracts do not efficiently hedge against drought risk in Kenya's agriculture. This is probably because the level of risk in Kenya's agriculture is higher than that which would be effectively covered by option contracts. It is recommended that further studies should be conducted to establish the factors that may affect the efficiency of option contracts in hedging against drought risk.

Finally, this study evaluated Kenya's readiness for climate finance. This is based on the premise that the level of a country's readiness greatly influences the amount of climate finance that it mobilises. It was found that Kenya has instituted

legislation and policies aimed at enhancing climate finance readiness. While these have been meticulously and pragmatically formulated, the implementation and effectiveness could not be confirmed. There is need for measures that enhance data availability which would make it easier to evaluate the performance of the implemented measures.

As a result of this study, the application of VaR for risk estimation in agricultural production is better understood. Similarly, in terms of financial risk management of weather-related risk in agriculture, the viability of SPEI drought index in pricing option contracts as well as the efficiency of weather derivatives in hedging drought risks are better understood. This study offers insights for investors and policy makers who wish to use financial instruments to manage weather risks in agriculture.

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Thank you very much! – Asante sana! – Ni wega Muno!

Dedication

This thesis is dedicated to my children, husband and all my other family members.

Declaration

I, Mercy Kangai Gatabi Kiremu, declare that this thesis is an original work undertaken at the University of Waikato Management School towards the requirement of an award of Doctor of Philosophy degree. No part of this work has been used here or anywhere, either now or in the past for similar purpose. Any ideas, thoughts, figures, and tables expressed or used are originally mine; and where prior works are referred to, they are duly acknowledged and cited.

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List of Abbreviations

Acronym	**Full Names**
ACRE	Agriculture and Climate Risk Enterprise
A-D	Anderson-Darling test
AEs	Accredited Entities
AfDB	African Development Bank
AFOLU	Agriculture, Forestry, and Land Use
AgGDP	Agricultural Gross Domestic Product
AIC	Akaike Information Criterion
ARIMA	Autoregressive Integrated Moving Average
ASAL	Arid and Semi-Arid Land
BFC	Baragwi Farmers' Cooperative
BIC	Bayesian Information Criterion,
CAPM	Capital Asset Pricing Model
CAT	Cumulative Average Temperature
CBK	Central Bank of Kenya
CBO's	Community Based Organisations
CDD	Cooling Degree Day
CDF	Cumulative Density Function
CFR	Climate Finance Readiness
CFU	Climate Funds Update
CME	Chicago Mercantile Exchange
CPI	Climate Policy Initiative
CRGP	Cumulative Rainfall in Growing Period
CSA	Climate-smart Agriculture
CSO	Civil Society Organisations
CV	Coefficient of Variation
CVaR	Conditional Value at Risk
DFI	Development Finance Institutions
EAC	East African Community
ERS	Economic Recovery Strategy
ESA	Eastern and Southern Africa
EU	European Union
EU BCP	European Union
EVD	Extreme Value Distributions
EVT	Extreme Value Theory
FAO	Food and Agriculture Organization of United Nations
FAOSTAT	Food and Agriculture Organization Statistics
FCPF	Forest Carbon Partnership Facility
FDI	Foreign Direct Investment
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
GCF	Green Climate Fund

GDP	Gross Domestic Product
GEF	Global Environment Facility
GEV	Generalised Extreme Value
GHG	Greenhouse Gases
HDD	Heating Degree Day
IBLI	Index-Based Livestock Insurance
ICIPE	International Centre of Insect Physiology & Ecology
IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation
IIED	International Institute for Environment and Development
ILRI	International Livestock Research Institute
INDC	Intended Nationally Determined Contribution
IPCC	International Panel on Climate Change
KACP	Kenya Agricultural Carbon Project
KALRO	Kenya Agriculture Livestock Research Organisation
KAM	Kenya Association of Manufacturers
KARI	Kenya Agricultural Research Institute
KCB	Kenya Commercial Bank
KEFRI	Kenya Forest Research Institute
KFS	Kenya Forestry Service
KNAP	Kenya National Adaptation Plan
K-S	Kolmogorov-Smirnov test
KWS	Kenya Wildlife Service
LCD	Least Developed Country
M&MRV	Measurement, Monitoring Reporting and Verification
MDB	Multilateral Development Bank
MLE	Maximum Likelihood Estimate
MoALMC	Minister of Agriculture, Land Management & Cooperatives
MRL	Mean Residual Life
MRSL	Measured by Mean Root Square Loss
MRV	Monitoring Reporting and Verification
MSEs	Micro and Small Enterprises
NCCAP	National Climate Change Action Plan,
NCCBC	National Climate Change Budget Codes
NCCC	National Climate Change Council
NCCRS	National Climate Change Response Strategy
NDA	Nationally Designated Authority
NDMA	National Drought Management Authority
NDVI	Normalized Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
NSE	Nairobi Securities Exchange
OECD	Organisation for Economic Co-operation & Development
OTC	Over the Counter

PDF	Probability Distribution Function
PET	Potential Evapotranspiration
POT	Point Over Threshold
PPP	Public Private Partnership
PV	PhotoVoltaic
RDI	Reconnaissance Drought Index
REDD	Reducing Emissions from Deforestation & Degradation
REDD+	Reducing Emissions from Deforestation and Degradation, and enhancing forest carbon stocks)
SDG	Sustainable Development Goals
SIDA	Swedish International Development Authority
SPEI	Standard Precipitation Evapotranspiration Index
SSA	Sub Saharan Africa
SSPs	socio-economic pathways
StARCK+	Strengthening Adaptation and Resilience to Climate Change in Kenya
TGB	Trees for Global Benefits
UK	The United Kingdom
UNDP	United Nation Development Programme
US	United States
USA	United States of America
USAID	United States Agency for International Development
USD	United States Dollars
VaR	Value at Risk
WD	Weather Derivatives

List of Definitions

Term	Definition
Burn rate analysis	A method of calculation used to approximate the value of an option
Call Option	An option/opportunity to buy assets at an agreed price on or before a particular date.
Derivatives	Financial products whose value is based (derived) on the underlying asset
European option	An option contract which may be exercised only at the expiration date of the option
Option Contract	A contract that gives the purchaser of the option the right to buy or sell a particular asset at a later date at an agreed upon price
Put Option	An option/opportunity to sell assets at an agreed price on or before a particular date.
Strike Price/Level	A strike price is the set price at which a derivative contract can be bought or sold when it is exercised.
Tick size	The smallest price movement of a trading instrument

Chapter 1: Introducing the Study

1.1 Introduction

Considerations of climate change often focuses on increasing temperatures and changes in precipitation. However, what is more important for agriculture is the impacts of these changes on agricultural production. The impact of climate change in agriculture includes drought and floods (Hay, Easterling, Ebi, Kitoh, & Parry, 2016). These events have a high covariate risks leading to huge losses to many people within the same locality. This affects the people's recovery time, especially in the absence of financial products to manage these risks. In addition, the high covariate risks pose a big risk to the providers of the financial products e.g. insurance companies and banks particularly when this is left to the private sector alone.

Furthermore the costs of relief can easily exceed government capacity because extreme events often involve widespread correlated losses (Gourley, 2017). In view of this, adaptation projects that mitigate extreme weather risks ex ante are economically preferable to ex post disaster relief. It is estimated that each dollar spent on hazard reduction saves the society an average of four relief dollars (Hanna, 2011).

While the majority of the Greenhouse Gases GHG emissions have come from industrialised countries, developing countries are more vulnerable to the impacts of resultant climate change (Woodward et al., 2014). Eleven of the 17 countries with low or moderate GHG emissions are acutely vulnerable to negative impacts of climate change while 20 of the 36 highest emitting countries are among the least vulnerable (Althor, Watson, & Fuller, 2016). The majority of the vulnerable countries are found in Africa and the island countries located in the Atlantic, Pacific and Indian oceans. This inequality is largely because the extent of the loss caused by climate change impacts is contingent upon the level of socio-economic development which determines the society's ability to prepare for, avoid and respond to climate change impacts (Van Vuuren et al., 2014). For this reason, the international community aims to mobilize at least USD 100 billion of climate finance annually for mitigation and adaptation in developing countries (Steckel et al., 2017). Similarly, developing countries are encouraged to adopt a low carbon development pathway to help reduce the amount of carbon emissions. Furthermore, the adoption of a low carbon development pathway is beneficial to developing countries as it helps reduce the risk of stranded assets which may arise due to environment-related risks (Caldecott, Harnett, Cojoianu, Kok, & Pfeiffer, 2016).

Climate finance provides funding opportunity for investments that lead to adaptation and mitigation to climate change. The global financial needs for climate change far exceed the available finance (Brown, Nanasta, & Bird, 2009). The financial needs for adaptation alone in emerging markets and developing economies are estimated at US $140 billion to US $300 billion annually by 2030, and at the global scale from US $280 billion to US $500 billion under moderate emission scenarios, yet public international finance flows for adaptation were only US $22 billion in 2017 (Alaerts, 2019). Enhancing adaptation for Africa's agriculture is very important. This is because agriculture provides food for the continents growing population in addition to being the main source of livelihoods in rural Sub-Saharan Africa (Davis, Di Giuseppe, & Zezza, 2017). It is predicted that between 2014 and 2050, Africa's population will double from 1.1 billion to about 2.4 billion people. This is expected to increase food demand by approximately 2.9% annually till year 2050. In contrast, agricultural productivity growth from 2001 to 2010 was averaged at only 1% a year. If this rate persists, Africa would only be able to meet about 25% of its total food demand in year 2050 (Snodgrass, 2014).

Evidently, a much faster growth in Africa's agricultural productivity is needed as an important part of addressing food insecurity. This overwhelming challenge for the agricultural sector is exacerbated by climate change whose impacts strains agricultural and natural systems through increased water shortages, increased magnitude and frequency of flooding and drought, changes in plant/animal disease and pest distribution patterns, and more generally, reduced suitability of some areas for agriculture (Hay et al., 2016). Climate finance provides an opportunity for Africa's agriculture to adapt to climate change while at the same time transitioning to low carbon pathway.

Agricultural production has always been a risky endeavour; yet, climate change and increasing market uncertainty have increased this risk. Further, the rollback of state protections has rendered small scale farmers, especially those in the Global South, particularly vulnerable to these present-day stressors (Isakson, 2015). The little allocations to agricultural sector's adaptation needs is evidenced in governments policies and plans, as an example, despite having an impact on millions of people, Kenya's proposed adaptation actions has allocated about 2% of the budget to agriculture & livestock and 6% to drought management. Contrary to this the infrastructure gets 53% of the total budget estimates (Government of Kenya, 2016a). This is despite the fact that agriculture is the mainstay of Kenya's economy.

1.2 Motivation of the Study

Kenya aims to achieve sustainable development by 2030. To realise this goal, approximately US$2.75 billion will be needed annually (International Institute for Environment and Development, 2014). However, Kenya has been able to mobilise approximately US$1 billion annually which is less than 50% of the total financial needs. Thus, to meet the climate change targets, Kenya will need to tap all sources of climate finance available from international, domestic, public and private sources (International Institute for Environment and Development, 2014). Private investments in climate-change adaptation are important. First, because the costs of adaptation are too high to be met by the public sector alone. Additionally, the USD 100 billion annual pledge includes funds from the private sector (German Development Institute, 2016).

However, the question on how to tap domestic sources of finance particularly from the private sector remains a challenge. Specifically, while financial risk exposure has been cited as a major concern for private investors, this topic has received very little attention if any. This study evaluates financial risk exposure and management in the agricultural sector in the face of the changing climate. To achieve this, the risk exposure to maize farmers will be estimated using the Value at Risk (VaR) method. Further, a drought-based option contract will be priced and evaluated for efficiency. The results from the analysis will be useful to insurers, government agencies as well as to the investors in estimating risk exposure and determining the viable financial products for hedging purposes.

1.3 Study Area

This study focuses on designing financial instruments for extreme events management in Kenya’s agriculture. Kenya is the dominant economy in the East African Community (EAC)) and is the economic, financial, and transport hub of the region. Kenya is strategically located as a gateway to the East and Central African region and serves five landlocked countries of the EAC namely, (Ethiopia, South Sudan, Uganda, Rwanda, and Burundi) that are relatively resource-rich. It is also the primary source of Foreign Direct Investment (FDI) for some of these countries.

Kenya has experienced positive growth with the highest GDP per capita of approximately 17% being recorded in 1971. This has been attributed to favourable economic policies such as those outlined in the Sessional Paper No. 10 on ‘African Socialism and Its Application to Planning in Kenya’. This report laid the foundations of a market economy and which enhanced the flow of foreign direct investments supported by the import substitution policy started before independence (Mwega & Ndung’u, 2004). The rapid growth from 1971 to 1980 which is followed by negative growth from 1981 to 1990 (Figure 2.1). The slow growth in this period has been attributed to the global recession, commodity price decline, delayed structural adjustment policies, and political succession in the country (Kimenyi, Mwega, & Ndung'u, 2015). However, between 2001 and 2010 the country sprang back to positive growth averaging about 5% annually (Central Intelligence Agency, 2018; Kimenyi et al., 2015). This positive development has been attributed to the implementation of bold economic and structural reforms under the Economic Recovery Strategy (ERS) and a favourable external environment (Kimenyi et al., 2015).

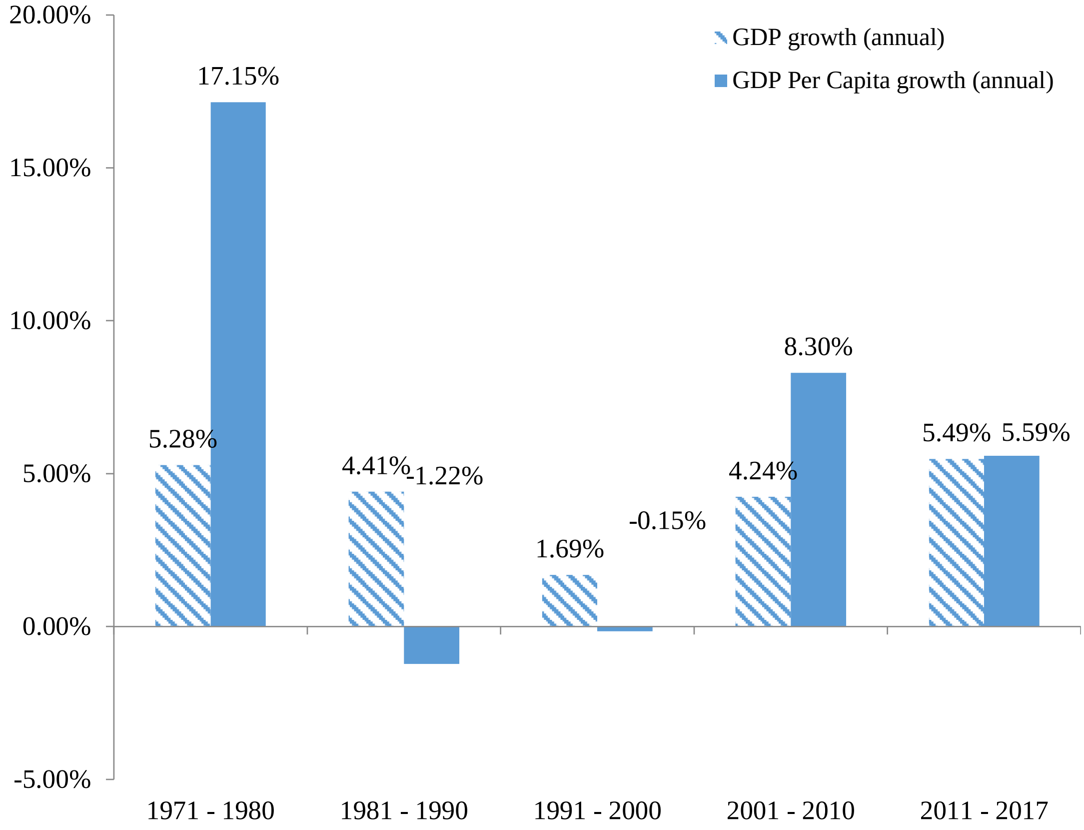

Figure 2.1 Kenya’s Annual Growth in GDP and GDP Per Capita (1971-2017)

(Source: Countryeconomy.com, 2017)

Kenya is classified as a low middle-income country and had the 6th highest GDP in SSA in 2017 (World Bank, 2018). This is confirmed by a comparison of the country’s GDP against that of SSA which reveals that the average GDP of SSA is lower than that of Kenya between 2011 and 2017 (Figure 2.1). Kenya has made major progress in financial deepening and financial inclusion and is a centre of innovation especially in mobile phone-based financial services. The growth of the phone-based financial services sector has seen formal financial inclusion rise from 26% in 2006 to 75% in 2016 (Ndung'u, 2018). In addition, it has created job opportunity and ignited economic growth in the country. While Kenya has a growing entrepreneurial middle class and steady growth, its economic development has been impaired by weak governance and corruption. Significant strides have been made towards strengthening of the institutions of governance through the 2010 enactment of a progressive constitution that has radically altered the previous dominance of the executive (Kimenyi et al., 2015).

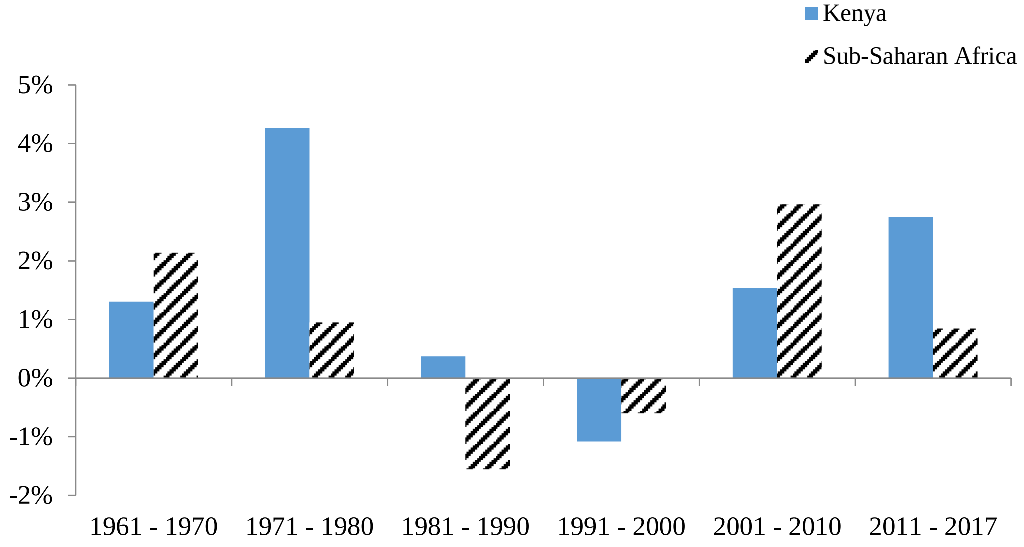

Figure 2.2: Kenya GDP per Capita Compared to SSA

(Source: Countryeconomy.com, 2017)

In 2019, Kenya has an estimated population of approximately 47 Million. Approximately 27 percent of these people are living in urban areas (Word Bank, 2016). Additionally, Kenya provides shelter to approximately 580,000 refugees from neighbouring countries. The country's GDP as of 2017 stood at $3,500 while the life expectancy was estimated at 64.3 years. The country's climatic conditions are varied ranging from humid to very arid (Table 2.1). Agro-climatic zones I–III are classified as medium to high potential productive areas (12% of Kenya) with a moisture index of more than 50%, annual rainfall above 1,100mm and mean annual temperatures below 18^{o}C. Most of the high potential productive areas are located above 1,200m and are categorised as being the only zones that are sustainable for agricultural production under rain-fed conditions.

Agro-climatic zones IV–VII are classified as semi-humid to arid (88% of Kenya) and have a moisture index of less than 50%, an annual rainfall of less than 1,100mm and mean annual temperatures ranging from 22^{o}C to 40^{o}C. These zones are normally referred to as the Kenyan rangelands and about 90% of the land area lies below 1,260m.

Table 2.1 Climatic Zones of Kenya

Zone	**Classification**	**Vegetation**	**Plant growth potential**	**Crop failure risk (%)**	**Approximate land area (%)**
1	Humid	Moist forest	Very high	0 - 1	0.1
2	Sub Humid	Moist and dry forest	High	1 - 5	9.3
3	Semi Humid	Dry forest and moist woodland	High to Medium	5 - 10	
4	Semi-Humid to Semi-Arid	Dry woodland and bushland	Medium	20 - 25	9.3
5	Semi-Arid	Bushland	Medium to low	75 - 95	8.5
6	Arid	Bushland and scrub land	Low	75 - 95	52.9
7	Very Arid	Desert scrub	Very low	95 - 100	19.8
Rest (Waters)	Waters				2.6

(Source: Sombroek, Braun, & Van der Pouw, 1982)

Kenya's economy depends highly on agriculture. Specifically, the agricultural sector contributes directly to approximately 26% of the annual GDP and another 25% indirectly. In addition, it supplies 65% of Kenya's total exports and employs nearly 70% of the population either full time or part time. Over 75% of agricultural output is from small-scale, rain-fed farming or livestock production (Kabubo-Mariara & Karanja, 2007). In rain-fed agriculture, the yields and consequently the agricultural revenues are greatly influenced by weather uncertainties (Ender & Zhang, 2015). Since the majority of Kenya's population are small holder rain-dependent farmers, the variability in rainfall is likely to affect agricultural production and consequently negatively distress the livelihoods of millions of people in the country.

Despite the key role that agriculture plays in Kenya's economy and the inherent risks in the sector, majority of farmers lack updated technology and have inadequate financial or extension services. This is exacerbated by recurrent crises such as drought in Kenya's Arid and Semi-Arid (ASAL) areas posing critical challenges to food security. Consequently, there is need to improve risk management to enable the farmers to manage the inherent risks posed by the climatic conditions and weather patterns. Use of climate smart financial products provides an opportunity to manage the risks as well as enhance resilience in the agricultural sector.

There are several financial instruments that can be used to manage financial risks due to weather uncertainty, with the most widely studied instrument being the weather insurance and derivatives (Zong & Ender, 2016). Kenya's financial market is a developing market and the trading of weather derivatives has not yet been launched. Some of the reasons fronted as challenges hindering the setting up of the platform are, low level investor sophistication, lack of commodities on a large scale and inadequate liquidity among others (Barasa & Mutende, 2013, March).

1.4 Financial Instruments for Climate Change Adaptation

The International Panel on Climate Change (IPCC), scientists as well as practitioners agree that financial instruments can play an important role within climate change adaptation (Linnerooth-Bayer & Hochrainer-Stigler, 2015). These tools enhance mobilisation of finance, risk sharing and transfer which is particularly important in addressing climate change impacts especially in vulnerable developing countries. The financial products for climate risk management can take the form of green bonds, catastrophe bonds, insurance and weather derivatives. Determination of the most suitable product to adopt is influenced by the type of risk and the risk management that is being addressed.

A summary of the climate risks, the associated frequency as well as the possible level of damage that these risks may cause is shown in Figure 2.3**.** It is observed that while extreme risks have a corresponding low frequency of occurrence, the associated loss to these events are extremely high. These extreme losses make the events unattractive to private providers of risk products such as insurers and other financial institutions. Thus, the most appropriate strategy of managing these events is by use of public and donor funds. Furthermore, the Government and donors can incentivise the private sector to cover these risks by providing catastrophic reinsurance to insurers willing to cover these risks so as to reduce their risk exposure (Kovacs & Kunreuther, 2001).

The second risk category is the 100 to 10 year return period. This represents medium to extreme losses and is characterised by medium to extreme losses. Finally, the 0-10 year return period losses represents the more frequent but low to medium level of losses. Risk financing or risk reduction should be applied for the 100-10 year return period losses while for the 0-10 return period, the most cost effective response should be adopted (Linnerooth-Bayer & Hochrainer-Stigler, 2015).

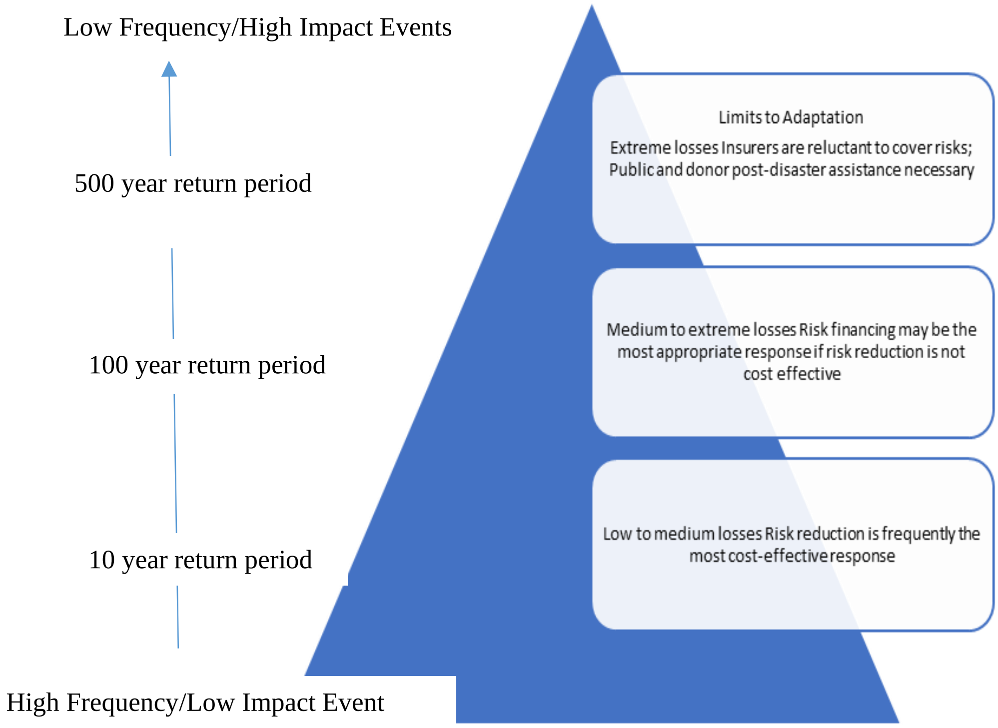

Figure 2.3: Risk Layers

(Source: Linnerooth-Bayer & Hochrainer-Stigler, 2015)

1.5 Innovative Climate Financing Projects in Kenya

1.5.1 Climate Smart Lending

Climate-smart agriculture (CSA) may be defined as "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food security and development goals" (Food and Agriculture Organization, 2013; Lipper et al., 2014). The aforementioned outcomes of CSA are referred to as the triple gains of adopting CSA. This form of agriculture encompasses a wide range of farming practices including but not limited to composting, agroforestry, minimum soil disturbance, use of crop rotations, retention of crop residues or other soil surface cover (Richards et al., 2014; Tennigkeit, Solymosi, Seebauer, & Lager, 2013).

Farmers in developing countries seeking loans face numerous challenges such as poor credit rating due to credit screening models that overestimate their risk of default. Consequently, they are denied access to credit and hence less resilient to climate change. In addition, financial institutions that fail to consider climate change impact face increased risk exposure (Basak, 2017). Climate-smart credit scoring incorporates climate risks and the measures taken by the farmers to manage these risks (including climate smart agriculture practices), when calculating credit worthiness.

The Climate Smart Lending Platform is a project that is promoting the incorporation of CSA when lending to farmers. The main aim of this Project is to mainstream Climate-smart Agriculture (CSA) metrics into the credit scoring systems of financial institutions.

This project involves four main actors; the investors; tool developers/service providers; local lenders; and the smallholder farmers. Figure 2.4 shows that investors provide finance to the tool developers and the local lenders. The tool developers develop credit products that incorporate CSA. These tools are availed to the lenders who use them to credit rate the smallholders. The lenders then lend the money obtained from the investors to the smallholders who have incorporated CSA in their farming practices. This creates strong incentives for farmers to adopt CSA practices in addition to improving the agricultural lending portfolio resilience to climate change, (CPI, 2017).

The portfolio resilience comes as a result of the enhanced farmer resilience as a result of adopting CSA. As an example, adoption of CSA could lead to two or more times yield during times of stressful weather (McCarthy, Lipper, & Branca, 2011). This in turn reduces credit providers’ climate-related default exposure due to increased farmer incomes and reduced losses in the event of unexpected climate events.

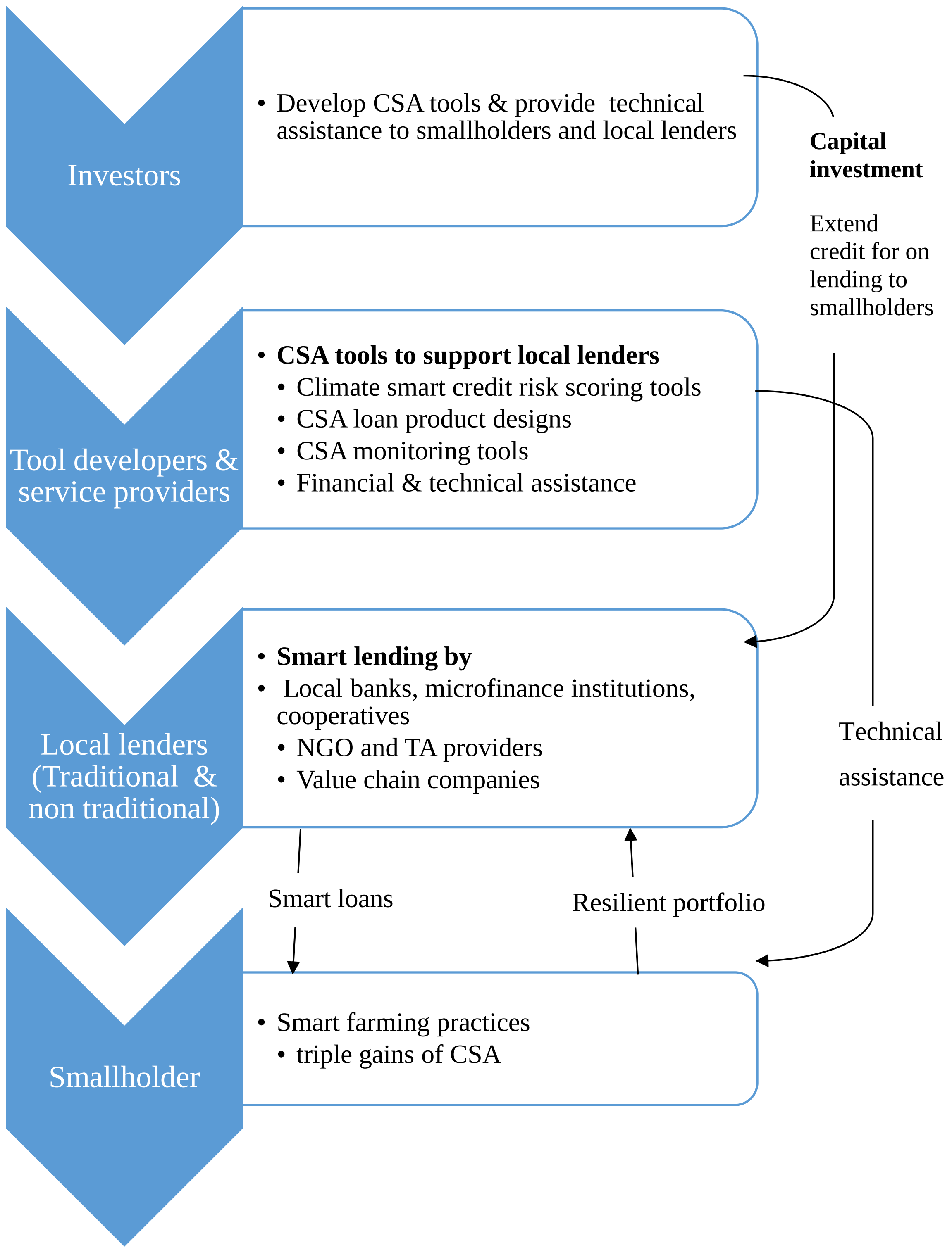

Figure 2.4: Climate Smart Lending Platform

(Source: Climate-Smart Lending Platform, 2016)

1.5.2 Agriculture and Climate Risk Enterprise (ACRE)

The Agriculture and Climate Risk Enterprise (ACRE) formerly known as Kilimo Salama is the largest index insurance programme in the developing world in which the farmers pay a market determined price to purchase insurance, and also the first agricultural insurance programme worldwide to reach smallholders using mobile technologies (Greatrex et al., 2015). ACRE's approach is based on three pillars which are; first provision of a wide range of products based on several data sources, including automatic weather stations and remote sensing technologies.

The second is ACRE's role as an intermediary between insurance companies, reinsurers and distribution channels/aggregators. Such aggregators include microfinance institutions, agribusiness and agricultural input suppliers. And finally, the third pillar is its link to the mobile money market, particularly the M-PESA scheme in East Africa (Greatrex et al., 2015).

Partnering with mobile phone Company allows the programme to quickly reach the many millions of farmers enrolled in M-PESA. Each farm was then monitored using satellite imagery for 21 days. If the index was triggered the farmers were automatically paid via M-PESA. This project has been a great success and by the year 2016, it had insured over 1,000,000 farmers in Kenya, Tanzania and Rwanda. Furthermore, insured farmers invested 20% more in their farms and earned 16% more than uninsured farmers with the total sum insured being over 12.3 million US dollars (Sibiko, Veettil, & Qaim, 2017). In addition, it is projected that the project will be serving about 3 million farmers across 10 countries by 2018 (Greatrex et al., 2015).

The impressive growth of this insurance programme has been attributed to several factors namely, the wide range of products offered by ACRE, its role as an intermediary between insurance companies, reinsurers and distribution channels/aggregators, its link to the mobile money providers and the wide range of partners working on the programme (Ntukamazina et al., 2017). The programme has leveraged the expertise of these partner network to implement new and innovative solutions to address the challenges that the farmers are exposed to (Greatrex et al., 2015).

1.5.3 Index-Based Livestock Insurance (IBLI) - Kenya and Ethiopia

Current and projected climate trends show increasing drought frequency and rainfall variability across most African dryland areas. The strong customary dependence on rangeland resources, few available livelihood alternatives, and political marginalization limit pastoralists' capacity to cope with the resulting harsher environmental conditions (King, Unks, & German, 2018).

The International Livestock Research Institute (ILRI), in partnership with Cornell University and the University of California – Davis, created IBLI to stabilize asset accumulation, enhance economic growth, and keep livestock keepers out of poverty traps by insuring them against the loss of their livestock due to drought (Greatrex et al., 2015).

The statistical relationship between livestock mortality data and the remotely sensed Normalized Difference Vegetation Index (NDVI) was used to price the insurance premiums. Similar to the ACRE programme, IBLI has multiple partners including insurance companies, reinsurers, research organizations and NGOs all playing different roles.

IBLI had successfully insured over 4,000 livestock herders by the year 2014 (Bastagli & Hardman, 2015; Hess, Richter, & Stoppa, 2002). IBLI covers 25-40% of total livestock mortality risk, in addition, it has been found to have other substantial immediate development benefits such as participating households are less likely to sell livestock during drought periods, more likely to buy livestock from others, and more likely to become self-reliant for food consumption (Greatrex et al., 2015).

1.6 Research Problem and Aim of the Study

Agricultural production is prone to many uncertainties with weather, market developments and other events directly influencing returns from farming (OECD, 2009). Risk is a persistent characteristic of life in developing countries, especially in rural areas where the economies heavily depend on weather conditions and experience frequent weather hazards, such as drought, floods and windstorms (Hess et al., 2002). Covariate risks created by weather-related events are problematic to countries with underdeveloped financial markets for transferring these risks through insurance or other means (L. Sun, Turvey, & Jarrow, 2015). This is aggravated by the low asset base and little access to well-developed insurance and credit markets by the households exposed to these risks making them financially ill-equipped to deal with weather shocks which amplifies the severity of catastrophe-induced poverty traps (Hess et al., 2002; L. Sun et al., 2015).

In spite of that, the financial risk exposure in the agricultural sector of developing economies arising from climate change impacts has received very little attention if any (Kabubo-Mariara & Karanja, 2007). Most of the studies focus on determinants of output such as the impacts of factors such as soil conservation and other farm technologies.

Given the importance of agriculture to SSA's economy and its vulnerability to extreme weather events, it is important that disaster loss is more accurately estimated. This is an important prerequisite for the development of risk-management and risk-financing tools to foster post-catastrophe recovery.

Furthermore, the development of these products would increase the types of financial products available to farmers to manage climate risks. This would ensure that the farmers have more options and choices in how they manage these risks. To achieve this, the following tasks were undertaken.

i. Characterise the risk associated with Kenyan agriculture as a result of climate change;
ii. Characterise the alternative financial instruments that can be used to manage these risks;
iii. Evaluate the performance of these instruments; and
iv. Review Kenya's readiness for climate finance.

Completion of these tasks provides information essential for understanding the implications for policy makers, development partners, financial institutions and farmers.

1.7 Significance of the Study

The key contributions of this paper lie in the accomplishments of the aforementioned objectives. First, the risk associated with agriculture as a result of climate change is characterised. While various studies have been carried out on risk estimation for the agricultural sector, the majority of these studies apply traditional risk measurement methods such as the mean-variance framework and delta-gamma-vega analysis. Consequently, by applying VaR as a risk measurement technique, this study contributes to existing knowledge on the subject by providing another tool for risk measurement. Very few studies, if any, have applied this technique in Kenya's agriculture. An accurate estimation of the weather risk is useful for estimating cost of the aid required at the different drought probabilities. Furthermore, a sensitivity analysis using this approach could be used to determine the most efficient approaches for allocating climate finance to adaptation alternatives (Webby et al., 2007).

Secondly, this study adds to the available financial risk management tools by assessing viability of the drought index SPEI as an underlying index for pricing weather derivatives. Given the relevance of weather risk to the agricultural sector, it would seem necessary to explore different underlying indices and therefore determine their reliability in pricing derivatives for the sector. Its success would permit the introduction of more financial instruments allowing the greater population to take advantage of these products. Furthermore, since the SPEI index accounts for both the precipitation and the evapotranspiration, its success is likely to provide a more accurate risk measurement index. A more accurate quantification of climate risk represents a measurable risk indicator for adaptation and planning purposes in addition to providing a starting point for raising climate finance for adaptation strategies (Little, Hobday, Parslow, Davies, & Grafton, 2015).

Thirdly, by presenting non-traditional measurement techniques and indices for agricultural risk evaluation and pricing, this study will promote interest and further research on this topic by other financial analysts and scholars who have state-of-the-art knowledge and access to analytical tools. This may generate more risk management products for the agricultural sector and therefore more options for farmers seeking to manage their risk exposure to climate risks.

Furthermore, this study provides useful information on the climate finance landscape of Kenya as a country and in the global context. It also discusses the measures that the government has instituted in order to attract more climate finance for low carbon investments. This enhances the knowledge on the status of climate finance readiness as well as providing a basis for evaluating the effectiveness of the measures taken to enhance climate finance readiness.

Lastly, the obtained results will be useful for insurers, bankers and other financial institutions in estimating their exposure when providing financial services to the sector (United Nations Development Programme, 2009). In addition, policy makers can use the information when evaluation the viable options for weather risk management.

1.8 Outline of this Thesis

The remainder of the thesis is organised as follows. In Chapter 2 entitled "A Synopsis of climate finance investments" an analysis of climate change-oriented investments is undertaken. This review is based on previous studies and reports that focused on both global and national climate finance investment over the last few years. In addition, the chapter analyses the possible climate finance needs in Kenya as outlined in the policy documents relating to climate change planning and the possible barriers towards achieving the climate investment projections.

Chapter 3 provides a brief review of climate finance and agriculture in Kenya. It reviews the impacts of drought in Kenya's agriculture and the possible use of climate finance based financial instruments to manage these risks. Chapter 4 evaluates the performance of climate finance with a special focus on the fund's contribution towards the transition to low carbon investment. Chapter 5 describes the methodology undertaken for the empirical analysis of the research questions raised in Chapter 1. Chapters 6, 7 and 8 build on Chapter 5 by providing the empirical results of the research question raised in Chapter 1. Specifically, Chapter 6 provides a detailed discussion of the empirical results on risk estimation using Value at Risk (VaR) on the national maize yield. Fifty years of data was used to estimate the risk.

Upon determining the risk, Chapter 7 which is entitled “hedging drought risk in Kenya with weather derivatives” then presents the empirical results for the pricing of weather derivatives using the SPEI drought index. The Subsequent chapter entitled efficiency of weather-based derivatives builds upon Chapter 7. It analyses and discusses the empirical results on the efficiency of SPEI based option contract in hedging against drought risk. Then Chapter 9 evaluates Kenya’s readiness for climate finance. And finally, the conclusions, contributions, recommendations are presented in Chapter 10.

Chapter 2: A Synopsis of the Climate Finance Investments

2.1 Introduction

Although there is no internationally agreed definition of climate finance, the term is generally used to refer to financial resources invested in mitigation and adaptation measures (Weikmans & Roberts, 2017). The global climate finance investments have grown from $359 billion in 2012 to $530 billion in 2017 with the highest investment of $472 billion being recorded in 2015 Figure 3.1 the majority of these investments were in East Asia & Pacific 32% followed by Western Europe which accounted for 26%. SSA's share of the investment stood at 3%.

The amount of climate finance needed to achieve low-carbon and climate-resilient growth in developing countries are enormous. Approximately $70-$100 billion is estimated to be needed annually from 2010 to 2050 in-order to meet the adaptation needs in developing countries (World Bank, 2010). At the same time, approximately $140-$175 billion is needed annually from 2010 to 2030 in order to meet the mitigation needs in developing countries.

However, the total flow of all climate finance from developed to developing countries range from US$ 40 to US$ 175 billion per year including annual flows of up to US$ 50 billion through public institutions and up to US$ 125 billion of private finance (Newell & Bulkeley, 2017). Clearly, the amount of finances needed to cater for adaptation and mitigation is significantly more than the finances that have been mobilised. Thus, there is need for mobilization of more funds if the climate investment needs are to be met.

Figure 3.1: The Global Annual Climate Finance Investments
(Source: Buchner et al., 2017; Climate Policy Initiative, 2018)

Figure 3.1 represents global climate finance investments from 2012 to 2017. The high investments in 2015 were mainly as a result of increase in renewable investments mostly in China, the U.S., and Japan. However, in 2016 the investment declined to approximately $455 billion mainly due to a combination of falling technology costs and lower deployment in other countries (Buchner et al., 2017; Climate Policy Initiative, 2018).

It is important to note that majority of the global investments in energy are in fossil fuel projects. This trend decreases the effectiveness of climate investment and also introduces risks to the financial system as, for example, oil or coal assets become "stranded assets" (Buchner et al., 2017; Mazzucato & Semieniuk, 2018). This risk may arise due to a variety of factors such as change in regulations, societal norms as well as falling technology costs among other causes (Caldecott et al., 2016).

Nonetheless, total funding for renewable energy has been rising at a remarkable rate with the total investments in renewable energy growing by a compound annual rate of 18% (Mazzucato & Semieniuk, 2018). These authors further state that in 2014, net investment into new capacity, as opposed to replacing depreciated assets, was twice as large for renewable energy as it was for fossil fuels in the power sector; a trend that is predicted to continue for the rest of the decade. Consistent with these findings, (Buchner et al., 2017) found that between 2012 and 2016, the renewable sector had more than doubled the investments in climate related projects. They also affirmed that the annual solar rooftop photovoltaic (PV) and onshore wind capacity additions and investment were on track to meet their share of the 2°C goal. On the Contrary, the performance of the other sectors has not been as positive. A wider scale up of investments across all sectors of the economy is needed if the 2°C limit target is to be achieved.

2.2 Sources of Climate Finance

Climate finance is raised and distributed using various public and private intermediaries (Hall & Lindsay, 2018). The private sector has consistently contributed majority of the climate finance providing over 55% of finances in all the years between 2012 and 2016 with the highest contribution of 73% being realised in 2012 Figure 3.2.

The providers of private climate finance include corporations and project developers, commercial financial institutions, institutional investors and households among other providers. The project developers are the highest contributors of climate finance as they deal with the renewable energy sector which has been attracting majority of the finances (Hall & Lindsay, 2018). While mitigation activities accounted for approximately 93% of climate finance between 2015 and 2016, 74% of that investment was spent on renewable energy generation (Buchner et al., 2017).

In contrast, climate finance from the public sector is raised mainly from donor governments and their agencies, multilateral climate funds, and Development Finance Institutions (DFIs). The DFI's are the major players in the public sector and they channel their finances through National, Bilateral, Multilateral agencies as well as climate funds. Remarkably, the multilateral DFI flows in 2016 were at 78% of their annual targets to be met by 2020 (Buchner et al., 2017). At this trend it is projected that these intermediaries will meet their year 2020 finance mobilization target.

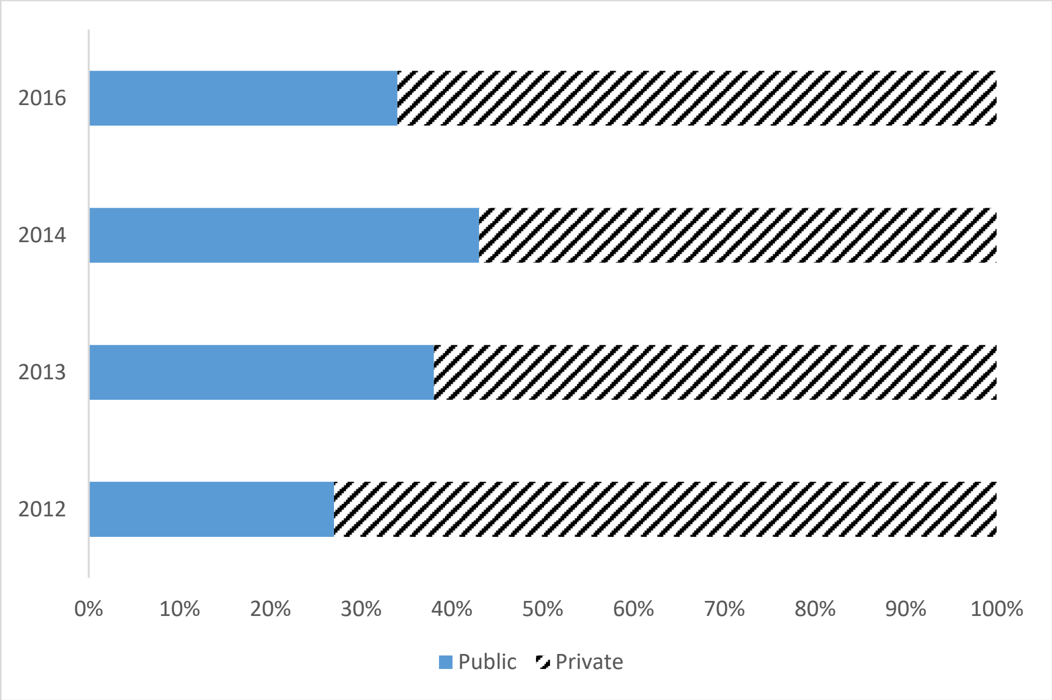

Figure 3.2: The Global Climate Finance from Private and Public Sources

(Source: Buchner et al., 2017)

Climate finance is raised and distributed through various financial instruments such as grants, debt, equity bonds derivatives among others. The market rate debt can be obtained from private financial institutions while subsidised debt is available from the government affiliated bodies (Hall & Lindsay, 2018).

An analysis of the mode of project financing in Kenya reveals that majority of projects are financed through partnerships between international organisations and local government organisations. Specifically, a review of 17 projects funded through the GEF facility of the World Bank program showed that about 60% of the projects were funded through partnership with the government affiliated bodies, National or County government institutions.

In contrast, 11% of the projects were co-financed by the end users including smallholder farmers who provided financing in kind. The private sector co funded approximately 21% of the projects (Global Environmental Finance, 2018). While the private sector participated in funding climate related projects, the presence of private financial institutions was very limited. Furthermore, while the global landscape shows that private funders provide most of the climate finance, the financing in Kenya seems to be mainly from domestic and international public institutions.

2.3 Distribution of Climate Finance

2.3.1 Thematic Allocation of Climate Finance

There is a big difference between the amount of funds invested in adaptation and mitigation projects with mitigation receiving the lions share. Terpstra (2013) analysed climate investments from various sources and found that all the different sources invested more in mitigation than in adaptation. Mitigation received 83% of finance raised by contributor countries, 77% of funding tracked by the climate funds, 81 % of the funds by multilateral development and 56% of all climate finance provided by OECD donors. Similarly, a systematic analysis of literature from the CPI reports indicates that more that 90% of the funds raised from 2012 to 2016 was invested in mitigation projects.

The question on the optimal allocation of finances between adaptation and mitigation remains unresolved. However, there is a consensus that more funds need to be mobilised if the 2°C goal is to be met.

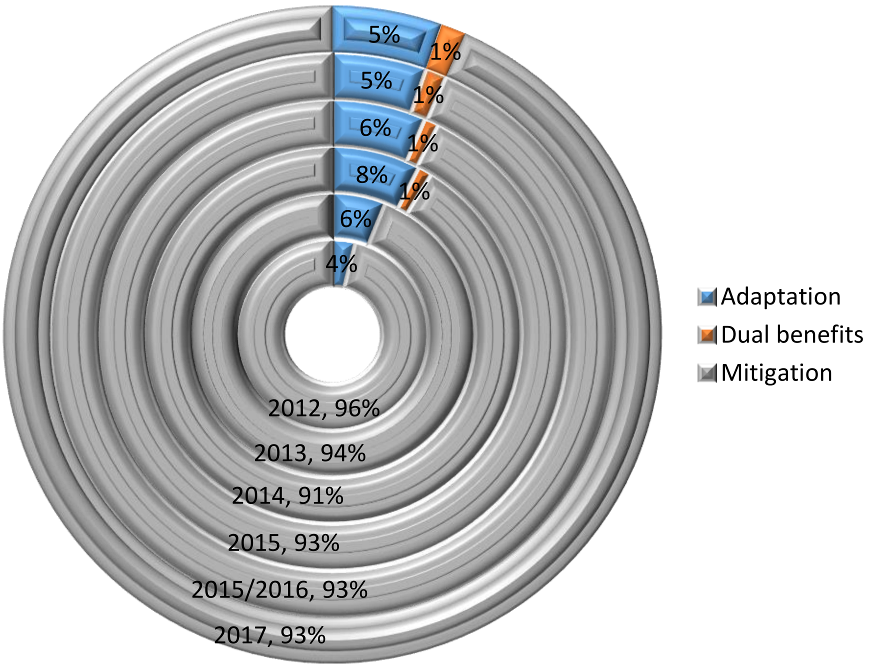

Figure 3.3: Distribution of Climate Finance
(Source: Buchner et al., 2017)

2.3.2 Geographic Distribution of the Finances in 2015

The bulk of the climate financed investments have been in Western Europe and East Asia Pacific Figure 3.4. Despite being highly vulnerable to the climate change impacts, SSA accounted for 3% of the global investments. This is probably because more than 60% if climate finance is invested in the countries where it is raised. Specifically, for the years 2014, 2015 and 2016, the share of climate finance from domestic sources was 74%, 80% and 77% respectively. The strong domestic investment preference was attributed to risk perception where by investors have a better understanding of the risks in their domestic markets compared to those of the international markets.

In contrast, while the global trends indicate dominance in domestic investments, this is not the case for the developing economies that mainly rely on international sources to raise climate finances (Buchner et al., 2017). Thus, if developing countries are to meet their climate investments needs, then they must seek ways to mobilise domestic climate finance as well as work on their risk profile in-order to attract more international climate investments.

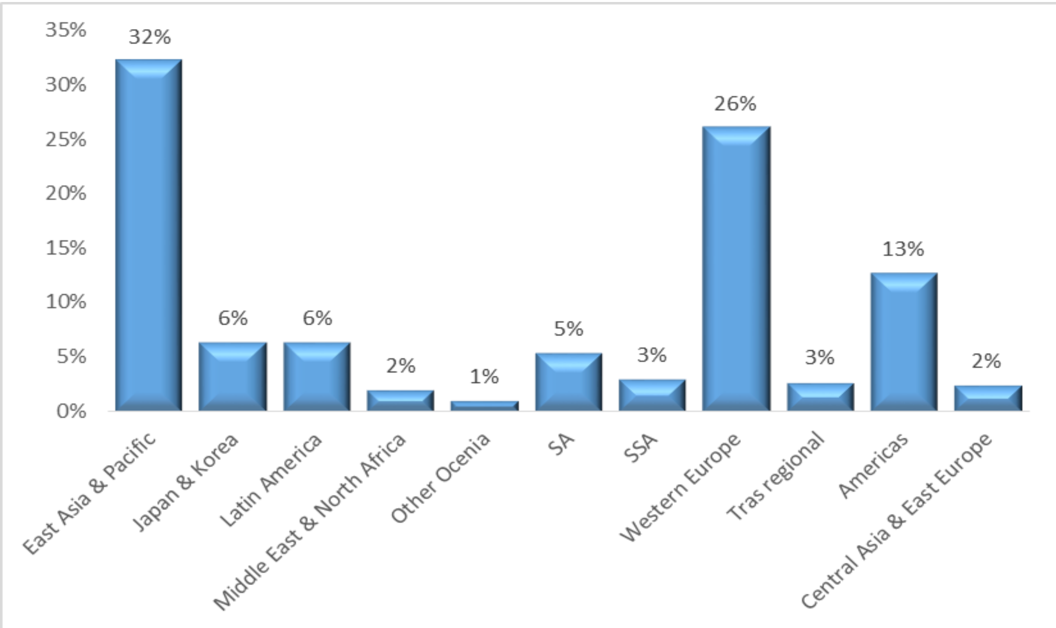

Figure 3.4: Geographic Distribution of Climate Investments

(Source: Buchner et al., 2017)

2.4 Climate Finance in Kenya: Estimated financial needs for adaptation in Kenya

Kenya is extremely susceptible to the impacts of climate change. The types of climate impact differ across Kenya's seven ecological zones. Specifically, the populous and agriculturally rich western provinces is likely to experience more frequent flash flooding and drought which are a serious risk to infrastructure and crop loss and subsequently lead to food insecurity with consequent threats to the economy through undermining farm based production (Caravani, Greene, Trujillo, & Amsalu, 2017).

In contrast, the drought-prone ASALs, are likely to experience an increase in the severity of existing climate hazards such as drought which may lead to food insecurity and undermine development progress in these regions (Caravani et al., 2017). Furthermore, a growing body of research makes both direct and indirect links between food insecurity and conflict – as proxied by scarcity and competition for natural resources (Helland & Sørbø, 2014). Specifically, extreme weather events in pastoralist areas have been linked to social consequences by eroding the customary social safety nets thereby, undermining food security and increasing potential for conflict over limited resources. Caravani et al. (2017). Additionally, as the communities respond to the negative impacts, they may result to adopting damaging coping strategies and depleting their assets leading to liquidity problems as well as reducing their overall income.

To address these impacts, taking into account both immediate and future needs, Kenya needs approximately $500m per year from 2012 onwards. Furthermore, adaptation costs are expected to increase by the year 2030 to between $1 and $2billion per year (Norrington-Davies & Thornton, 2011).

In comparison, between 2002 and 2018, approximately 23% ($3,760Million) of the total global climate finance was approved by multilateral climate funds for projects in SSA, out of this, approximately 3% (98Million) was for projects in Kenya. (Climate Funds Update, 2019). These funds were invested mainly in mitigation projects where approximately 69% was invested while 30% was spent on adaptation and 1% on reducing emissions from deforestation and degradation (REDD), through the World Bank's Forest Carbon Partnership Facility (FCPF) Figure 3.5.

Further analysis shows that majority of the funds allocated to mitigation (69%) was invested in the energy sector. In contrast, 20% of the finances approved was used in agriculture while multi-sectorial projects received the remaining 10% (Caravani et al., 2017; Climate Funds Update, 2019).

Since Kenya's economy is highly dependent on the performance of the agricultural sector (Awokuse & Xie, 2015), there is need to allocate more climate finance to agriculture in order to enhance the sectors resilience to climate change.

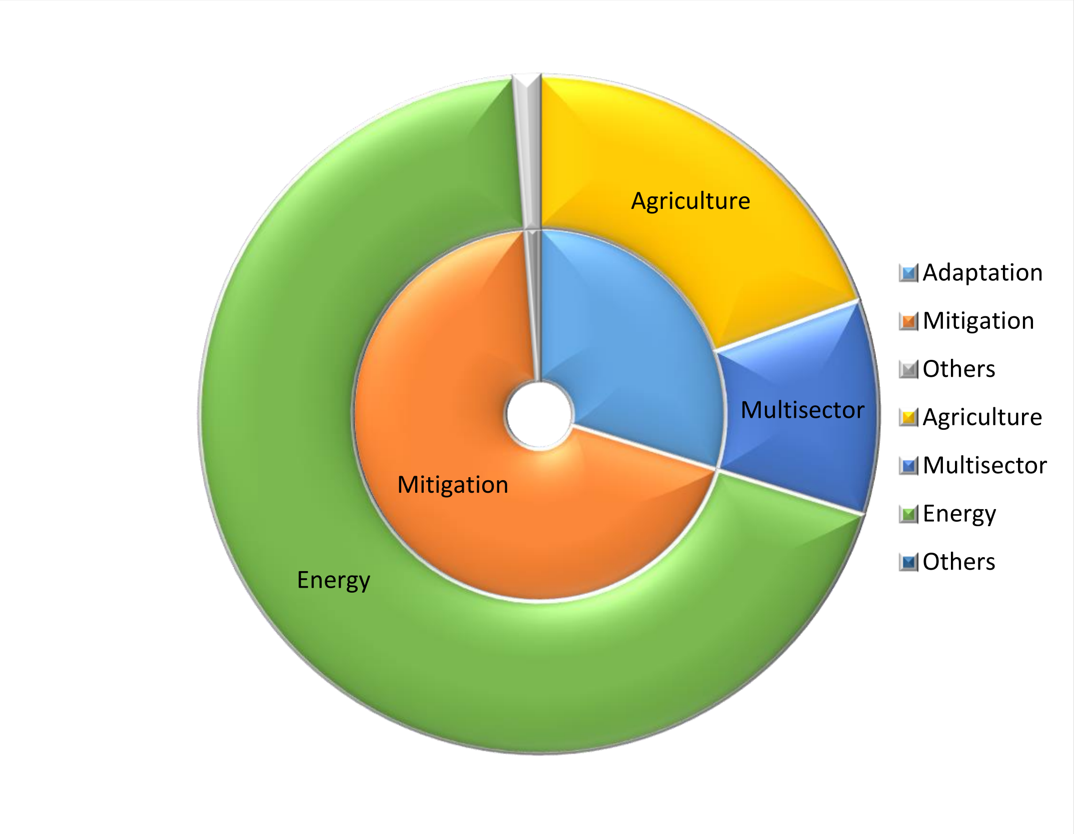

Figure 3.5: Distribution of Funds across Themes & Sectors

(Source: Climate Funds Update, 2019)

Undoubtedly, there is a huge difference between the climate investments needed to address climate change impacts in Kenya and the funds received for the same purpose. To meet its climate investment targets, Kenya will need to tap all sources of climate finance available from both the private sector and private sector both locally and internationally (International Institute for Environment and Development, 2014). In view of this, the Government of Kenya has introduced various strategies and policies aimed at tapping the global climate finance as well as mobilising domestic climate finances. At the national level, the Government of Kenya has developed a range of climate change policies based on an analysis of vulnerability across the country and broad consultations as part of development of the Kenya National Adaptation Plan (KNAP) 2015-2030 (Caravani et al., 2017). A review of this report shows that Kenya has budgeted for approximately USD $38 billion between 2015 and 2030 in for investment in adaptation. More than half of these funds (53%) will be allocated to infrastructure development followed by the water and sanitation (13% of the funds) while the energy sector will require approximately 9% of the total budget Figure 3.6.

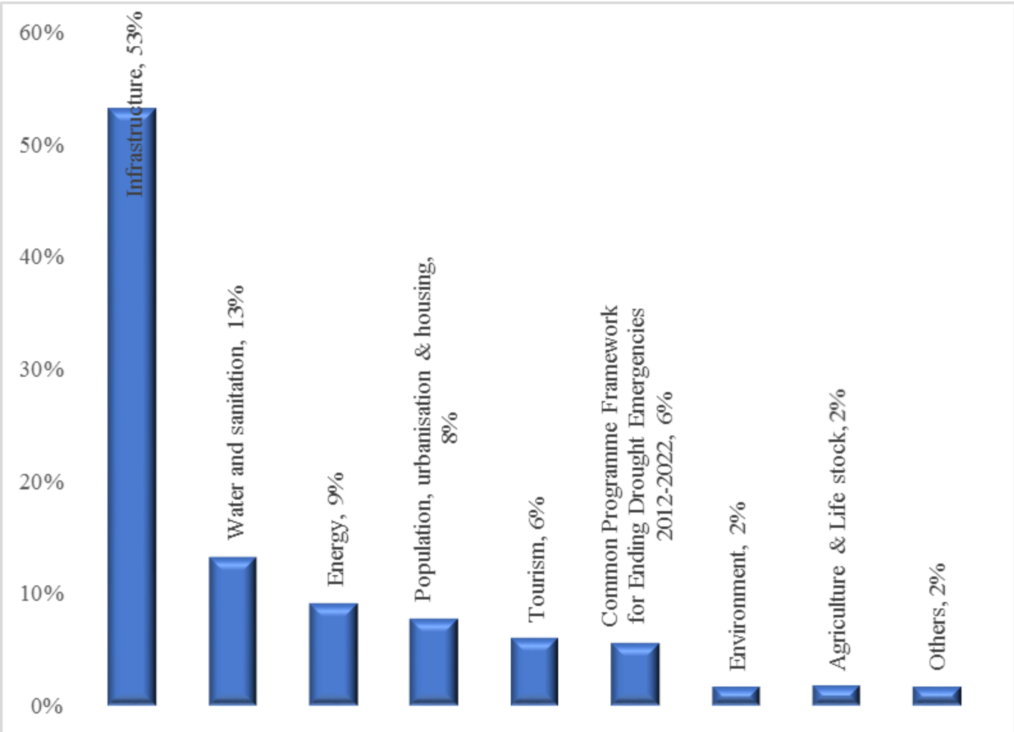

Figure 3.6: Kenya National Adaptation Plan 2015-2030 Budget Estimates (Source: Government of Kenya 2016)

In contrast, while the KNAP estimates rank the water and sanitation sector as the second highest in terms of funds needed to meet the 2015 – 2030 adaptation needs, this sector did not attract funds from the multilateral organisations (Caravani et al., 2017; Climate Funds Update, 2019; Government of Kenya, 2016a). This implies that the government needs to institute mechanisms to ensure that the sector attracts funds from both the public and the private sector if the identifies adaptation needs are to be met.

Furthermore, while the overall contribution of the agricultural to Kenya's GDP is about 52% (25.4% directly and 27% indirectly), this sector accounts for only 2% of the estimated adaptation funds leading to the question on the accuracy of the estimates in determining the agricultural financial needs in relation to the adaptation goals. The KNAP report then analysed the possible challenges that could be faced in achieving the set adaptation objectives Figure 3.7. Financing was identified as a major challenge to all the 20 sectors that were analysed. This was followed by capacity building at 90% and awareness creation at 70% of all the sectors analysed.

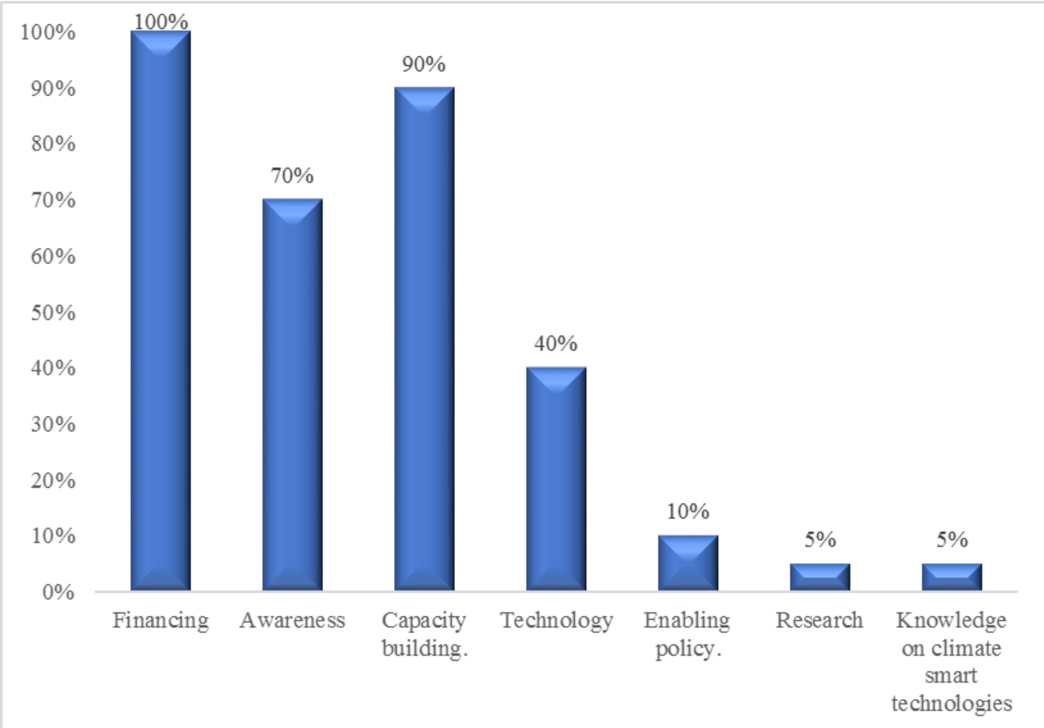

Figure 3.7: Challenges towards Meeting the KNAP Objectives

(Source: Government of Kenya, 2016a)

2.5 Conclusion

This chapter set out to review climate finance investments at the global level and carry out a comparison on how the global climate finance scene aligns with the Kenyan government's climate finance budgets and projections. The global climate finance investments were analysed through a systematic review of the literature from the CPI climate finance reports as well as the climate funds update data base. The national climate finance outlook was evaluated through a governance and institutional lens, by examining projected climate finance budget estimations as set out through national policy processes and strategies and to evaluate how these estimates are allocated across the various sectors and themes.

At the global level, the study finds that climate finance investments have been growing for the last few years. Some specific sectors did record a positive trajectory in relation to the finances raised vis a vis the projected needs by the year 2030. In particular, it was observed that the annual solar rooftop photovoltaic (PV) and onshore wind capacity additions and investment were on track to meet their share of the 2°C goal. Similarly, the multilateral DFI flows in 2016 were on course to meeting their annual finance mobilisation targets to be met by 2020. While these two areas showed a positive course towards meeting their year 2030 goals, the same cannot be said of the other sectors. Thus, a lot needs to be done to increase climate investments in the other sectors if the less than 2^{o} Celsius limit target is to be met.

Over the period studied, available evidence shows that significant levels of climate funding in Kenya and other developing countries came from international climate funds. This is in contrast to the global climate investment landscape which indicates that that majority of climate finances is invested in the country of origin. Thus, the region needs to put strategies in place that will help mobilise more domestic funds as well as attract more international climate funds in order to meet their investment needs.

At the national level, The Government of Kenya has been responding to climate change impacts through various policies aimed at ensuring better planning for the management of the climate change impacts. In particular the government has set out a detailed projection of the financial needs for the various sectors as estimated using various needs.

The national climate investment distribution by theme was consistent with the global climate investment landscape. Specifically, both the global and national investments allocated more funds to mitigation compared to adaptation. However, while the Government of Kenya has water and sanitation as a sector that should require more than half of the budget estimates, this sector had not attracted funds through the CFU updates.

Thus, the national policy narratives on funding with regard to this sector needs to be reviewed in order to enhance climate finance mobilisation as set out in the adaptation budgets.

This study finds that scaling up climate investments in Kenya is an ambitious programme, which will require substantial investment. A number of barriers that imped mobilisation of the necessary capital include policy and regulatory weaknesses, difficulties in accessing commercial finance and technical capacity shortcomings. This challenge is compounded by the fact that overcoming these barriers will also require public finance.

While the KNAP recognises the enormous amounts of finances needed to scale up climate investments in Kenya, this study finds that the recommendations on mobilisation of climate funds provides very little strategies on how to involve the private financial institutions including the stock markets in mobilising climate funds. Furthermore, their recommendations focus more on the energy sector whose characteristics may be significantly different from those of other sectors such as the agricultural sector whose main participants are smallholder farmers.

In the next chapters this study will estimate yield loss due to extreme weather events using the Value at Risk (VaR) method and evaluate the potential use of weather derivatives to mobilise finances/ manage the climate risks.

Chapter 3: Climate Finance and Agriculture

3.1 Introduction

Deliberations around weather patterns have taken a different political, economic and social significance due to the threat of climate change (Randalls, 2006). This author affirms that creation of financial markets based on the weather emphasises the significance of weather-talk as well as the processes of creating meteorological and financial knowledge that can predict or model the weather better.

To gain an understanding of the key issues around weather risk exposure in Kenya's agriculture and the importance of effective weather risk management in the sector, this chapter provides a background on Kenya's agriculture, the implication of weather risk to the sector and the application of derivatives as a risk management tool. Specifically, section 3.2 presents a review of Kenya's agriculture and its significance to the country's national GDP. Subsequently, the implications of climate change to the sector with a special focus on drought occurrences in the country was reviewed and presented in sections 3.3 and 3.4 respectively.

Upon reviewing the agricultural sector in light of climate change and the implications of climate risk to the sector, sections 3.5 and 3.6 present the possible approaches to weather risk estimation with a special focus on the application of VaR as a risk estimation technique. Then the approaches adopted to manage weather risk in Kenya's agriculture are presented in section 3.7. And finally, section 3.8 introduces the framework for this research illustrating the connection between extreme weather, the resulting weather risk in agriculture and describes the application of weather derivatives as a risk management tool.

3.2 Agriculture in Kenya

Agriculture contributes to approximately 30% of Kenya's GDP (Central Intelligence Agency, 2018; Kabubo-Mariara & Karanja, 2007). The performance of Kenya's economy is highly dependent on the performance of the agricultural sector (Awokuse & Xie, 2015). Kenya's agricultural sector comprises six subsectors namely industrial crops, food crops, horticulture, livestock, fisheries and forestry. The main food crops that are grown in Kenya are maize, wheat, beans, peas, bananas and potatoes with maize and beans being the most important crops that are grown in approximately 90 percent of all Kenyan farms (Government of Kenya, 2009).

The most important export crops in Kenya are coffee and tea (Alila & Atieno, 2016). These are grown by a large number of smallholder producers as well as a few large estate farmers. The country ranks among the world's leaders in black tea production with over 400,000 tons of black tea being exported every year (Kimutai et al., 2016).

Similarly, Kenya produces high-quality Arabica coffee that competes well on the world market. Immediately after independence until 1988, coffee was the country's leading export earner accounting for over 40 percent of total exports in some years (Aksoy, 2012). After the 1988–89 peak in coffee production and the subsequent decline in global prices, the share of total coffee exports declined to approximately 14 percent between the 1990 and 1999 and 5 percent from year the 2000 onwards (Aksoy, 2012). Reforms in this sector have the potential to increase return to the farmers and therefore attract more investors.

A summary of the agricultural production and export by sub-sector is presented in Figure 4.1. It is observed that the horticultural sub sector is the highest contributor of Agricultural GDP (AgGDP) at 33% followed closely by the food crops subsector that accounts for 32% of the AgGDP. The industrial crops subsector is the biggest export earner accounting for more than 55% of the agricultural export earnings.

While the food crops subsector was the second highest contributor of the AgGDP by accounting for 32% of the AgGDP, this sub sector accounted for only 0.5% export earnings. This implies that the majority of food crops produced are consumed in the country.

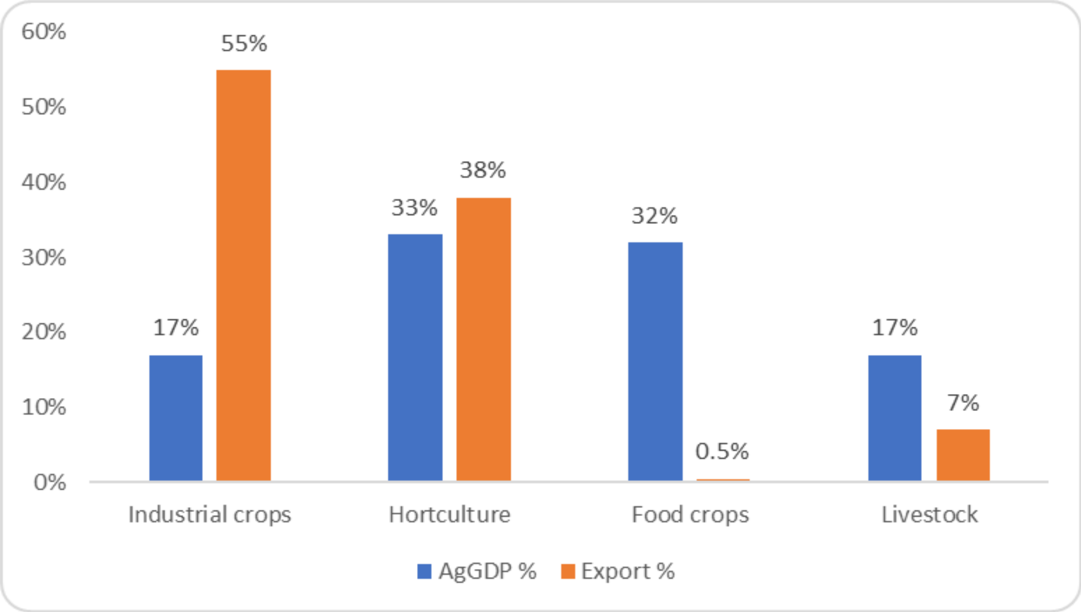

Figure 4.1: Summary of Agricultural Production and Export by Sector

(Source: Government of Kenya, 2010a)

Like other countries in East Africa, Kenya faces seasonal water shortages that make it important to use and distribute water in an optimal way. Irrigation-based farming is limited due to water scarcity as well as the high spatial and temporal variability of water resources (Damkjaer & Taylor, 2017).

Commercial horticulture is among the leading foreign exchange earners and a major employer but it is also one of leading water users in the country (Lanari, Liniger, & Kiteme, 2016). The main products from this sector include cut flowers, vegetables, fruits, nuts, herbs and spices (Government of Kenya, 2010a). Markets for Kenya horticultural exports are heavily concentrated in The United Kingdom, Holland, France and Germany which account for over 80 percent of the total volume of horticultural exports (Lanari et al., 2016). The United Kingdom (UK) has been a particularly important destination because of its historic ties with Kenya.

The domestic horticulture is dominated by small-sale production. Approximately 500,000 smallholder farmers are involved in horticulture producing 40 percent of exported fruits and 70 percent of exported vegetables. However, due to the capital-intensive nature of flower production and the phytosanitory requirements by importers, flowers and some vegetable production is dominated by large-scale producers (Government of Kenya, 2012b; Nyoro, 2002).

As can be seen in Figure 4.1 the livestock subsector is the fourth most important agricultural subsector in Kenya in terms of the contribution to AgGDP. It contributes to approximately 17% of the country's AgGDP and is practiced in different forms across the different agro ecological zones in Kenya (Government of Kenya, 2010a). The most common livestock kept in Kenya include cattle, sheep, pig and poultry among others. Kenyan cattle producers own approximately 14 million indigenous (Zebu) and over four million dairy cattle (Behnke & Muthami, 2011). The majority of dairy production is by small-scale farmers who keep between 2 and 3 cows on land sizes of approximately between 1 and 1.5 hectares.

Most beef is produced in range lands, although the farmers in these regions are small holders, they usually keep large herds of livestock mainly because of communal grazing in the rangelands. (Government of Kenya, 2010a) The large-scale farmers own ranches and keep introduced breeds of livestock.

Table 4.1 Livestock Population in Kenya - 2009 Census Figures

Description	Population	Production
Introduced Cattle	3,355,407	✓ 1.5 b litres of milk valued at (Ksh 100b ✓ 320,000 tonnes of beef valued at (Ksh.62.1billion)
Indigenous Cattle	14,112,367	
Sheep	17,129,606	✓ Total of 84t mutton & chevon (Ksh.14b)
Goats	27,740,153	
Camels	2,971,111	✓ 7000 tonnes meat (Ksh 1 Billion) 200 M litres of milk (Ksh 2 billion)
Pigs	334,689	✓ 12 tonnes of meat (Ksh 1.2 B)
Indigenous Chicken	25,756,487	✓ 20t Valued at (Ksh 3.5b) 1.3b eggs valued at (Ksh.9.7b
Chicken Commercial	6,071,042	
Bee Hives	1,842,496	✓ 14,600t honey &140t of bee wax valued at (Ksh 4.4 billion)
Donkeys	1,832,519	

(Source: Behnke & Muthami, 2011; Government of Kenya, 2010a)

3.2.1 Production scale

As earlier discussed, Kenya's agriculture is predominantly small scale. There are two other scales of production namely medium and large-scale production. As described in Table 4.2 small-scale production accounts for 75 percent of the total agricultural output and approximately 70 percent of marketed agricultural produce. Adoption of improved inputs and machinery by small scale farmers is relatively low compared to the uptake by the farmers in the medium and large-scale farming categories. In addition, the small-scale farmers have a lower access to credit facilities compared to the other farming categories. This is associated with factors such as lack of collateral, unstable income among others.

Table 4.2: Production Scale in Kenya

Farming scale	Characteristics
Small Scale Farming	- 0.2 – 3 ha - Mostly commercial basis - Accounts for 75% of total output - 70% marketed produce - Adoption of improved input low - In rangelands o Mainly pastoralist with huge herds of livestock o Production is mainly subsistence
Medium-Scale Farming	- 3 – 49 ha - Receptive of technology - Commercial agriculture - Better chances of getting credit
Large-Scale Farming	- 50 ha for crops and 30,000 ha for livestock - contributing to total of 30% of marketed produce - Main crops, tea, coffee, maize and wheat in addition to livestock - Use improved technology – increased productivity

(Source: Government of Kenya, 2010a)

Overall, the agricultural sector in Kenya is diverse in many forms. This is influenced by the weather conditions across the country as well as factors such as level of education, access to credit and access to land. Agriculture is very critical to

Kenya's economy. As a result, improvements in this sector is likely to positively impact on the overall performance of the country's economy.

3.3 Climate Change and Agriculture

Climate change is projected to have a growing impact on food security in Sub Saharan Africa (SSA) (Midgley, Dejene, & Mattick, 2012). It is likely to alter the functioning and resilience of ecosystems which support the livelihoods of millions of people in SSA and provide important safety nets in times of need (Midgley et al., 2012; Schlenker & Lobell, 2010).

Over 60% of Africa's households are smallholder rain-dependent farmers. Only 6% of cultivated land in SSA is irrigated, this is mainly in South Africa, Egypt, Madagascar, Morocco (New Partnership for Africa's Development, 2013). Rain-fed crop yields in some countries could decrease by approximately 50% due to climate change (Radhouane, 2013). This may have a catastrophic impact on the livelihoods of millions of farmers in SSA and the achievement of the Sustainable Development Goals (SDGs), mainly SDG-1 (No Poverty) SDG 2 (Zero Hunger) and SDG-13 (Climate Action).

Kenya's annual temperature variations are generally small (less than 5°C) throughout the country. The country's mean temperatures are closely related to the ground elevation with the arid regions of the North Eastern Province along the Somalia coast and to the west of Lake Turkana experiencing the highest temperatures where the night minimum may be as high as 29°C during the rainy seasons. In contrast, high altitude regions experience cooler temperatures with the coldest areas being the tops of the mountains where night frost occurs above 10,000 feet and permanent snow or ice cover the area above 16,000 feet (Mt Kenya) (Kabubo-Mariara & Karanja, 2007).

Most of the high potential areas in Kenya are located above an altitude of 1200m and have mean annual temperatures of below 18°C while 90% of the semi-arid and arid zones lie below 1200m and have mean annual temperatures ranging from 22^{o}C to 40^{o}C (International Livestock Centre for Africa, 1991). The high potential areas are mainly suitable for livestock farming (mostly cattle and sheep), cash crops (coffee, tea and pyrethrum) and key food crops (maize, beans and wheat). The medium potential zones favour farming systems similar to the high potential areas, but temperatures are higher and productivity lower. In these zones, barley, cotton, cassava, coconut and cashew nuts are also cultivated. In contrast the arid and semi-arid areas are less suited for arable agriculture but support sorghum, millet, livestock and wildlife (Kabubo-Mariara & Karanja, 2007).

Kenya is very susceptible to droughts with its impacts affecting many sectors of the economy. (Kichamu, Ziro, Palaniappan, & Ross, 2017). Moreover, the resulting drought impact reaches well beyond the areas experiencing the physical drought which further compounds the negative effects Wilhite, Svoboda, and Hayes (2007).

3.4 History of Drought Risk in Kenya

Sub Saharan Africa (SSA) has been cited as the region that is most susceptible to the impacts of climate change. This is mainly because its economy is extremely dependent on rain-fed agricultural production (Kotir, 2011; Wheeler & Von Braun, 2013). It is also the region with the highest proportion of food insecure people with an estimated regional average of 26.8% of the population undernourished in 2010–2012 (Porter & Reinhardt, 2007; Schlenker & Lobell, 2010). Given that majority of Africa's population are smallholder rain-dependent farmers, the impacts of climate variability would have adverse effects on food security and affect the livelihood of millions of people in the region.

Kenya has suffered several natural disasters ranging from drought, floods landslides and epidemics which have affected the livelihood of millions of people and even caused mortality (Guha-Sapir, Below, & Hoyois, 2016). Compared to other natural disasters, droughts have been more devastating in addition to being more frequent (Adhikari, Nejadhashemi, & Woznicki, 2015). These assertions are confirmed by D'Alessandro, Caballero, Simpkin, and Lichte (2015) who conducted an agricultural risk assessment for Kenya and found erratic rainfall, punctuated by severe droughts to have profound impacts on both crop and livestock production thereby ranking it as the biggest risk facing Kenya's agricultural sector.

In the last 100 years, Kenya has experienced approximately 28 major droughts (Huho & Mugalavai, 2010). The majority of these occurred in the last half of the 20th Century (Table 4.3). Furthermore between 1990 and 2010, seven national disasters were declared in Kenya with five of these being as a result of drought specifically in 1991-92, 1994-95, 1999-2002, 2004-2006 and 2008-09 (Table 4.3) while the other two occurred 1997-98 and 2003 and were due to floods related events (Huho & Mugalavai, 2010). Kenya experienced other severe weather-related emergencies within the same period (1960-2017) which although not declared a national disaster, their impact was fairly threatening.

Kenya's vulnerability to food insecurity is probably because over 80% of the land mass is classified as Arid and Semi-Arid Land (ASALs) which is highly susceptible to drought. In the past, Kenya recorded deficits of food due to drought resulting from a shortfall in rainfall in 1979-1980, 1984, 1999-2002, 2011-12, 2016-17 (Table 4.3). Widespread drought occurrence accompanied by rising levels of year-on-year rainfall variability are getting more unpredictable and increasing in frequency (D'Alessandro et al., 2015; Mutu, 2017). As an example, Kenya experienced an extreme rainfall event during two out of every three years, on average, between 1980 and 2012. The combination of high dependence on rain-fed agriculture and the high poverty rates among smallholder farmers and pastoralists who have limited coping capacity makes Kenya particularly vulnerable to the effects of these extreme weather events (D'Alessandro et al., 2015).

The increase in frequency and duration of these events leaves insufficient recovery time for the farmers before the next shock occurs. To illustrate this, during the 2008 to 2011 drought, crop related drought losses extended from 2008 to 2011 with crop losses, beginning in 2008 going up to 2011. This is probably because farmers who were indebted in 2008 became even more so in subsequent years leaving less income for reinvestment. Furthermore, faced by such circumstance, farmers could not use the proceeds from sale of surplus to purchase inputs for the preceding seasons (Government of Kenya, 2012a).

Table 4.3: Summary of Drought Events in Kenya between 1960 And 2013

Period	**Location**	**Associated disaster**	**Deaths**	**People affected (Millions)**
1965	Unspecified		*	0.26
1971	Countrywide	Food shortage	*	0.15
1979/1980	Turkana district	Food shortage	*	0.04
1984	Wide Spread	Food shortage	*	0.60
1991/1992	North Eastern regions		*	2.70
1994/1995	Northern & North Eastern districts		*	1.20
1997/1998	Wide Spread		*	1.60
1999/2002	Countrywide	Food Shortage	85	23.00
2004	Wide Spread	Crop failure - Food shortage	80	2.30
2005/2006	ASAL districts of Eastern, Coast, North Eastern and Rift Valley province	Famine	27	3.50
2008/2009	Wide Spread		4	3.80
2011	ASAL districts of Eastern, Coast, North Eastern and Rift Valley province	Famine	*	4.30
2011/2012	ASAL districts of Eastern, Coast, North Eastern and Rift Valley province	Food shortage	*	3.75
2014/2015	ASAL districts of North Eastern province, Rift Valley province & Marsabit Eastern province		*	1.60
2016/2017	Wide Spread	Food shortage	*	3.00

*Unknown; (Source: Guha-Sapir et al., 2016)

Evidently, Kenya has experienced several drought incidents in the recent past. Additionally, the occurrence of these droughts is frequent and in the absence of proper measures to cope, the short duration between consecutive droughts makes it difficult for rain dependent farmers to recover from the effect of droughts (Huho & Mugalavai, 2010). It is therefore crucial to enhance estimation and projection of drought driven financial risk exposure for drought preparedness. This is because the projections would indicate the probable finances needed to counter the likely losses that may be incurred due to drought occurrence and therefore enable better management of post-event recovery. Likewise, these projections could be used to evaluate the cost and benefits of adopting various adaptation measures.

3.5 Weather Risk Management in Agriculture

Farmers face a myriad of risks, some of which are as a result of climate change. In view of this, there is a need for risk management processes and products to be put in place to help the farmers to cope. There are four main approaches that farmers can use to manage risks namely mitigation, transfer, coping and risk avoidance or risk prevention. The latter is however hardly possible in agricultural production especially in developing countries where there are very few alternative sources of off farm employment (Bryla-Tressler, 2011). The appropriate risk management approach depends on various factors including the type of risk and magnitude as well as the available risk management options (Table 4.4).

Table 4.4: Risk Management Tools

POTENTIAL RISK MANAGEMENT MECHANISMS			
	HOUSEHOLD / COMMUNITY	**MARKETS**	**GOVERNMENTS**
Nonspecific	✓ Sharecropping ✓ Farmer self-help groups ✓ Water resource management	✓ New technology ✓ Improved seed	✓ Irrigation infrastructure ✓ Extension ✓ Agricultural research ✓ Weather data systems
Low	✓ Crop diversification ✓ Savings in livestock ✓ Food buffer stocks	✓ Formal savings	
Moderate	✓ Labor diversification ✓ Risk pooling (peers, family members) ✓ Money lenders	✓ Formal lending ✓ Risk sharing (input suppliers, wholesalers)	✓ State-sponsored lending
High / Catastrophic	✓ Sale of assets ✓ Migration	✓ Insurance	✓ Disaster relief ✓ State-sponsored insurance

(Source: Bryla-Tressler, 2011)

To effectively benefit from the available risk management options, there is need for the risk exposure and consequently the loss to be accurately estimated. These estimates are necessary when pricing financial products for hedging against the risk as well as calculating the payoffs to farmers once the risk event happens.

3.6 Value at Risk (VaR)

Value at Risk (VaR) is a measure of risk developed by the financial industry and widely used to meet the mandatory regulatory requirements for reporting financial exposure. It is defined as the maximum loss expected to be incurred at a specified probability within a defined period of time (Manfredo & Leuthold, 1999; Webby et al., 2007). Accordingly, VaR calculations estimate the risk of a portfolio over a certain holding period with a special focus to the lower tail of the probability distribution (Manfredo & Leuthold, 1999; Pérignon & Smith, 2010).

There are three broad approaches of estimating VaR namely; the parametric, non-parametric and semi-parametric methods. RiskMetrics and GARCH methods are classified as parametric approaches and can be used under both normal and non-normal distribution assumptions. Historical simulation method is a non-parametric approach that uses the empirical distribution of past returns to generate a VaR. While the Extreme Value Theory (EVT), CAViaR and quasi-maximum likelihood are classified as semi-parametric approaches Fan, Zhou, Jin, and Liu (2011).

VaR offers an attractive alternative to traditional risk measurement methods such as the traditional mean-variance framework and delta-gamma-vega analysis by; First, providing a single, summary statistic that measures the worst expected losses during a given time period, with a specified level of confidence, under normal market conditions (Philippe, 2001).

Secondly, VaR quantifies risks in terms of potential dollar or percentage losses, as opposed to classifying risk with respect to standard deviations relative to the expected returns (Hawes, Wilson, & Dahl, 2005). This author emphasises that although measuring risk in terms of standard deviations provides accurate estimates of risk exposure for normally distributed random outcomes, managers and decision makers think of risk in terms of dollars which makes VaR easy to understand.

Additionally, unlike traditional risk measures which consider any deviation from the expected return as a contribution to risk, VaR focuses on downside risk. In reality, decision makers do not view the potential for increased revenue as a true risk. Therefore, traditional risk measures that do not make this distinction can give distorted impressions of risk to those interpreting the figures.

Furthermore, VaR does capture the nonlinear payoffs of portfolios that contain options or option-like instruments. One of the fundamental assumptions of most traditional risk measures, including analytical VaR, is that returns of a given amount above or below expected returns occur with equal likelihood. While this assumption holds for portfolios that contain only physical assets, forward contracts, and futures contracts, the presence of options in a portfolio invalidates this assumption by introducing nonlinear payoffs (Hawes et al., 2005).

Despite the fact that VaR appears to address a lot of the weaknesses associated with other risk-measurement techniques, it should be applied with caution (Manfredo & Leuthold, 1999; Philippe, 2001). This is not perfect and it has several limitations as an example, VaR only describes the loss that will be exceeded with some level of confidence but says nothing about the absolute worst possible losses.

In addition, it assumes that the portfolio under consideration will remain constant over the entire time horizon under study. In practice however, the portfolio composition changes during the time horizon that VaR is measured due to normal trading activity which reduces the accuracy of the VaR estimate.

Thirdly, VaR relies on historical data making it difficult to quantify the risk associated with assets for which historical data are not available. Furthermore, it is possible for traders to "game" the VaR via options strategies and due to the superior information about VaR that a trader may have compared to the historically estimated VaR number (Philippe, 2001). Thus, VaR is not flawless and is most beneficial when used with the other traditional risk management tools that decision makers have and use. The only place where VaR may be responsibly substituted for traditional measures is in the boardroom where VaR provides an intuitive, easily understandable summary of total risk exposure (Linsmeier & Pearson, 2000).

Traditionally, VaR was mainly used in the finance and energy sectors. However, it is becoming popular in other fields such as natural resources management and agriculture (Hawes et al., 2005; Jackson, 2010; Manfredo & Leuthold, 1998). For example, Wang, Wang, and Wang (2015) as well as used VaR to measure agricultural drought disaster risk in the Chinese agricultural sector. Whereas (Webby et al., 2007) applied VaR and Conditional Value at Risk (CVaR) to address water resources planning and operational problems on the Mekong river. They demonstrated the use of the two risk measures in estimating the probable financial exposure for the government or potential aid don donors as a result of any natural or human-induced variability in the rivers water levels.

3.6.1 Extreme Value Theory (EVT)

One of the main challenges in modelling VaR is that most quantification approaches assume that the return data series of the asset under consideration follows a normal distribution (Singh, Allen, & Robert, 2013). The assumption of normality is not valid when the data series have heavy tails, which are characterised by extreme events left outside the bounds of a normal distribution when modelling VaR. Nevertheless, this problem can be addressed by using the distribution free assumption of quantile modelling statistics, and tools such as quantile regression or by applying extreme distribution based methods such as Extreme Value Theory (EVT) (Singh et al., 2013).

EVT is a branch of statistics dealing with the extreme deviations from the median of probability distributions. It seeks to assess, from an ordered sample of a given random variable, the probability of events that are more extreme than any previously observed (Santinelli, Morio, Dufour, & Jacquemart, 2014). EVT is widely used in many disciplines, such as structural engineering, finance, earth sciences, traffic prediction, and geological engineering. The Block Maxima Method (BMM) and Peak Over Threshold (POT) approaches are used for Extreme Value Analysis (EVA) (Hussain, 2016; Tzagkarakis et al., 2015).

The Generalized Extreme Value (GEV) family distributions including the Gumbel, Frechet and Weibull can be applied to estimate the extreme values using the BMM. In contrast, the POT method is applied to model the distribution of all observations that exceed or fall below a certain high/low threshold (Tzagkarakis et al., 2015). The Peak over threshold method models a distribution of excess over a given threshold. This method is preferred when analysing extreme events because it models the behaviour of a large exceedances over a given threshold (Singh et al., 2013).

To adopt the POT method, it is important that the threshold μ above which the excesses will be modelled be determined. The classical fixed threshold modelling approach uses graphical diagnostics, essentially assessing aspects of the model fit, to make an a priori threshold choice (Scarrott & MacDonald, 2012) . Some of the commonly used diagnostics and related statistics include the Mean residual life (or mean excess) plot, the Threshold stability plot(s) and a suite of the usual distribution fit diagnostics (e.g., probability plots, quantile plots, return level plots, empirical and fitted density comparison). This approach has the advantage of being simple because it requires practitioners to graphically inspect the data, understand their features and evaluate the model fit, when choosing the threshold. An important downside of these approaches is they do require significant expertise and can be rather subjective (Scarrott & MacDonald, 2012) Additionally, application of this approach when there are many datasets can be time-consuming.

3.6.2 Evaluation of Yield Risk

Several studies that have determined agricultural yield loss have been carried out in Kenya (Osgood et al., 2017). As an example, while piloting the use of index based insurance in Kenya, Osgood et al. (2017) used rainfall as the underlying index to price the insurance contracts for farmers as well as determine the payoffs in the event of loss. Similarly, Mungai, Ocheche, Othieno, and Wagacha (2015) applied a drought index when pricing weather derivatives for large scale wheat farmers in the Narok region of Kenya.

Modelling yield risk should be approached in a similar way to modelling the probability distribution of the crop yield in question (Xu, Zhang, & Zhang, 2011). There are two ways of modelling the crop yield distribution namely the parametric and the non-parametric approaches. Prior studies indicate that exclusive modelling of crop distribution by following normal distribution to be problematic.

Consequently, modelling of the yield distribution needs to be carefully selected (Wang et al., 2015). Both parametric and non-parametric methods are based on the laws governing average; however agricultural catastrophic events have a low probability with the high consequences falling in the tail of the specific distribution. This makes the use Extreme Value Distributions the most appropriate in estimating the agricultural catastrophic risks (Xu et al., 2011).

3.7 Weather Risk Management in Kenya's Agriculture

Weather risk refers to uncertainty in cash flows and earnings caused by weather events such as temperature, humidity, rainfall, snowfall, and stream flow among others (Brockett, Wang, & Yang, 2005). According to the Chicago Mercantile Exchange's (CME) website, approximately 20% of the US economy is directly affected by weather. Specifically, in 2008 the aggregate inter-annual dollar variation in U.S. economic activity that was attributable to weather variability was approximately 3.4%, or $485 billion of the country's Gross Domestic Product. Similarly, approximately $1.25 trillion of the European economy and $700 billion of the Japanese economy are exposed to weather risks (Brockett et al., 2005; Lazo, Lawson, Larsen, & Waldman, 2011).

In Kenya, losses as a result of weather variability have affected various sectors. The agricultural sector has been very vulnerable experiencing an estimated crop loss of more than US$5 billion from 1980–2012, or roughly an average of US$155 million annually. In particular, more than $250 million of losses was experienced in 2012 while the year 2009 experienced losses of approximately $300 million (D'Alessandro et al., 2015). Furthermore, the main agricultural crops in Kenya experienced significant production losses in one out of every three years starting from 1980 to 2012 due to adverse risk events. Maize crop experiencing the highest loss by production value. It accounted for nearly 20 percent of total indicative losses.

Nevertheless, the emergence of weather risk markets provides a promising and vibrant option for weather risk sharing. What's more, these markets have experienced rapid growth with frequent emergence of new weather-based risk management tools (Paulson & Hart, July, 2006). This is particularly the case in developed countries such as the US which have more developed financial markets.

In contrast, the development of derivative markets in the developing countries has been especially slow. As an example, there was an unsuccessful attempt to introduce derivatives at the Nairobi Securities Exchange in the early 2000s (Barasa & Mutende, 2013, March). Unfortunately, the lack of well-developed derivative markets in developing countries means that when natural disasters occur, households are frequently required to make a choice between preserving assets and destabilizing their consumption. Any of these choices could potentially lead to permanent consequences such as induction into the poverty traps (Janzen & Carter, 2013).

The question then arises, can financial instruments enhance the transfer of risk in such a way that reduces the need for households to rely on costly coping strategies that undermine their future productivity? To answer this question, we evaluate the weather-based derivatives for maize farmers in western Kenya.

3.7.1 Index Based Financial Derivatives

Derivatives allow businesses, investors, and municipalities to transfer risks and rewards associated with commercial or financial outcomes to other parties. A derivative contract is defined as an agreement between two parties, where one (the writer) promises to make a financial commitment to another (the purchaser or contract owner) if pre-defined conditions associated with the underlying asset eventuate (Little et al., 2015). They are mainly used to hedge against unwanted financial risk; to speculate in the hope of financial gain; or to benefit from asymmetry in information or circumstances via arbitrage.

Weather derivatives enable parties to trade weather related risks. The most commonly used instruments include futures, options and swaps (Musshoff, Odening, & Xu, 2006). For weather derivatives, temperature, rainfall and wind are the main underlying indexes that are used. The first weather derivative took place in 1996 between two firms in the energy industry (Cyr, Kusy, & Shaw, 2010). Since then the weather market between 1998 and 2008 grew remarkably by over $31 billion. These derivatives have been used to hedge against the risk in reduction of wine consumption, dairy production, losses by golf course, travel agencies, garment manufacturers, hair salons and drought risks (Cyr et al., 2010).

In agriculture weather derivatives have been used as a risk management tool for the probable losses that may arise due to variability in weather. As an example, using rainfall as the underlying index, Cyr et al. (2010) priced option contracts to hedge the risk in viticulture in the Niagara region of Canada. It was found that by using weather derivatives farmers would be able to hedge against losses in periods of excess rainfall. Specifically, using the burn rate analysis it was shown that in year 1977 farmers in the Niagara region would have been paid approximately $273,600 against a premium of $38,246 (Cyr et al., 2010).

In the same way rainfall based weather derivatives have been used for grain farmers in developed countries such as the United States of America (USA) and dairy farmers in Canada (Zhang, Zhang, & Tao, 2017). In Africa, index-based insurance has been the most commonly used weather-based risk management tool. Weather derivatives such as the options contracts have also been used to manage drought risk in countries such as Ethiopia, Kenya, Mali, and Morocco (Agrawala et al., 2008). Majority of these studies use rainfall and temperature as the underlying index with very few studies such as (Mungai et al., 2015; Zhu, Pollanen, Abdella, & Cater, 2012) using a drought index to price the contracts. The Index that they used was the Reconnaissance Drought Index (RDI).

Weather Derivatives for Maize Farmers in Kenya

A weather derivative is a contract between two parties that stipulates how payment will be exchanged between the parties depending on certain meteorological conditions during the contract period (Zeng, 2000). There are three commonly used forms of weather derivatives: call, put, and swaps.

Before the rise of weather derivatives, commodity futures contracts were used to hedge against price risk faced by farmers. Weather derivatives in contrast can provide farmers with an opportunity to hedge production risk whose variability is linked to weather variability. Weather derivatives are different from standard derivatives in complex ways. for instance, the underlying object (weather) is not traded in a spot market and unlike the mainstream financial derivatives which are useful for price hedging but not for quantity hedging, weather derivatives are useful for quantity hedging but not necessarily price hedging, (Campbell & Diebold, 2005). This provides a possibility of addressing agricultural production risk by issuing derivatives based on weather elements (Stoppa & Hess, 2003).

Several studies have been carried out on the modelling and pricing of weather derivatives in Kenya. As an example, Okemwa, Weke, Ngare, and Kihoro (2015) showed how to calculate risk neutral prices for rainfall derivatives. They used a standard rainfall model to simulate the rainfall process and then using the obtained results, estimated the probable risk as a result of rainfall variation.

In contrast, Mungai et al. (2015) explored the use of derivative instruments in managing drought catastrophic risk for large scale wheat farmers in Kenya. To achieve this, they used the rainfall and temperatures data to estimate the Reconnaissance Drought Index (RDI). This index was then used to price the drought option contracts, whose pay offs are the difference between the strike price (K), given as the aridity index for Narok and the value of the RDI. The study found that use of put option contracts would effectively hedge against drought catastrophic risk for large scale wheat farmers in Kenya.

In Kenya, non-governmental organisations have been the main players in the use of weather derivatives with government institutions and the Nairobi Securities Exchange (NSE) lagging behind in their adoption. As an example, Swiss Re, The Earth Institute at Columbia University and the Millennium Promise Alliance pioneered weather derivative contracts protecting several villages in Kenya, Mali and Ethiopia against severe. The option contracts were offered to smallholder farmers for protection against drought-related livelihood shocks such as food shortages and famines. Approximately 150,000 people are expected to benefit from this project (Hellmuth, Osgood, Hess, Moorhead, & Bhojwani, 2009)

3.7.2 Efficiency of Option Contract

Efficient transfer of risk has the potential to enhance resilience and therefore avoid the poverty trap. Weather derivatives provide an alternative in managing weather risks. Furthermore, effective hedging of weather risks has the potential to lead to an increase in global production by over USD$250Billion (Cyr et al., 2010). Besides, weather-related risks as a result of climate change could lead to losses of up to 19% of the Gross Domestic Product (GDP) in some countries and regions by the year 2030. Furthermore, using Weather Derivatives (WD) in the agricultural sector could help in hedging weather risks especially those associated with yield variations (Zong & Ender, 2016).

However, while derivatives trading has been introduced in more developed financial markets such as those of Unites States of America (USA) and Europe, the uptake in developing economies such as Kenya has been low. In the early 2000s there was a push by stakeholders in the financial industry for a derivatives trading platform. This lead to the reorganisation of the Nairobi Securities Exchange into four main segments, one of which is the Futures and Options Market Segment. Its operationalisation however did not take off, (Barasa & Mutende, 2013, March). This failure has been attributed to challenges such as low level investor sophistication, lack of commodities on a large scale, inadequate liquidity, among others.

The majority of the studies on WD focus on how to price the contracts (Alaton, Djehiche, & Stillberger, 2002; Erhardt & Smith, 2014; Zhu et al., 2012). Similar studies have been conducted in Kenya as well. As an example, Mungai et al. (2015) conducted a study on the use of drought index to price a weather derivative while Okemwa et al. (2015) modelled and used a rainfall index to price an option contract for the Kenyan market. While pricing of derivatives is an important aspect of WD, it mainly addresses the sellers' needs in the WD market.

For potential purchasers like farmers, the question whether WD are efficient hedging instruments is as important as the pricing (Ender & Zhang, 2015; Zong & Ender, 2016). Yet, the efficiency problem has not been analysed sufficiently (Zong

& Ender, 2016). Besides, majority of the studies on efficiency have been conducted for developed markets such as those of USA, Germany and some parts of Europe.

This study therefore analysed the efficiency of SPEI based WD in hedging against risk of loss by Kenya's maize farmers due to weather uncertainties. This study finds that the use of SPEI based option contracts did not reduce the farmers risk exposure. There is need for further studies on issues such as the optimum strike level and price and its effect on the efficiency of the SPEI based option contracts.

3.8 Key Themes to Agriculture & Climate Finance

This study evaluates the use of financial products to manage weather risks for maize farmers in Kenya with the weather event of interest being drought. Figure 4.3 is a simple diagrammatic representation of the relationship between the extreme weather event and the risk exposure to farmers. This framework presents three possible concerns for agricultural investors namely, the yield risk exposure, which according to Hess et al. (2002) results from agriculture's is inherently dependence on the vagaries of weather, such as the variation in rainfall. As a result, a change in the weather patterns usually results in changes in agricultural production especially for rain dependent farmers and similarly affects the farmers' ability to repay debt.

Secondly, farmers and other stakeholders are interested in knowing the financial products that are available to them as well as the optimum prices that should be charged to them and finally, the farmers would be especially interested on information regarding the efficiency of these contracts in hedging against weather risks (Vedenov & Barnett, 2004). To address these questions three empirical approaches are adopted. First the VaR approach is applied on the yield to estimate the yield risk exposure. Then, the Viability of SPEI as an index for pricing derivative contracts is evaluated, and finally we compare the revenue with and without an option contract hedge to evaluate the weather contracts efficiency in hedging against these risks.

3.8.1 Drought

In their study, Wilhite and Glantz (2009) found that there were numerous published definitions of drought. These definitions were influenced the differences in regions, needs, and disciplinary approaches. These authors summarised the various definitions into categories based on the basic approaches in measuring drought (Figure 4.2).

The four categories are meteorological drought, hydrological drought, agricultural drought, and socioeconomic drought. These four can be further narrowed down based on the first, the physical characteristics of drought e.g. meteorological drought, soil moisture drought or hydrological drought or by the consequences of drought on socioeconomic and environmental systems, i.e. its negative impacts. These impacts can either be direct (e.g. reduced crop yields) or indirect (e.g. increased costs for food due to reduced crop yields) and can occur across a wide range of temporal and spatial scales (Blauhut et al., 2016).

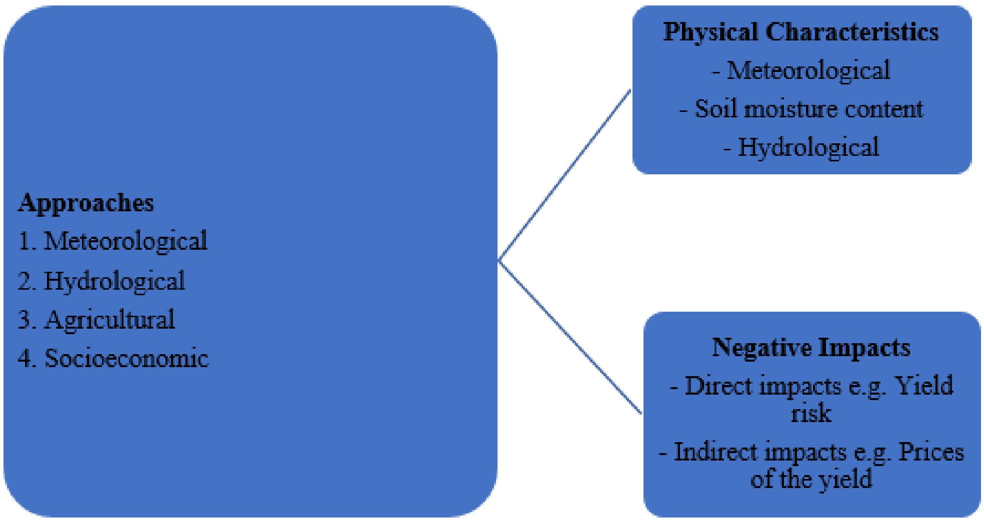

Figure 4.2: Classification of Drought

To link drought with agricultural risk, this study adopted the impacts approach and focused on the effect of drought to farmer's production/yield. Then, a drought index was used as the underlying index to price the weather derivative. The decision to adopt the impacts approach was informed by the fact that a robust drought event attribution that quantifies the probable risk of such events helps to support decisions such as post disaster recovery, pricing of insurance and other financial products (Stott, 2016). In addition, an analysis of the efficiency of these financial products in managing drought risks could be helpful in improving their design and therefore usefulness to the buyers.

3.8.2 Yield Risk

The main direct effects of drought is a fall in crop production due to inadequate and poorly distributed rainfall (Toulmin, 1987). When this happens farmers experience losses and possibly have to make some adjustments to cope. To quantify the drought risk, this study adopted the impacts approach with the risk measure being the changes in yield. This approach borrows from Wilhite and Glantz (2009) who considered changes in production as a way of classifying drought. The variation in yield variation was obtained by comparing the average/expected yield with the actual yield. After estimating the yield variation, the VaR technique was used to estimate the possible risk as a result of the variation in weather. Xu et al. (2011) and Wang et al. (2015) adopted this approach when estimating drought risk in China's agriculture. The calculated VaR represents the yield risk that farmers are exposed to as a result of weather changes. After obtaining the probable yield risk, this study then explored the application of a drought index to price an option contract for the maize farmers.

3.8.3 Pricing of Weather Contracts

Financial products provide an attractive alternative for weather risk management. The most commonly used weather based financial instruments are weather derivatives. These are mostly in the form of options, swaps and future contracts. Most of the contracts are traded Over the Counter - OTC though some can be traded on Future Exchanges (Paulson & Hart, July, 2006). The Value of the WD is derived from the underlying climatic risks as measured by means of indexes built from available meteorological data. For a weather based agricultural derivative to be efficient, the correlation between the chosen weather variable and the yield should be high.

The most commonly used weather variables when designing weather derivatives are temperature and rainfall because they have been cited as the main weather variables affecting crop yield (Leng, Zhang, Huang, Asrar, & Leung, 2016; Mungai et al., 2015). However, most of the models that have been used to construct the underlying index use only one of the factors at a time. This implies that the resulting models only account for one factor when valuing the derivatives. To counter this problem, adoption of a weather variable that takes into consideration both rainfall and temperatures should be considered.

This study contributes to the existing body of knowledge by exploring the use of the Standardized Precipitation Evapotranspiration Index (SPEI) to price of an option contract. SPEI Index was first proposed by Vicente-Serrano and other in 2010 as an improved drought index that is especially suited for studies of the effect of global warming on drought severity Begueria, Vicente-Serrano, Reig, and Latorre (2014). This Index is calculated by obtaining the difference between precipitation and reference evapotranspiration (P – ETo) to obtain the monthly climatic water balance in the soil. Consequently, it is designed to take into account both Precipitation and Potential Evapotranspiration (PET) to characterise drought. This presents one of SPEI's main advantage over other drought indices which is its ability to identify the role of evapotranspiration and temperature variability with regard to drought assessments in the context of global warming (Ming et al., 2015).

The SPEI index can be estimated for different time lags ranging from 1 month to 24 months. The values at different lag shows the intensity of drought related to different ecosystem e.g. seasonal lag (3, 6 month lag) for agricultural drought and long-term (12, 24, 48 month lag) for hydrological drought (Miah, Abdullah, & Jeong, 2017). In addition, the drought index can be used to determine the level of drought or flooding during the specific periods. Table 4.5 presents the different SPEI values and their corresponding meaning.

Table 4.5: The SPEI Categories

Drought/Wet severity	**SPEI**
Extreme drought	SPEI ≤ -2
Severe drought	-2 < SPEI ≤ -1.5
Moderate drought	-1.5 < SPEI ≤ -1
Near Normal	-1 < SPEI ≤ 1
Moderately wet	1 < SPEI ≤ 1.5
Severely wet	1.5 < SPEI ≤ 2
Extremely wet	SPEI > 2

(Source: Miah et al., 2017; Ming et al., 2015)

The three main approaches that are adopted when pricing of weather contracts are the actuarial approach, extended risk neutral valuation and utility maximization including consumption based asset-pricing models (Cyr et al., 2010). These authors clarify that irrespective of the nature of the underlying weather variable that is used, each of the three pricing approaches has its limitations. Notably, even though the actuarial approaches are commonly employed by practitioners they lack a sound theoretical underpinning.

In contrast, the extended risk neutral valuation approaches do not result in unique prices, but rather price bounds which, in general, can be quite large. And finally, while the asset pricing models such as CAPM can be used to estimate a market price for risk, they require assumptions that may be considered to be more restrictive and unrealistic than the argument of no-arbitrage employed in the Black-Scholes-Merton approach. While the pricing of weather contracts remains problematic, they still offer significant potential for the hedging of important weather related risk factors, as evidenced by their increasing use (Cyr et al., 2010).

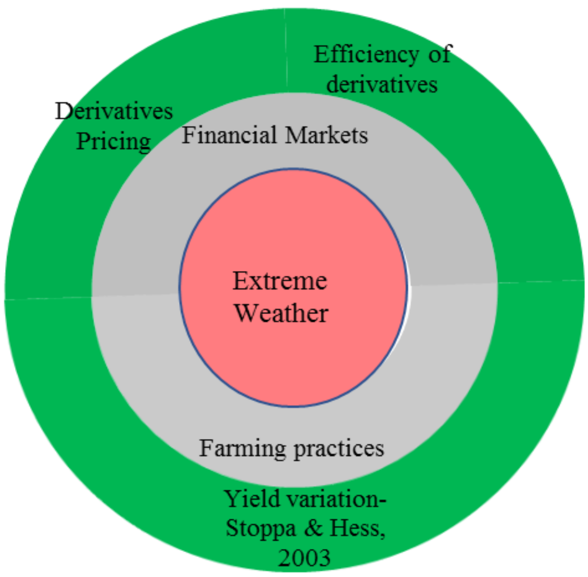

Figure 4.3 A Simple Analytical Framework Linking Extreme Weather to Drought Risk

3.8.4 Efficiency of Weather Contracts

The efficiency of WD refers to how well the WD contracts shield the farmers from the weather risks. While the use of weather derivatives as a risk management tool has received considerable attention in the literature in the recent past, the bulk of these studies have focused on the pricing of the contracts and institutional frameworks that would be required to introduce weather-based insurance, especially in developing countries (Vedenov & Barnett, 2004).

While these studies contribute to the literature and decision making, they focus more on the seller's side of the market. Nonetheless, Potential purchasers of weather derivatives are not only concerned with the price but also with how well the contract help to cushions them from the probable weather risks.

This analysis contributes to the existing literature on WD by considering the efficiency of SPEI priced weather derivatives as risk management instruments for crop production. In particular, an option contract for maize farmers in western Kenya will be priced and evaluated for efficiency in risk reduction. To evaluate the efficiency of option contracts, the risk exposure with and without the contracts will be estimated. To achieve this, a revenue function with the contract and without the contract will be estimated. Using VaR, the risk in both situations will be estimated. A detailed description of the analysis procedure is presented in Chapter 3 while the results are explained in chapter 6

3.9 Conclusion

This chapter surveyed existing literature pertaining to Kenya's agriculture and weather patterns whilst also identifying the sectors susceptibility to drought events. In addition, the application of weather based financial products was reviewed and presented.

The available literature shows that Kenya is highly susceptible to drought. This is probably because the country's arid and semi-arid regions experience high temperatures and low rainfall making them more sensitive to variations in weather. Drought events were also cited to have impacts across different sectors of the economy and beyond the physical places that they occurred.

Given the country's vulnerability to drought and the effects of drought on the economy it is important to put measures in place to help the communities to cope. Accurate estimation of the drought risk provides a base for government and other stakeholders to estimate the resources that would be needed when drought occurs.

Chapter 4 reviewed the application of VaR to estimate drought risk for maize farmers in Kenya. Subsequently, the use and effectiveness of index-based weather derivatives as risk management tools for financial loss arising due to drought was evaluated. The review of Kenya's agriculture and the use of weather derivatives to manage climate risks provides a better understanding on the topic and lays the foundation for estimation of drought risk in chapter 6 and modelling of weather derivatives for maize farmers in Kenya in chapter 7 and Chapter 8.

Chapter 4 provides a broad overview of climate finance performance identifying the challenges encountered when mobilising/ accessing climate finance and the innovative ways that have been adopted to manage these obstacles.

Chapter 4: Climate Finance: Experience to Date

4.1 Introduction

A global shift towards the low carbon economy is key to achieving the U.N. climate change negotiations goal of limiting global temperature increases to less than 2 degrees Celsius above pre-industrial levels (Meltzer, 2015). Significant financial resources will be needed to limit the global warming to less than 2 degrees (Baker, Bergstresser, Serafeim, & Wurgler, 2018; Zhang, Zhang, & Managi, 2019). Approximately $53 trillion will be needed for energy-related investments by 2035 while the global infrastructure will need approximately US$6.2 trillion annually or approximately US$93 trillion in total between 2015 and 2030 in order to transition to the low carbon pathway(Granoff, Hogarth, & Miller, 2016; Zhang et al., 2019). Similarly, at least $70 to $100 billion of investment will be needed every year for every year from 2010 to 2050 if climate change adaptation needs are to be met (Sovacool & Van de Graaf, 2018).

The financial resources needed to support African countries to adapt to climate change are enormous. It is estimated that approximately US$100 billion to $200 billion is needed for mitigation in developing countries while adaptation cost estimates vary widely, anywhere between the World Bank's $10-$40 billion in 2020 to the UNDP's estimate of $86 billion annually (Brown et al., 2009)

Climate finance provides funding opportunities to aid the transition to low carbon investments as well as to adapt to climate change. In addition, climate finance is also used to support developing countries to reduce emissions, decarbonise their economies, and adapt to the impacts of climate change (Nakhooda et al., 2014). This is based on the concept that the contribution of countries to climate change, and their capacity to prevent and cope with its consequences, varies enormously with developed countries contributing the most to climate change while the developing countries have the weakest capacity to cope (Haites, 2011). Thus, developed country parties made a commitment to provide financial resources aimed at helping developing countries to cope with the impacts of climate change. This is confirmed by analysis of climate funds sources which shows that that the high-income countries account for more the 90% of the climate funds pledged and deposited for climate investments Figure 4.1

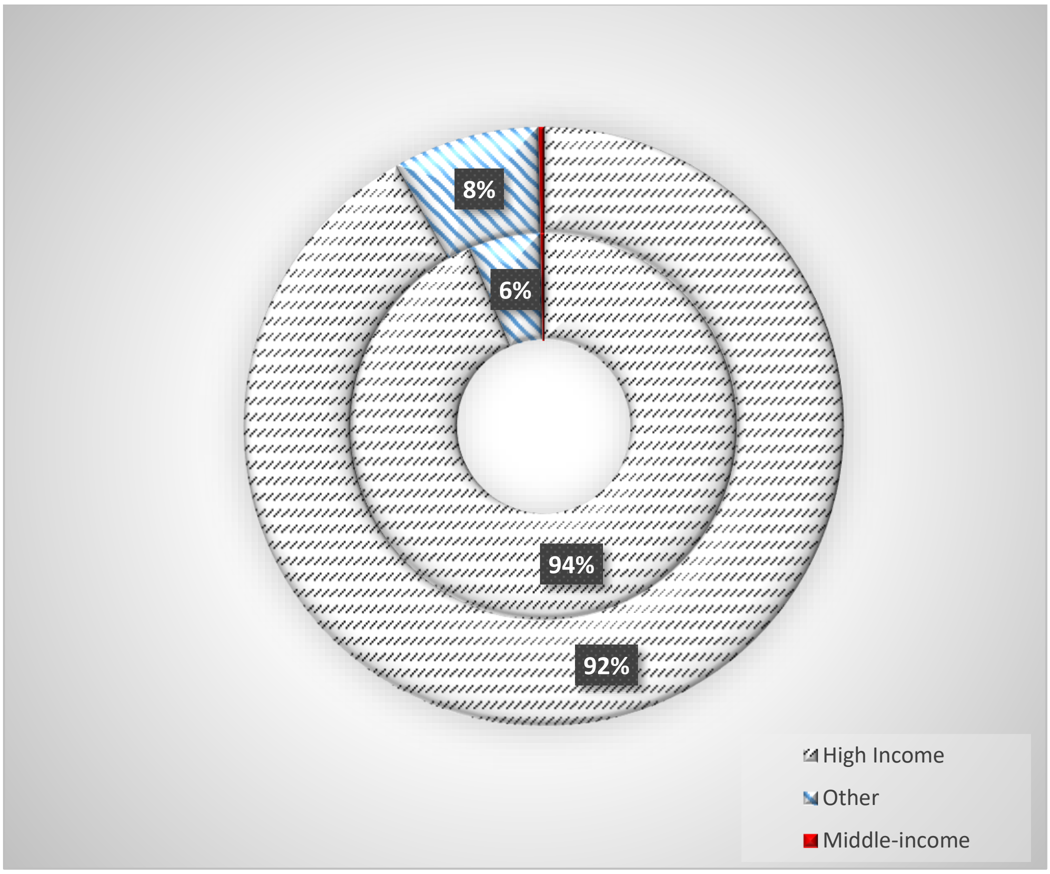

Figure 4.1 Funds Sources by Income Level

(Source: Buchner et al., 2017; Climate Funds Update, 2019).

In order to justify a continuation or scale-up of their commitments, governments and other providers of climate finance need evidence on the performance of climate funds. This section evaluates climate finance investments in SSA with a focus on the current gaps and the innovative financing mechanisms that have been adopted to upscale climate investments.

4.1.1 Energy

Climate investments can be broadly classified into three categories namely, agriculture, forestry and renewable energy. The energy sector is the largest producer of GHG emissions with the energy related-activities accounting for approximately 68% of total anthropogenic greenhouse gas emissions (Chirambo, 2018).

Presently, Africa contributes only a small fraction of the global emissions. In the year 2009, continental Africa accounted for approximately 3.2 % of global CO_2 fossil fuel emissions and Sub-Saharan Africa for less than 1 % of global emissions (Calvin, Pachauri, De Cian, & Mouratiadou, 2016). However, without mitigation efforts Africa would become a major emitter of carbon by the end of the century (Schwerhoff & Sy, 2017). Furthermore, the continent should avoid becoming heavily dependent on carbon intensive energy options and in so doing circumvent the risk of stranded assets that may arise from the carbon intensive investments (Caldecott et al., 2016).

A worldwide transition to a low-carbon energy future is a costly undertaking. The global renewable energy capex costs are estimated to increase from $1.8tn per annum in 2015 to $2.6tn annually by 2050, and even this level of spending would not bring the world in line with the 2°C target (Lo, 2017).

It is estimated that Africa and the Middle East will need approximately $450 billion for renewable energy for the decade from 2010 to 2020 (Kaminker & Stewart, 2012; Schwerhoff & Sy, 2017). This is an arduous task especially for the African continent which is already experiencing a financing gap in the energy sector (Schwerhoff & Sy, 2017). This is confounded by the expected population and economic growth which will lead to an increase in demand for energy. Indeed, the total population in SSA is expected to more than double in size between 2015 and 2050 with some countries such as Zambia, Angola, Uganda, Mali, Tanzania, Burundi, and Democratic Republic of Congo experiencing more than 150% growth in population (Cleland & Machiyama, 2017). At the same time, SSA is expected to experience fast economic growth. According to the World Economic Outlook of the International Monetary Fund, GDP growth will be above 5.5% per year from 2015 to 2019 while the shared socio-economic pathways (SSPs) expect in a "middle-of-the-road scenario" that GDP in Sub-Saharan Africa will grow with an average annual rate of 3.5% until 2100, so that it almost reaches the development level of the US today (Schwerhoff & Sy, 2017).

The expected social and economic development and population growth in sub-Saharan Africa will lead to an increase in per capita energy consumption (Warner & Jones, 2018). Faced with the existing financing gap for energy investments and the challenge of offering a development perspective to a rapidly growing population, it might be tempting for Africa to pursue a strategy of fuelling growth with the cheapest source of energy available (Schwerhoff & Sy, 2017). This would however lead to more GHG emissions and the risk of straddled assets trapped in fossil fuel related energy investments.

However, the continent has the opportunity to close in the financing gap while avoiding the straddled asset risk by tapping on the available climate funds. This is because most of the clean energy investments are geared towards reducing the sectors emissions of the GHGs which are considered as the principal contributors to climate change. Consequently, climate finance is now considered as an integral factor that can influence the rates of clean energy deployment nationally and globally, and more particularly in developing nations (Chirambo, 2018).

Compared to the other sectors, the energy sector has had more success in attracting the available climate finance. An analysis of the global climate finance flows shows that mitigation has received the majority of climate finance to date (Nakhooda, 2013). However, during the period starting 2003 to 2016, only approximately 40% of the approved amounts had been disbursed to the various projects (Table 4.1). This implies that less than half of the funds approved have been released to the respective projects. This phenomenon is replicated across all the climate finance themes. As a result, section 4.2 to 4.4 will evaluate some of the identified challenges in relation to climate finance disbursements and the various ways that these challenges have been managed by different actors.

Table 4.1: Main Funds Supporting Mitigation (2003-2016, USD millions)

Fund	Pledged	Deposited	Approved	Projects approved
Clean Technology Fund (CTF)	547	5,404	4,959	101
Global Energy Efficiency & Renewable Energy Fund (GEEREF)	170	164	89	11
Global Environment Facility (GEF4)	1,083	1,083	926	234
Global Environment Facility (GEF5)	1,350	777	746	172
Global Environment Facility (GEF6)	1,101	1,078	349	76
Partnership for Market Readiness (PMR)	127	118	52	30
Green Climate Fund (GCF)	10,255	9,896	314	7
Scaling-Up Renewable Energy Programme (SREP)	745	742	236	29
Totals	**15,378**	**19,262**	**7,671**	**660**

(Source: Nakhooda, 2013)

4.1.2 Forest and Land Use

Deforestation is the second largest anthropogenic source of carbon dioxide emissions after fossil fuel combustion (Van Der Werf et al., 2009). The sector accounts for up to 18% of the emissions or approximately 5.8 billion tonnes of CO_2 equivalent released into the atmosphere each year (Holloway & Giandomenico, 2009). Furthermore, approximately 50% of the terrestrial organic carbon is stored by tropical forests making these forests very important in regulating global climate (Araya & Hofstad, 2016). Thus, reducing emissions in the sector has the potential to significantly contribute to the global climate change agenda. In view of this, the Reducing Emissions from Deforestation and Forest Degradation (REDD) policy of the United Nations was developed in 2008. The REDD policy did not cater for the emissions reductions from conservation and sustainable management of forests which have been shown to contribute significantly to avoided emissions. Thus, in 2010 the REDD policy was modified to include conservation and sustainable management of forests and named REDD+ (Reducing Emissions from Deforestation and Degradation, and enhancing forest carbon stocks) (Araya & Hofstad, 2016; Holloway & Giandomenico, 2009).

REDD+ aims to provide incentives to developing countries in return for forest conservation, with the goal of reducing greenhouse gas emissions (Neto, 2015). In the recent past, the principle of providing financial incentives to developing countries for REDD and REDD+ has gained widespread acceptance by policy makers at the global scene (Clements, 2010). This mechanism is a performance-based payment for ecosystem service through which developing countries are rewarded by developed countries for their efforts towards forest conservation (Neto, 2015) REDD+ is highly attractive to policy makers mainly because economic analyses show that it is a relatively cheap and cost effective way of reducing GHG emissions and climate change mitigation (Araya & Hofstad, 2016). In addition, it enhances environmental conservation while promoting financial transfers to some of the poorest countries and their peoples (Holloway & Giandomenico, 2009).

4.1.3 Agriculture

According to the Intergovernmental Panel on Climate Change (IPCC), the Agriculture, Forestry, and Land Use (AFOLU) sector contributes approximately 25% of global greenhouse gas emission (Intergovernmental Panel on Climate Change, 2014). Consequently, transitioning this sector to a low carbon pathway has the potential to eliminate significant amounts of GHG's that are emitted to the atmosphere.

Previous studies indicate that transforming the agriculture sector and building resilience will not be possible without significantly increasing the amount of capital available for climate-smart investments (Palmer, 2016). Access to finance, credit facilities and other financial services has long been a challenge for agriculture mainly because of the perceptions of low profitability and high risks (Palmer, 2016; Salami, Kamara, & Brixiova, 2010). Consequently, robust financial investments are needed to support this sector to develop while at the same transitioning to low the carbon investment pathway. To achieve this, innovative financing mechanisms need to be introduced to meet the sector's requirements.

Climate finance presents funding opportunities for climate related agricultural initiatives in developing countries. The agricultural sector could benefit from these funds by aligning their investments to the climate related activities. While climate finance presents financing opportunities for the agricultural sector, the flow of funds to relevant projects has been slow. This chapter analyses the opportunities and challenges that the agricultural sector has encountered when accessing climate finance.

4.2 Benefits of climate finance

There is great potential for reducing GHG emissions across the various sectors in our economy by investing in low carbon alternatives. Various funds have been set up with the aim of financing climate smart investments in different parts of the world. These funds have been used to finance several climate related investments across the different sectors around the globe. For developing economies, the funds have been set up with the aim of managing climate change as well as improving the livelihood of the people in the communities. This brings up the question - are the funds achieving the objectives that they were set for? Are the communities benefiting? The following section presents a summary of the possible benefits of climate financed projects in agriculture. The agricultural sector was chosen because of the major role it plays in developing economies such as Kenya.

4.2.1 Increased productivity of agricultural yield

Agriculture in Africa is exposed to a variety of risks and uncertainties such as market risks, institutional risks and production risks. Agricultural production risks are aggravated by climate variability such as drought and floods – pest and disease outbreaks and windstorms (Asfaw & Lipper, 2016). These risks increase the unpredictability of domestic production and staple food prices. Furthermore, in the absence of risk management institutions, farmers adopt less risky and less profitable land uses that lower overall productivity and consequently the possible incomes from the farming ventures. Nonetheless, various studies show that the adoption of effective risk mitigation strategies has the potential to increase farm incomes by as much as 30 percent (Antonaci, Demeke, & Vezzani, 2014). This implies that channelling of climate finance towards climate risk management has the potential to manage agricultural risks including production risks as well as increasing the incomes of the respective farmers.

An analysis of the impacts of climate financed agricultural projects in Nepal reported increased productivity in the regions that benefited from the climate financed projects compared to those that had not embraced climate related agricultural investments. Specifically, investment in climate related investments led to increased productivity of cereal crops for the regions that adopted climate smart farming techniques (MoALMC, 2018). Similarly, the adoption of climate smart investments has been credited with increased agricultural yield in various part of Kenya (Branca, McCarthy, Lipper, & Jolejole, 2011). As an example, the Kenya Agricultural Carbon Project-KACP is a climate smart project in Western Kenya which promotes sustainable agricultural land management (SALM) practices. The project comprised of over 60,000 smallholder farmers on 45,000 ha of land. The adoption of SALM practices was expected to result in increased risk adjusted crop yields and carbon revenues. An analysis of the project performance showed that there was an overall increase in yield in the project area. As an example, the data collected for an average household in Kitale revealed that the farmers' grains crop yields increased per hectare (2,253kg/ha/yr compared to 1,140kg/ha/yr) (Tennigkeit et al., 2013) Evidently, climate oriented agricultural investments have been shown to lead to benefits for the farmers who adopt them. Hence, channelling climate finance towards transitioning agriculture to climate smart investments has the potential to increase productivity, enhance food security as well as improve incomes of the communities and in that way improve the livelihood of these communities

4.2.2 Increased Resilience of Farmers

The term resilience generally refers to the capacity of a system to withstand a shock or stress as well as its ability to develop capacities to prepare for, adapt, and also potentially transform to in order to manage the identified stress (Asfaw & Davis, 2018; Bousquet et al., 2016; Schwarz et al., 2011). In agriculture the term is also used to refer to farmer's ability to absorb and recover from shocks and stresses to their agricultural production and livelihoods. The issue on increasing agricultural productivity while ensuring sustainability and resilience to climate change impacts is a major challenge especially for developing economies. However, experts suggest that the use of ecologically based management strategies may represent a robust means of increasing the productivity, sustainability and resilience of agricultural production (Altieri & Koohafkan, 2013, January). Therefore, channelling of climate finance to environmentally friendly farming practices such as SALM or CSA provides an opportunity to enhance farmer's resilience (Zilberman, 2018).

Several projects that aim at increasing farmers resilience have been implemented in SSA. These include use of climate focused practises such as SALM practices, cash transfer programmes and other climate risk management strategies (Asfaw & Davis, 2018; Tennigkeit et al., 2013). The majority of these projects have been found to be successful in enhancing farmer resilience to the negative impacts of climate change. As an example, the adoption SALM practices within the KACP project was credited with improved crop resilience to drought (Atela, 2012). This is probably due to the improved soil quality in the project areas as well as the extra revenue revenues obtained from carbon sales and the sale of surplus produce which was invested in purchase of improved farm inputs. Similar results were obtained in Nepal where access to climate funds enhanced farmers access to improved irrigation facilities, drought and flood-resilient plant varieties which helped to improve the resilience of the farmers to climate change impacts (MoALMC, 2018).

In general, there is a strong relationship between increased productivity and improved resilience to climate change. In most cases the improved productivity leads to surplus income and better investment choices by farmers. For instance, a study by Branca et al. (2011) found that adoption of climate smart agriculture resulted in higher yields even in times of drought which reduced the possible losses from the adverse effects of the weather changes. Furthermore, the improved yield and resulting higher incomes lead to a decrease in the need to rely on adverse risk coping mechanisms such as disposal of assets, increased debt among others (Asfaw & Davis, 2018).

Overall, an analysis of the impact climate financed investments on farmer resilience shows that these programmes have a significant positive effect on the household's resilience. The uptake of these investments has been shown to lead to higher incomes, investment in better farm infrastructure which all lead to better coping capacity during adverse weather. Consequently, channelling of climate funds to climate related investment presents an opportunity to strengthen farmers capacity to cope with the adverse impacts of climate change.

4.2.3 Enhance access to finance

Access to sufficient and adequate finance and other financial services for agriculture has been, and continues to be, a significant challenge for SMEs and smallholder farmers (Hazell, Poulton, Wiggins, & Dorward, 2010; Palmer, 2016). This is mainly because the sector is perceived to have low profitability, low margins for financiers, high actual or perceived risks, inadequate enabling environments as well as high transaction costs (Palmer, 2016). Furthermore, the smallholders are in many occasions not able to provide collateral for loans as required by most financial institutions. This locks them out from receiving credit facilities and other financial products that require collateral. The lack of access to finances makes it difficult for the farmer to invest in value adding infrastructure as well as climate smart techniques which would raise their productivity, incomes as well as resilience to climate change.

However, climate finance can be used to catalyse private finance to the agricultural sector. This can be achieved by addressing the barriers that smallholders face while accessing finance. In essence, climate finance has been successfully employed as a means enhancing smallholders' access to finance. This has been achieved through various ways such as the sophisticated climate-smart credit scoring platforms developed by the climate smart lending platform for use during the loan assessment process (Climate-Smart Lending Platform, 2016). This approach was found to be successful leading to 95% adoption of CSA as well as an increase in approximately 12% of income in the project area (Climate-Smart Lending Platform, 2016). Furthermore, the inclusion of credit scoring system has an added benefit to the lenders in that it leads to climate proofing of the financiers lending portfolio.

Alternatively, climate finance can be used to enhance the adoption of innovative financing techniques such as mobile banking which has been shown to greatly reduce the Financial Institutions transaction costs when lending to smallholder farmers (Hellin, Hansen, Rose, & Braun, 2017; Palmer, 2016). The use of mobile technology has been adopted in countries such as Mexico, Brazil and Kenya to improve distribution channels and increase outreach of financial services (Hellin et al., 2017). In Kenya, mobile technology called M-PESA is widely used in providing insurance services while M-Kesho is used to provide credit facilities for mobile phone holders (Hellin et al., 2017; Palmer, 2016). These services have improved insurance penetration and access to credit especially in rural areas as it reaches even those clients in remote parts.

4.2.4 Enhancing liquidity to the agricultural sector

The ability of agrarian economies to adapt to the challenges posed by climate change is crucial if such economies are to cope with the negative impacts of climate change. Liquidity has been cited as a key factor in strengthening the adaptive capacities of farmers with respect to climate change (Mulwa, Marenya, & Kassie, 2017). However, the agricultural sector in developing countries has consistently experienced liquidity challenges mainly due to the disconnect between the sectors unique characteristics and the financier's requirements (Palmer, 2016). For instance, while most financial institutions require that their loans be paid on a monthly or weekly basis, the agricultural sectors financial flows are mainly seasonal putting a strain on the farmers' ability to meet the monthly payments (Falco, Donzelli, & Olper, 2018). Access to credit relaxes liquidity constraints thus enhancing adoption of practices that enhance adaptation in agriculture (Mulwa et al., 2017). Thus, channelling climate finance towards increasing the sectors liquidity is key in enhancing the adoption of climate smart strategies and thereby increasing the sectors resilience. These finances can be channelled through public private partnerships where by public sector could provide finances to the private sector for onward lending to climate smart investments. These funds could be in the form of low-cost debt, grants or market rate loans.

4.2.5 Enhance The Credit Rating Services For Small Holder Farmers.

Access to up-to-date expert based credit information is a major challenge for lenders when evaluating the credit worthiness of smallholders and SMEs (Havemann, 2011; Palmer, 2016). Furthermore, the agricultural sector lacks expert credit evaluation systems which are key to the management of financial risks (Havemann, 2011). These factors increase the sectors risk profile while at the same time hindering credit risk assessment thereby lowering the flow of credit finance to the sector. Nonetheless, climate financed investments have the potential to address these barriers and subsequently unlock finances flowing to the agricultural sector. This can be achieved by funding the establishment of effective credit rating agencies that address the unique characteristics of the smallholders and SMEs.

A case study by Palmer (2016) reveals that the establishment of credit agencies is valuable in unlocking finances to the smallholders and SME's. This author studied the effect of establishing credit bureaus in Ecuador during the 1990s banking crisis. During this time, the government introduced regulations that allowed the establishment of private credit bureaus. These agencies collected information from all lenders including the micro lenders who catered for the majority of the rural borrowers who are mainly composed of smallholders and SMEs. The result was an increase in lending by the micro finance institutions as well as a drop in the credit default.

4.2.6 Financial Risk Management

Risk coupled with the expected return are the primary factors that influence private sector investment activities. Low-carbon technologies are much more capital-intensive compared to the high-carbon alternatives. This increases their associated investment risks, financing costs and makes them less attractive to investors (Campiglio, 2016; Schmidt, 2014). This is confounded by other risk contributing factors such as the specific market risks. It is therefore no surprise that from the literature reviewed, most of the climate finance is invested in the countries of origin where investors are more conversant with the market risks.

Given the importance of investment risks during the investment decision making process, de-risking is potentially a powerful tool for redirecting financial flows from high to low-carbon investments (Schmidt, 2014). Climate finance provides an opportunity to innovatively finance these climate smart investments and ultimately lower their risks.

There are several approaches that can be employed to de-risk climate investments. These could be aimed at either reducing, transferring or compensating for the identified risks (Waissbein, Glemarec, Bayraktar, & Schmidt, 2013). Blending climate finance from various sources presents an opportunity to create a fund containing a different risk return profile. This combination has the potential to reduce risk, lower the cost of capital, and crowd-in private sector capital into green investments (Meltzer, 2018). For instance, by combining climate finance from various sources such as from Multilateral Development Banks (MDBs) and climate funds, a form of blended finance that is created for onward lending to the different interested investors. The eco.business fund lending project is an example of such an approach towards risk management for sustainable investments (Palmer, 2016). In this project, a climate fund was established to provide finances to businesses involved in biodiversity conservation and sustainable resource. The project was structured as a public-private partnership, with different capital tranches offering a diversified risk-return profile for different categories of investors. In addition, technical assistance was offered to the various actors to enhance their capacity for the project delivery. This project has been hailed as a great success and it demonstrates one of the ways that climate finance can be employed to mobilise private funds for climate investments (Palmer, 2016).

Credit guarantee, risk transfer facilities such as insurance schemes and weather derivatives represent other forms of risk management strategies that could benefit climate related investments. There is no one best solution for de-risking climate investments. Choices should be made after considering the specific risk drivers as perceived by the investors.

4.3 Climate Finance Challenges

As noted above, Climate Finance provides funding opportunities for the various climate related themes/sectors. Yet, the flow of these funds to various projects in the different sectors has been slow. This has been attributed to a range of factors. Since this study focuses on financing agriculture in the face of climate change, the following sections will focus on the challenges faced by the agricultural sector in attracting climate finance as well as the possible ways of overcoming these challenges.

Analysis show that only a small portion of total climate finance flows into agriculture. The climate funds analysis reveals that of the total amount that was tracked in 2017, only 20% was invested in agriculture (Climate Funds Update, 2019). This scenario is replicated in government projections which allocates a small amount of funds for adaptation in agriculture. In particular, the government of Kenya's projections of climate finance needs shows that the agricultural sector will get approximately 2% of the projected finances (Government of Kenya, 2016a). This is contrary to the available evidence which shows that adverse impacts of climate change affect millions of people who depend on agriculture for their livelihoods (Gemeda & Sima, 2015).

The discrepancy between the climate finance needs and allocations in agriculture has been attributed to various factors. These factors are in part due to the inherent challenges faced by agriculture in attracting finance as well as challenges relating to delivery of donor funds. This section reviews and evaluates the barriers preventing the flow of climate finance to agriculture.

4.3.1 Inadequate Enabling Environments

Lack of access to adequate financial services especially for small scale farmers has limited the range of activities, the type of technology used and the scale of operations adopted by the farmers (Alila & Atieno, 2016). Besides, the amount of credit available to farmers has been on the decline over time since independence. This is probably because of poor policies and regulations governing the agricultural finance sector which not only discourages lending to the sector, but they also create additional barriers to the flow of liquidity to agriculture (Palmer, 2016). Moreover, these challenges are also experienced when mobilising private climate finance. Specifically, it has been noted that private adaptation has not been mainstreamed in key government policies. Consequently, the Kenyan private sector appears unfamiliar with the concept of adaptation which limits the mobilisation of private climate finance (Pauw & Adis, 2016).

However, Kenya is implementing institutional and regulatory frameworks aimed at creating incentives for private investments in climate-related activities (Pauw & Adis, 2016). A move that is expected to enhance climate investments in the country.

4.3.2 Lack of Capacity to Manage Exposure to Agricultural Risks

Agricultural finance in developing countries face various constraints such as high risks, high transaction costs and low returns (Gashayie & Singh, 2015). The sector is dominated by smallholders who have less access to financial services compared to larger scale farmers. Lack of appropriate financial services has been identified as one of the major problems experienced by smallholder farmers and is a major constraint to smallholder commercialization in developing countries (Kiplimo, Ngenoh, Koech, & Bett, 2015). However, blending climate finance with private agriculture finance can help address some of these challenges.

An example on blended finance is the Strengthening Adaptation and Resilience to Climate Change in Kenya (StARCK+) project of The United Kingdom's Department for International Development. This project provides repayable grants to micro-finance institutions and their agribusiness partners for lending to farmers (Dinesh & Verhage, 2017). This is aimed at catalysing private sector investment for agricultural adaptation through offering loans to farmers who would otherwise have not been eligible for loans from the private sector. Blended climate finance can be used as a catalyst not only unlocking additional sources of finance but it can also help tighten the links between financial institutions, smallholder farmers and SMEs; and provide technical assistance to build the capacities of everyone involved in the financial ecosystem.

4.3.3 Mismatched Time Horizons of Climate Finance and Climate Investments

One of the challenges associated with climate finance is the possible mismatch between investment horizon and the funding timelines (Phelps, Webb, & Koh, 2011). Specifically, REDD+ are known to take place over a long span of time raising the question of the willingness of the land holders to be bound over such a long timeline. When climate funds is from voluntary public sources, the availability of funds over the long timelines is not guaranteed as the donors priorities might change over time (Phelps et al., 2011)

4.3.4 Slow Disbursement of Authorised Funds

To evaluate the accessibility of climate finance, data from the climate funds database was used to analyse the flow of finances from the donors to the point of delivery to the projects. The climate funds database provides a record of the multilateral funds that have been channelled to climate change investments globally.

This study finds that approximately 30 Million USD has been pledged for climate projects out of which approximately 26 Million (86%) had been deposited for onward lending to climate smart investments. Further, approximately 19 Million USD (74%) of the deposited funds had been approved for various projects across the different climate change themes. However, only 36% of the approved funds had been disbursed to the various projects Figure 4.2. This slow rate of disbursement is consistent with the findings of Afful-Koomson (2015) who found the mean initial disbursement time lag for donor funded projects to be approximately 1.9 years.

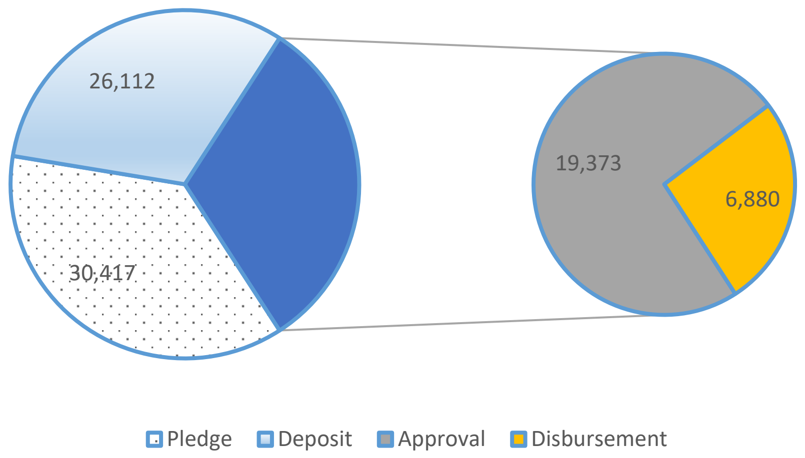

Figure 4.2 Climate Funds Disbursement Overview as at February 2019

(Source: Climate Funds Update, 2019)

Previous studies have found that many of the climate funds are slow to disburse the approved funds to the selected projects (Resch, Allan, Álvarez, & Bisht, 2017; Schalatek, Caravani, Nakhooda, & Watson, 2012). A slow disbursement of funds may lead to delay in implementation of projects and consequently affect their efficiency in meeting their set deadlines. The overall impact of the delayed project might even jeopardise the goal of keeping global warming to less than 2^{o}C. It is important to note that slow disbursement of funds is not unique to climate funded projects alone.

Prior studies indicate that donor funded projects especially those in SSA experience extremely low/slow disbursements of finances which leads to heavy cost to the respective countries and subsequently undermines the effectiveness of aid in Africa (Ayoki, 2008). Similarly, a study by Keng'ara (2014) revealed that it took up to 15 months for a project to receive the first funds disbursement after signing of loan protocol agreement. In addition, the time lag between submitting of the project replenishment request and funds disbursed was found to be approximately 6 months. This led to within year delays in implementation of project activities. In view of this, further analysis were conducted to evaluate the disbursement rate of climate finance. It was established that while the overall disbursement was low at 36% only, the slow rate was not consistent across all the sub themes. For instance, approximately 61% and 46% of funds had been disbursed for the mitigation – REDD and adaptation subthemes Figure 4.3. In contrast, mitigation general received only 28% of the disbursed funds.

The question then arises, what are the factors influencing the disbursement rates. According to Nakhooda et al. (2014), climate funds are provided in the form of loans, capital as well as grants. This means that some of the providers of funds need to be repaid as at when the loans fall due. As a consequence, if funds are received as loans then they would have to be disbursed as loans which limit the degree of financial risk that the lenders are willing to take. As a result, the type and number of investments that could be funded by these funds is limited resulting in to an overall slower rate of disbursement.

A different explanation for the slow rate of funds disbursement is that most donor funded projects have heavy and stringent reporting requirements. This may lead to untimely submission of required reports as the recipients of funds may face challenges related to report preparation. The ultimate result is that the funds disbursement process is more lengthy and challenging leading to delayed project implementation (Mnyawi, Mbasa, & Lawuo, 2013).

4.3.5 Insufficient Administrative Capacity and Technical Knowledge

Despite being set up to help developing countries cope with the impacts of climate change, climate finance is poorly accessed by developing countries. As an example, Africa was only able to access 3.6% of the global climate finance in 2014 (Buchner et al., 2014). This is despite of the fact that Africa is one of the regions that are highly vulnerable to the impacts of climate change. The low access to climate funds has been attributed to challenges such as difficulties in the selecting, designing, and implementing projects and programmes in a way that meets the relevant standards. The process to access the funds is not only time consuming but it also requires a high level of coordination and technical expertise (Tippmann et al., 2013). Yet, Africa has limited capacity in many areas such as policy analysis, climate change knowledge and project formulation, which undermines the continent's readiness to access climate finance resources, and leads to limited absorptive capacity to receive and manage funds at scale (African Development Bank, 2012, December). Additionally, small and medium-sized enterprises (SMEs) in middle income and developing countries have been found to face other challenges such as inability to recognize and evaluate the materiality of climate change risks and a lack of knowledge on how to manage these risks. (Trabacchi & Mazza, 2015). These challenges represent significant barriers to private investors in responding to climate change and hence hinders mobilisation of climate finance from the private investors.

4.3.6 Ensuring the 'Bankability' of Potential Investments

Mobilisation of climate finance is dependent on the ability to develop 'bankable projects' a requirement that often presents a challenge for most countries (Ellis & Pillay, 2017; Rossi, Gancheva, & O'Brien, 2017). A study on access to the Green Climate Fund by developing countries revealed that that most governments did not have the necessary capacity to develop bankable projects (Ellis & Pillay, 2017). This finding is similar to that of Rossi et al. (2017) who found that local and regional authorities in the European Union experienced challenges in relation to meeting the bankability requirement. These authors argue that demonstrating 'bankability' of climate investments is often challenging due to factors such as lack of sufficient data about future returns on investment. This is especially so for adaptation projects because there is no single metric that can be used to quantify the benefits of adaptation actions. Moreover, the benefits of adaptation actions might arise so far in the future that they cannot be integrated in the financial assessment of a project.

As noted, the shortage of bankable projects is a major challenge for green projects in Africa. It hinders access to climate funds and causes delays to projects and ultimately results in higher project costs for the various projects. However, Koh (2018) notes that the shortage of bankable projects is mainly an outcome of project preparation hence it can be solved if enough project preparation is done in advance. Furthermore, several initiatives have been set up to enhance Africa's capacity to prepare bankable projects. These have the potential to improve the overall performance of the continents access to the funds.

4.3.7 Lack of Awareness about Climate Change and Climate Finance Options

Climate change mitigation and adaptation issues have become the subject of intense global deliberations in the past few decades. This is because possible negative impacts that climate change poses to the societies. As detailed in earlier chapters, implementing mitigation and adaptation measures requires significant financial flows. As a result, various funds and mechanisms have been set up with an aim of financing climate investments. However, despite the intense global interest in climate change and its impacts, lack of awareness has been cited as a significant barrier to climate change adaptation and mitigation in developing countries (Elum, Modise, & Marr, 2017). Similarly, a study on climate change awareness in Punjab found the rate of climate change awareness among local officials to be very low with more than half of the respondents that were interviewed stating that they were not aware of the phenomenon of climate change (Shahid & Piracha, 2016). A further analysis on the adoption of climate finance instruments found that the uptake of these instruments was hindered by lack of awareness of the finance instruments of the instruments that are available (Elum et al., 2017; Rossi et al., 2017). This suggests that there is need to educate the different actors on climate change as well as the financing instruments that are available for managing the impacts of climate change.

4.3.8 Size of the Projects

In developing markets, there are many unique hurdles to developing viable and innovative climate smart projects. Size has been cited as one of the major hurdles when developing climate smart investments. This is probably because large-scale projects generally tend to dominate and attract the lion's share of financing (Otieno, 2015). In contrast, many small-scale projects face difficulties in accessing donor funds despite providing the most promising solutions in areas with high levels of poverty and in rural settings. For instance, the agricultural sector in developing economies is highly vulnerable to climate impacts but it is also dominated by smallholder farmers. Smallholders lack the needed capacity to identify the sectors financial needs for adaptation and mitigation purposes as well as being poorly and ineffectively linked to financiers among other challenges (Sadler et al., 2016).

Majority of agricultural projects qualify for climate finance under the adaptation sub theme. Figure 4.3 presents a summary of the climate funds status from the climate funds update data base. It is observed that while adaptation had the second highest number of projects that had been approved to receive climate funds, the sub theme ranked much lower in terms of funds pledged and deposited. This is probably because the projects are much smaller and therefore account for much less funds compared to projects in e.g. mitigation general which despite accounting for only 10% of the projects had a corresponding higher percentage in terms of funds pledged and deposited at approximately 22% and 25% respectively.

Interestingly despite accounting for almost half of the projects approved and funds pledged, the multiple foci theme received approximately a third of the disbursed funds which was only 19% of the funds pledged for the sector.

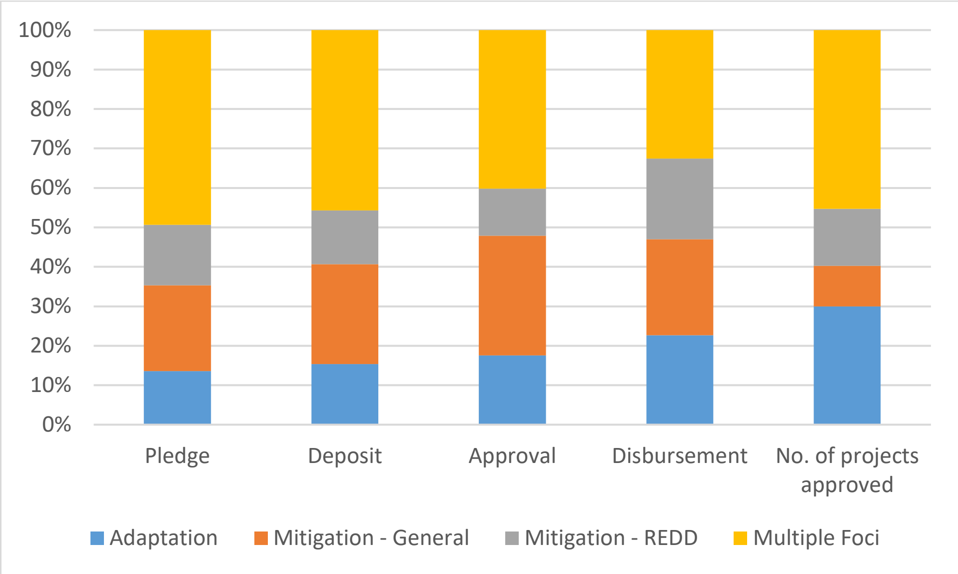

Figure 4.3: Funds Status at February 2019

4.4 Suggested Solutions to Scale up Climate Investments in SSA

Despite there being numerous challenges that climate change poses for the African continent, the regions access to climate funds remains low. The continent encounters numerous obstacles when designing and implementing climate investments. A review of literature reveals that the barriers for mobilizing climate finance in developing countries are not always specific to climate change activities and many apply more broadly to development finance (Halonen et al., 2017).

The majority of the challenges experienced during implementation of climate investments are similar to those experienced by most donor funded projects in developing countries (Ayoki, 2008; Keng'ara, 2014). However, there are some barriers that are specific to financing mitigation, adaptation or cross-cutting projects (Halonen et al., 2017). Hence, successfully addressing the barriers to climate-related investments requires that the specific category of barriers is identified and addressed accordingly. Since the barriers to climate investments are similar to those experienced by other development projects, solutions aimed at mobilising climate finance will likely also mobilize more finance for broader sustainable development activities. In this section, we review some of the innovative ways that have been adopted by various projects to overcome the barriers experienced by climate investments in SSA.

4.4.1 Enhancing bankability of climate projects

The lack of bankable projects has been cited as a challenge to accessing climate finance. Bankability for climate change projects goes beyond the standard/ traditional definition of bankability with the term being perceived differently among stakeholders (Ellis & Pillay, 2017). Thus, understanding the funder's perspective of 'bankable' is necessary in order to develop successful project proposals and thereby enhance access to climate finance. Upon understanding the concept of bankability, a concerted effort involving good project preparation, management implementation experience as well as presenting the business case would enhance the building of a project pipeline which is attractive to investors so that private sector actors can get on board (Halonen et al., 2017).

Public sources of finance can be looped in to de-risk climate investments and thereby enhance the scope of bankable projects (Gardiner, Bardout, Grossi, & Dixson-Declève, 2015). This can be implemented through various mechanisms including technical assistance grants, funding for financial ecosystem development, and financial instruments including catalytic first loss capital, debt guarantees, and other forms of blended finance (Ward, 2011). For instance, The Africa Development Bank (AfDB) manages different facilities that provide multiple financial instruments (preparation grant, grants, concessional debt, equity, etc.) which ultimately enhance project bankability (Assouyouti, 2017). The use of these and other risk sharing financial instruments helps to take on and share some of the risks that otherwise would prevent projects and programmes from being 'bankable'(Ward, 2011).

4.4.2 Aggregating Small Scale Projects

Project size has been cited as a key factor in attracting climate finance small ventures experiencing more difficulties in attracting climate funding compared to larger projects (Rossi et al., 2017). This has been attributed to factors such as lower profits due to higher costs that arise when managing smaller projects. Specifically, climate finance actors such as buyers and brokers of carbon finance prefer projects that deliver large volumes with low transaction costs and minimum uncertainty. Furthermore, the smallholder projects are situated in remote geographic locations, involve large number of farmers leading to additional work to aggregate carbon sequestered. All these factors lead to an increase the transaction costs and consequently deter prospective investors (Öborn et al., 2017).

Nonetheless, project bundling has been proposed as a viable option when dealing with small projects. By bundling projects together, the afore mentioned obstacles can be overcome and hence make these projects more attractive to the financiers and other actors (Rossi et al., 2017). In Africa, aggregation has been applied for several projects with success. As an example, the KACP project in western Kenya run by Vi Agroforestry covers 60,000 farmers, organized in 3,000 registered farmer groups. The supported farmer groups/organisations were mainly small civil society organisations consisting of Community Based Organisations (CBO's), common interest groups, training groups and financial services associations (Öborn et al., 2017; Tennigkeit et al., 2013).

Similarly, the Trees for Global Benefits project in Uganda adopted a group marketing approach when selling the carbon credits that had been sequestered by individual farmers (Öborn et al., 2017). These projects have reported success in their areas of operation with the Trees for Global Benefits (TGB) converting into a self-financing mechanism that provides upfront funding for farmers to initiate forestry activities while the KACP has resulted in increased yield in the project areas as well as carbon sequestration as a co-benefit (Öborn et al., 2017).

4.4.3 Capacity Development/ Technical Assistance

Meeting the criteria and requirements of resource providers in mobilizing financial resources to replenish national climate funds remains a challenge. Consequently, provision of technical support on how to meet these demands is likely to have a real impact on the amount of private climate finance that is mobilised (Abeille, Bolscher, Ligot, Million, & Veenstra, 2015). Indeed, some providers of climate finance have recognised the need for technical assistance to climate related investments and do incorporate it as part of the support provided to the relevant projects. This assistance has been provided by different agencies in the various form such as policy advice, support for project development and for funding applications, provision of data, programme coordination, and institutional capacity-building

(Abeille et al., 2015). employing climate finance for capacity building or technical assistance enhances mobilisation climate funds both directly and indirectly addressing the existing gaps that prevent low carbon and climate-resilient investments (Stadelmann & Falconer, 2015). While technical assistance does enhance mobilisation of climate finance, it is usually difficult to quantify the amounts of funds that this approach mobilises.

4.4.4 Partnerships

Adequate finance from both public and private sources is needed in order to implement the Paris climate agreement and transition to a low carbon economy. Consequently, a strong public commitment is needed to engage with the private sector and ensure climate finance is leveraged and deployed effectively (Gardiner et al., 2015).

A mix of public and private sources of financing has often been applied in the form of Public Private Partnerships (PPP) to mobilise the funds needed to finance investments. While Partnerships offer the opportunity to link the actions of diverse actors operating at different scales and flexibility, their adoption and implementation should be approached with caution bearing in mind the needs of the vulnerable and disadvantaged groups within the project areas (Broto, Macucule, Boyd, Ensor, & Allen, 2015).

The PPP approach has been successfully adopted to finance climate related investments in various part of the world. In Kenya, the Sangana Public Private Partnership (PPP) aims at enhancing climate change adaptation and mitigation within the Kenyan coffee sector. The members of this partnership include the Sangana Commodities Ltd, Baragwi Farmers' Cooperative (BFC), GIZ, 4C association and the World Bank (Hillier et al., 2013). This partnership, developed a verifiable climate module under the 4C coffee association standard. BFC members have significantly improved their livelihoods through adoption of CSA practices under the project as a result of: increased yields, improved crop quality (PWC, 2011).

4.5 Conclusion

The main objective of climate finance is to support climate investments with an aim of enhancing climate change adaptation and mitigation in developing countries. The majority of the climate funds invested in developing countries originate from the developed countries. Therefore, the performance of climate finance in relation to achieving the intended objective is of interest to the providers of the funds in order to review the need for the continued provision of these funds.

In this chapter, the question was asked, does climate finance work? To answer this query this section reviewed climate financed investments with a view to establish the experiences to date in relation to the benefits of climate investments, the challenges faced when mobilizing climate finance and the innovative ways in which climate projects have adopted to overcome some of the challenges that are present. This chapter focused on agriculture due to the important role the sector plays in developing countries' economies.

The analysis found climate finance did realise some of its main objectives. This is evidenced by the numerous benefits that have been reaped from the investments reviewed. In particular, implementation of these investments in agriculture has resulted in increased productivity, resilience to climate change as well as climate change mitigation through carbon sequestration.

While the narrative on the performance of climate finance investments is positive, the rate at which climate funds are disbursed to investments in developing countries could be better. Particularly the developing countries, face challenges at the different stages of climate finance delivery. These need to be addressed to improve the effectiveness and equitable distribution of funding for climate action in the region. Some of the challenges faced during climate finance access and delivery include but are not limited to climate funds lack of capacity to manage agricultural risks, inadequate enabling environment, mismatch between climate finance and climate investments time horizon among other challenges. These challenges are unique to the specific project being analysed based on the project needs and the project location. The challenges faced by these projects can be managed through adoption of innovative measures bearing in mind the specific needs of the project in question. These measures could range from policy support to address the identified gaps in order to lay the ground ready for the climate investments to measures during the project implementation such as risk management, capacity development among others. Addressing these gaps has the potential to increase the flow of climate funds and therefore enhance the delivery of the envisaged benefits of increased productivity, enhanced adaptation and mitigation to climate change.

Chapter 5: Data and Methods

5.1 Introduction

This chapter lays the foundation for chapters 6, 7 and chapter 8 by systematically detailing the procedure used to obtain the results presented. First in section 5.2, the study location is identified and characterised. Then a detailed explanation of the procedure adopted to select the crop that is used in this study is presented in section 5.3. Subsequently, the datasets used and their sources as well as the data collection procedures are presented in section 5.4. And finally, the detailed description of the methods used to analyse the objectives of the study are deliberated in sections 5.5, 5.6 and section 5.7.

In Section 5.5, the procedure and method used to estimate the drought risk is outlined. The results from this analysis are presented in chapter 6. This is followed by section 5.6 which explains the procedure adopted to price weather derivatives. The results from this section are deliberated in chapter 7 while section 5.7 details the method adopted to evaluate the efficiency of the option contracts. The findings from this analysis are presented in chapter 8. Finally, section 5.8 concludes the chapter.

A summary overview of this research detailing the overall objective, specific tasks undertaken as well as the techniques applied to achieve these objectives is presented in Figure 5.1. It provides a visual display of how the objectives, evaluation techniques and results have been organised within the chapters in the thesis.

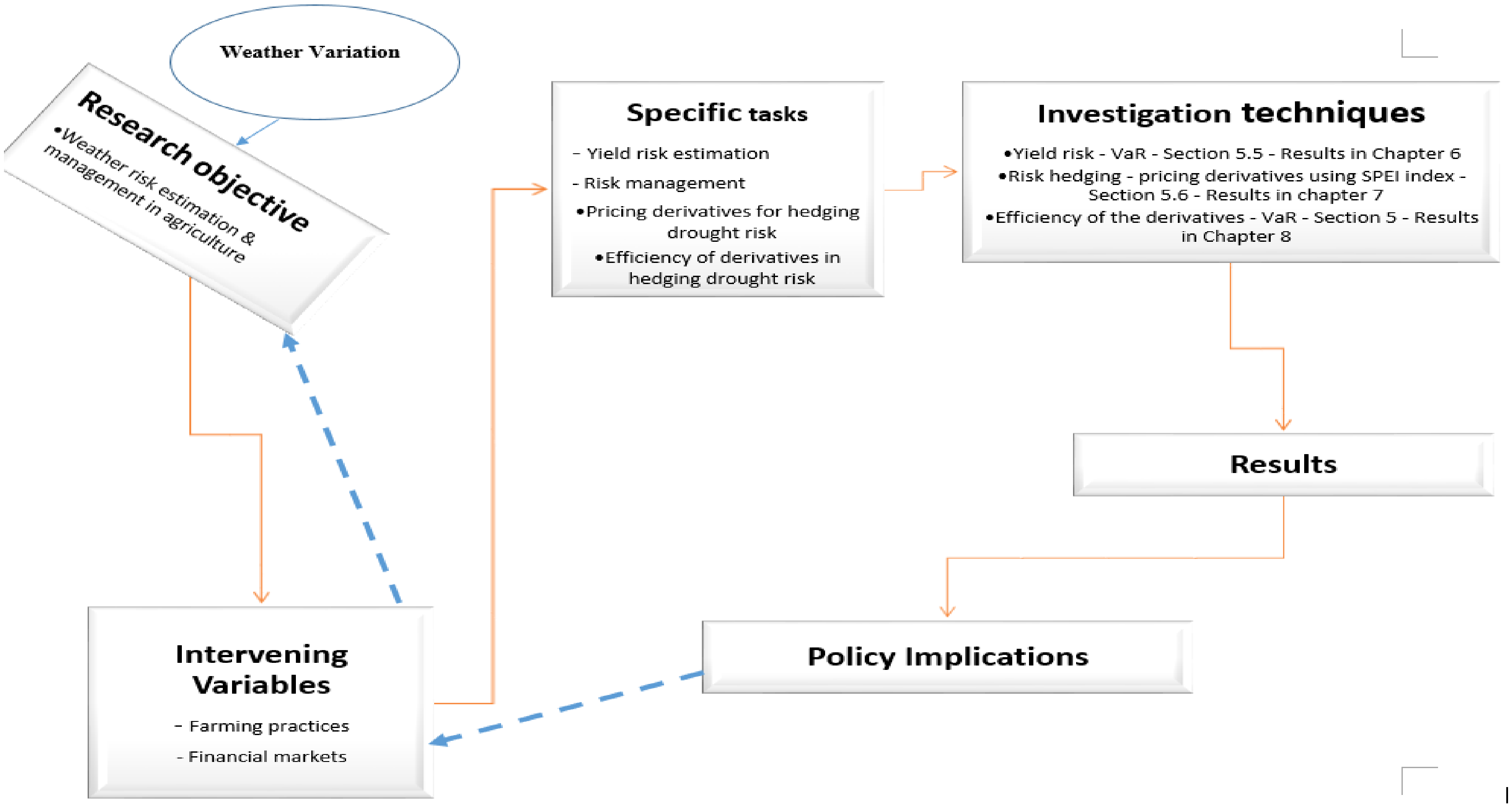

Figure 5.1: A Framework Linking Extreme Weather, Drought Risk and Policy Implications

(Source: Authors Design)

5.2 Selection of Location

This study focuses on Kenya's western province. The average rainfall in the region ranges from 1,000 to 2,000 mm annually and is distributed in two cropping seasons in most of the region. The long rains are from March to July and the short rains from August to November. Agro-ecologically, the region is classified by the Kenya Agriculture and Livestock Research Organisation (KALRO) as a moist transitional agro-ecozone characterised by medium to low soil fertility levels. The cropping system is dominated by maize and bean intercrops grown on small plots averaging 0.5–1.0 ha (Marenya, Barrett, & Gulick, 2008). The Western Kenya region was selected for this study because it is one of the country's major food basket (Ali-Olubandwa, Kathuri, Odero-Wanga, & Shivoga, 2011). Accordingly, a better weather risk management in this region would better cushion the country during times of adverse weather.

When designing the option contracts, selection of the site is very important because if the individual production side and the place for which the WD are designed are not perfectly matched, basis risk would arise (Manuela & Ruyuan, 2015). Basis risk arises whenever there are differences, or mismatches, between the underlying hedged item and the hedging instrument (Coughlan et al., 2011). These differences can take many forms, ranging from differences in the timing of cash flows to differences in the underlying variables that determine the cash flows.

The presence of basis risk means that hedge effectiveness will not be perfect and that, after implementation, the hedged position will still have some residual risk. This implies that if the place where the weather variable is measured is different from the areas where the WD is used as a risk management instrument, the effect of WD might be distorted (Manuela & Ruyuan, 2015). It is important to note that while basis risk is present to some degree in most financial hedges, it does not automatically invalidate the case for hedging (Coughlan et al., 2011). Besides, an attempt to eliminate basis risk while designing WD would offset the advantage of lower transaction costs of WD because of the additional costs if weather variables are measured at different weather stations.

5.3 Crop Selection

Maize is considered as one of the most important food crops in the world and, together with rice and wheat, it provides at least 30% of the food calories to more than 4.5 billion people in 94 developing countries. In SSA as a whole, the top sources of calories ranked in order of importance are maize, cassava, rice, sorghum, wheat, and millet (Schlenker & Lobell, 2010). Specifically, Maize contributes approximately 45 % of the food calories in Eastern and Southern Africa (ESA), and is a particularly important source income (Shiferaw, Prasanna, Hellin, & Bänziger, 2011). Notably, maize is the main staple food in Kenya, accounting for 65% of total staple food caloric intake and 36% of total food caloric intake; it is estimated that the average Kenyan person consumes 88 Kgs of maize products per year (Ariga, Jayne, & Njukia, 2010; Mohajan, 2014).

Approximately 40% of Africa's maize-growing area experiences occasional drought leading to moisture stress related yield losses of approximately 10–25 % (Fisher et al., 2015). Research shows that SSA will experience approximately 20% decline in precipitation by the year 2050 due to climate change (Omoyo, Wakhungu, & Oteng'i, 2015). This is likely to have a huge impact on maize yield due to the considerable relationship between weather and climate on crop yields under rain fed agriculture. This is confounded by Kenya's reliance on rain-fed maize production in meeting its food needs and growing consolidation of production toward maize (and dry beans). The country's heavy reliance on rain-fed maize production coupled with the unpredictable weather has rendered the country increasingly vulnerable to supply disruptions and food shortages (D'Alessandro et al., 2015).

To cope with the declining yields, production gains have come largely through land expansion into marginal areas that receive lower and more variable rainfall and are susceptible to extreme weather events. For instance, the ASALs of Kenya experience major droughts once in every 5 years resulting in widespread food insecurity, poverty, and irreversible decline in herd sizes (D'Alessandro et al., 2015; Omoyo et al., 2015). This trend coupled with Kenya's increasingly erratic rainfall has amplified year-on-year yield variability, with substantial food security implications (D'Alessandro et al., 2015)

Maize is a very important crop for food security in SSA. Harvest failures and losses attributable to changing climate conditions such as drought stress is one of the most pressing concerns for rain-fed agriculture. As majority of farmers in SSA are rain dependent farmers, evaluating the response of maize to a changing climate can provide viable options for enhancing adaptive capacity of small holder farmers in SSA.

5.4 Data Collection

This study covers the period from 1961 to 2014. The data used in the analysis is secondary data obtained from several different sources. Figures relating to annual grain production, the area planted and the yield were gathered from the Food and Agriculture Organization of the United Nations (Food and Agriculture Organization, 2017). This data was used to calculate the annual yield variations for all the years under study. The country's rainfall and temperature data were obtained from National Oceanic and Atmospheric Administration (NOAA), 2017). This was used to compare yield and rainfall to establish the relationship between the two variables.

Information relating to periods of drought and other disasters in Kenya was gathered and compiled from various Government reports, United Nations Development Programme (UNDP), scholarly articles and FAO reports.

To price the WD, the SPEI index data for Kitale region in western Kenya was used. This was obtained from spei.csic.es/database.html website. The specific coordinates used for data extraction were latitude of 35.25 and longitude of 1.25. A total of 660 SPEI06 monthly indices from January 1960 to December 2014 were obtained.

To price the option contracts, this study attempted to extrapolate the spatial scale from farm level to regional level. However, difficulties were experienced when designing the WD at regional level because of the limitation in the yield data which was only available at the national level. Manuela and Ruyuan (2015) and Vedenov and Barnett (2004) encountered similar difficulties when tracking down yield at the farm and county level. They countered this challenge by using the regional data for their analysis. Thus, following these authors, the national production data was used for analysis in this study.

5.5 Analysis of Objective 1 – Estimating Yield Risk in Kenya's Agriculture

This section details the approach adopted to estimate the yield risk in Kenya's agriculture. Time series data of maize production from 1961 to 2014 was used. First the yield variation was estimated for the period under study. Then, the appropriate model was derived/developed by fitting the yield variations into various models and selecting the best suited model. After selecting the model, the yield risk was estimated using the VaR method. The following section details the yield loss estimation process.

5.5.1 Estimating Yield Variation

The first objective of this study was to establish the risk exposure in the agricultural sector as a result of drought occurrence. This was done by estimating the yield variation from 1961 to 2014. Thus, using the data from the FAO website, the grain loss was estimated by comparing the actual yield in a specific year (Y_t) with the average actual yield (Y_a). The average yield data is detrended given that it is likely to experience an increase over time due to factors such as technological progress and infrastructure improvement. Special consideration should be taken when estimating the average yield. Van Ittersum et al. (2013) argues the appropriate approach is to define yield (Y_a) as the average yield of the past 5 years for irrigated and 10 years for rain-fed cropping systems achieved by farmers in a given region under dominant management practices and soil properties.

Nevertheless, the average actual yield should be determined on a case-by-case basis, following the principle of including as many recent years of actual yield data as possible, to account for weather variability, while avoiding the bias due to the technological time-trend (Ewert et al., 2011; Van Ittersum et al., 2013).

Specifically, in data-poor countries where long-term statistics are not available a minimum of 5 recent years may be used. It should be noted however, that that this may not be sufficient to account for year-to-year variability in yields due to weather, especially in harsh rain-fed environments. Similar to (Iizumi & Ramankutty, 2016), the yield loss for a given year t, is calculated as a percentage of the yield difference from a normal/average yield Y_d (Equation 5.1).

$$\frac{Y_t - \bar{Y}_a}{\bar{Y}_a} * 100 = Y_d$$

Equation 5.1

Where;

$\bar{Y}_a$	is defined as a 5-year running mean of yields for the interval t-2 to t+2
Y_t	Represents Yield in year t
Y_d	Represents the deviation of the actual yield from the average yield.
t-2	Two years prior to the period under analysis
t+2	Two years preceding the period under analysis

5.5.2 Modelling Disaster Loss

This study estimates the loss as a result of extreme weather conditions such as drought. This requires that the obtained yield losses be fitted into the appropriate statistical model to help make the predictions. To achieve this, two approaches were adopted. First, the obtained yield losses were fitted into various models using the easy fit software. Then, the obtained distributions were ranked based using the K-S, A-D, and Chi-Square and compared 14 different models. To get the best model, the average of the models rank using these three methods is obtained and used to select the most suitable distribution. This approach is similar to the one adopted by (Wang et al., 2015). When this approach was adopted, the highest ranked model was the Generalized Extreme Value (GEV).

The second approach was the Extreme Value Theory based on Points over Threshold. According to literature, this approach does provide a promising solution to modelling agricultural losses since these are as a result of an extreme weather events (Xu et al., 2011). These authors further assert that the using POT helps to overcome traditional methods when modelling disaster risk in agriculture. In this approach, the excesses over the threshold are regarded as the agricultural disaster loss and these have been shown to follow a Generalised Pareto Distribution GPD. Thus, to evaluate this approach, the series of the yield variations was fitted into the Extreme Value Distribution (EVD) using the R software and the POT method based on EVT was applied to model the extreme losses. This required that the Threshold μ be determined so as to get the losses above this threshold. To determine the threshold, the Mean Residual life Plot was used. Then the Maximum Likelihood Estimator (MLE) procedure was used the determine GPD parameters given the threshold μ:

$$G(y) = 1 - \left(1 + \frac{\xi y}{\delta}\right)^{\frac{-1}{\xi}} \qquad \text{Equation 5.2}$$

Where; G(y) is the CDF defined on the set,

$y = (x - u)$, σ (σ > 0) and ξ (-α < ξ < +α)

δ	Is the scale parameter
ξ	Is the shape parameter
u	Is the location parameter
x	is the yield loss seies

The MLE approach is used to estimate the GPD parameters given the threshold *u*. and the suitability of the model was tested by use of quantile plot, density plot and the return level plots.

Secondly, the GEV model was also modelled and tested for suitability.

$$Gx = \exp\,[-\left(1 + \xi\frac{x - \mu}{\sigma}\right)^{-\frac{1}{\xi}}] \qquad \text{Equation 5.3}$$

Where; $1+\xi\,(x-\mu)/\sigma > 0$; $\mu \in \Re$, $\sigma > 0$ and $\xi \in \Re$.

After modelling the yield variations, the diagnostic plots for the two models were plotted in a diagram and compared to determine the model that was best suited for our distribution.

5.5.3 Assessing the Risk

We used VaR method to estimate the agricultural drought risk. VaR is defined as the size of loss x in the expected worst-case scenario during a certain period of time at a given confidence level. Thus, VaR gives the maximum possible loss of a portfolio in a given holding period (Xu et al., 2011). This can be defined as the random variable x that describes portfolio loss, with a probability distribution function (x), given a confidence level $\alpha \in (0, 1)$ (Wang et al., 2015), and can be expressed as;

$$VaR(\alpha) = \max(\frac{x}{F(x)} \geq \alpha) \qquad \text{Equation 5.4}$$

This can be transposed as:

$$P(\Delta x > VaR = 1 - \alpha) \qquad \text{Equation 5.5}$$

Where;

P	is the probability of the portfolio loss,
α	is the confidence level
F(x)	is the probability distribution function
ΔX	is the loss of portfolio in the holding period, and
VaR	is the value at risk under confidence level α.

VaR calculates the upper quantile of *F(x)* under the stated confidence level α. In this study the *P* is the probability of yield loss, α is the confidence level, *F(x)* is the probability distribution of the yield losses, ΔX *is* the estimated yield loss during the period. In finance, the time horizon over which VaR is calculated is much briefer (often, one day ahead) than that for which natural resource-based investments would be considered (Webby et al., 2007). In this study we calculate VaR for the discrete time period of one calendar year. The obtained VaR will represent the drought risk in a year. This is calculated at the event of 10, 20, 50 and 100 year return period which corresponds to the VaR at the confidence level of $\alpha = 0.1$, $\alpha = 0.05$, $\alpha = 0.02$ and $\alpha = 0.01$ respectively. The results of the analysis are deliberated in Chapter 6.

5.6 Analysis of Objective 2 - Hedging Drought Risk

This section presents the process adopted to price a weather-based option contract that will be used to hedge against the drought risk. When designing a weather based financial derivative, it is important that an underlying index that relates to the risk being hedged against be determined (Cyr et al., 2010). While many businesses are predisposed to weather risk, most of them are more susceptible to temperature changes making temperature the most commonly used underlying index when pricing weather derivatives (Mungai et al., 2015; Oetomo, Stevenson, De Vries, & Van Lennep, 2004).

Broadly speaking, futures (forward) and options are the main types of weather derivatives that are written on temperature indices. These are mainly modelled as Cumulative Average Temperature (CAT), Heating Degree Day (HDD) and Cooling Degree Day (CDD) with the degree day denoting the difference between a reference temperature and the daily observed temperature (Gülpınar & Çanakoḡlu, 2017). These indices are borrowed from the energy industry and are designed to correlate with domestic demands for heating and cooling (Mungai et al., 2015). Although these indices serve the various sectors that they are applied in, the agricultural sector is very sensitive to changes in temperatures. While maize crop has been cited to be more susceptible to moisture stress during the growing period, evidence also suggests that global warming is harmful for agricultural productivity and that changes in temperature are much more important than changes in precipitation.

This study seeks to incorporate the two views on the effect of weather variables when pricing the weather contract. In this regard, two indices are used namely; rainfall and a drought index. While rainfall has been used on many occasions to price option contracts, drought indices have not gained the same level of popularity as precipitation. If the drought index is found to be viable in pricing the contracts, then it will provide a more holistic approach because it incorporates both precipitation and evapotranspiration when calculating the index.

Besides the underlying weather variable, a weather contract must specify such basic elements as the accumulation period, the strike level, the index location (which records weather variable used to construct the underlying index), and the tick-size (i.e., fixed lump-sum to be exchanged between parties for each level of degree days). It should be noted that the choice of these elements is a key issue when pricing weather contracts. Indeed Cyr et al. (2010) documented this fact and advised that these variables need to be determined by the producer after consideration of their specific idiosyncratic operations. Nonetheless, this chapter did not focus on the analysis and modelling of the production risk factors that would be considered in the determination of strike level and tick size.

5.6.1 The Burn Rate Analysis

To achieve objective 2, two approaches were adopted. The first was the use of burn rate analysis methods which employed the rainfall data to estimate the option price. The burn rate analysis method was used to estimate the option price. It involves pricing the option contract based on the discounted average of the contract payoff from previous years. Maize production has been cited to be highly sensitive to rainfall variability especially during the growing period Cyr et al. (2010). D'Alessandro et al. (2015) reiterates that relative to most other crops, maize is highly susceptible to moisture stress. Consequently, this section considers the valuation of an option contract with cumulative rainfall during the growing period as the underlying index. The period of the study was from 1961 to 2014. The obtained rainfall was grouped into four categories in line with the rainfall seasons in Kenya and the crop of interest which is maize. The four categories are, the growing season for the long rains, the growing season for short rains, the combination of the two growing seasons and the annual rainfall.

To identify the stochastic process of the Cumulative Rainfall in Growing Period (CRGP) the time series analysis was used. Using the R programme the CRGP data was fitted into the Autoregressive Integrated Moving Average– (ARIMA ()model. The following parameters were estimated, with a mean of 31.6 and a standard error of 1.4. The resulting model is:

$$CRGP = \mu + e_j \qquad \text{Equation 5.6}$$

5.6.2 Derivatives Prices Using the SPEI Index

The second approach applied the equilibrium model with the SPEI index being used to model and price the option contracts. SPEI at seasonal lag 3 to 6 month lag has been cited as best suited to describe agricultural drought (Miah et al., 2017). Consequently, the SPEI of interest in our study was SPEI03, to SPEI06. This study arbitrarily picked and used SPEI06 for the analysis. Further, only the indices during the growing periods were used. This is because agricultural risk is best managed using the growing season (Hansen & Indeje, 2004). The number of observations that fitted this criterion were 330 indices corresponding to the 6 months of the growing season during the long and short rains season. Since the study seeks to calculate the option prices for drought contracts, only negative SPEI was considered. This is because the negative SPEI's indicate different levels of dryness. Consequently, the number of observations reduced to 159 being the SPEI data within growing period that had negative values.

5.6.3 Estimating the Option Prices

First, the payoff that the farmers would receive was estimated. Similar to Zhu et al. (2012), an agricultural drought index was used to model an European put option contract (Equation 5.7).

$$f(I) = S \bullet \max(K-I, 0) \qquad \text{Equation 5.7}$$

Where;

- I Represents the drought index
- K Represents the strike level
- S. Represents the relationship between drought index and loss of farmer's income

The drought index I should take smaller values when the drought is severe. Accordingly, the holder will receive S•(K-I) when a drought is more severe and exceeds the strike level K. Nonetheless, when I is larger than K, the holder will choose not to exercise the contract which means they receive no pay-out. For this reason, the value of the option contract can never be negative as the holders would choose not to exercise the option

After estimating the pay-out, this study used the equilibrium approach to price a put option contract for the Western Region of Kenya. The advantage that the equilibrium approach has compared to the standard risk-neutral pricing approach is that it does not require the specification of a market price of risk, making it particularly suitable for pricing in incomplete markets. In addition, in pricing weather derivatives, the standard derivative pricing models based on no-arbitrage concept and market completeness assumptions has been found to be inappropriate because the underlying variable is a non-tradeable asset (Brody, Syroka, & Zervos, 2002; Manfredo & Richards, 2005).

Mungai et al. (2015) & Zhu et al. (2012) adopted this equilibrium technique to price drought option contracts for Kenya and China respectively. However, while these studies used the RDI as the underlying index, this study uses the SPEI index. The price of the option contract is expressed as the present value of the expectation of its payoff (Equation 5.9).

$$V = E_Q \, [e^{-} \int_0^T r(t)dt \, f(I)] \qquad \text{Equation 5.8}$$

Where;

T	is the duration of the contract
r^T	is the risk-free rate
I	is the drought index
K	is the strike price and
Q	is the probability density function for all the possible values of I

To simplify this equation, S is assumed to be one and r^t to be constant over the length of the contract. Thus (Equation 5.9) is obtained.

$$V = e^{-r\tau} EQ \, [max \, (K-I,0)] \qquad \text{Equation 5.9}$$

The drought index I represents the drought index while the strike level K is set at -1. This threshold is selected because the values from 0 to -1 represent near normal conditions while all the indices less than -1 are considered as drought conditions.

The value of the interest rate r is obtained as the average rate for the 90 day Treasury bills issued from 1997 to 2017 (Index 1). The 20 year period was selected as it represents all the data that was available on the Central Bank of Kenya (CBK) website. Using the 159 observations of SPEI06 obtained, the terminal values of the option contracts at a strike level of -1 were calculated.

5.7 Analysis of Objective – 3 – Efficiency of Option Contracts

This section analyses the efficiency of the SPEI based weather derivatives in reducing the risk exposure of Kenya's maize farmers to the financial risks arising from weather uncertainties. An option contract is priced and assumed to be bought by farmers for hedging purposes. The Cumulative SPEI Index during the growing season was used as the underlying index for option pricing purposes. The growing season was used because it has been shown to have more influence on agricultural yields (Iizumi & Ramankutty, 2015).

5.7.1 Calculation of the Payoff

From the obtained SPEI indices, the expected payoff to those farmers who bought the option contract was calculated. The payoff is calculated as follows:

$$P = \alpha \min (SPEI_n - K, 0) \quad \text{Equation 5.10}$$

Where;

SPEI	is the weather index
K	is the strike level
α	Represents the tick size which was set at $100

5.7.2 Price of the Call Option

According to Alaton et al. (2002) the price of an option can be obtained under the assumption that the probability that (min $(SPEI_n - K, 0)$) is very small. However, in situations where the assumptions do not apply, then the Monte Carlo simulation should be used. In our study, the rule was not applicable as there were several instances where the calculated (SPEI- K,) was zero. It was therefore necessary to simulate data so as to overcome this challenge. Following (B. Sun & van-Kooten, 2014) , the price of the option contract is calculated as;

$$P = D\sigma\emptyset\left(\frac{K-\mu}{\sigma}\right) + D(\mu - K)[1 - \varphi\left(\frac{K-\mu}{\sigma}\right)]$$ Equation 5.11

Where;

μ is the mean value of the weather index, K is the strike values, Ø is the normal probability density function and ϕ is the cumulative probability distribution function (CDF) K=0, D=100.

5.7.3 Selecting the Best Model

Following Zhu et al. (2012), the distributions obtained are ranked according to Kolmogorov Smirnov, Anderson Darling, Chi-Squared. An average of the ranking was calculated and the model that ranked highest according to the obtained average was selected.

5.7.4 Efficiency Analysis

To conduct the efficiency analysis tests, a revenue function with and without the option contract was modelled. According to Manuela and Ruyuan (2015), the revenue without the GDD contract is equal to the gross income of selling the commodity. Which can be expressed as:

$$R_t = pY_t^{det} \quad R_t = pY_t^{det}$$ Equation 5.12

While the revenue with the option contract is expressed as:

$$R_t = pY_t^{det} + contract\ payoff - contract\ price$$ Equation 5.13

Where the commodity price of the crop is p,p and Y_t^{det} is the time detrended yield. It is important to detrend the yield so as to eliminate the time related drifts so that ideally, weather is the only factor that is causing the yield changes

After obtaining the revenues with and without the contract, the efficiency test criteria was applied so as to get an insight of the implications of the weather contracts. The test criteria applied in this study is the Value at Risk (VaR).

$$Pr(R < VaR\alpha) = \alpha$$ Equation 5.14

The VaR measures the value of return at a given risk level at a given time horizon. It is calculated using the inverse of the CDF of the return distribution.

5.8 Conclusion

Chapter 5 lays out the foundation and approaches taken in obtaining the results presented in the subsequent 3 chapters. It describes the location of this study, the data used in the analysis as well as the process adopted to select the crop that was analysed. It also characterises the model variables and expounds on the research methods used for data analysis. A schematic diagram summarising the research objective and the corresponding analytical procedures is presented in Figure 5.1.

Chapter 6: Estimating Drought Risk in Kenyan Agriculture

6.1 Introduction

This chapter presents the results of the empirical study of the yield risk in Kenyan agriculture as a result of drought. A description of the study location, crop selection and data collection are is provided in Chapter 5, Section 5.2, 5.3 and 5.4 respectively. A detailed description of the model used to estimate the risk is provided in Chapter 5, Section 5.5.

This chapter has eight sections. First, an overview of natural disasters in Kenya with a focus on the country's vulnerability to drought is provided in section 6.2. This is followed by an analysis of the relationship between maize production per ha and the rainfall received in the season. Then a presentation of the results on the relationship between maize yield, rainfall and prices is provided in section 6.4.

After the background analysis on the relationships between the maize yield, rainfall received, and the prices, section 6.5 described the process of obtaining the yield losses and presented the results therefrom. Then in section 6.7, the obtained yield losses were modelled into the best suited statistical distribution which was used when estimating the yield risk as presented in 6.7. Finally, the conclusion is provided in section 6.8.

6.2 Overview of drought disasters in Kenya

Drought is a natural occurrence that can become a natural disaster if not adequately managed (Blauhut et al., 2016). These authors argue that unlike other natural hazards, it has a creeping onset and does not have a unique definition which makes determining the beginning or end of a drought event difficult.

Kenya has experienced many disasters between 1960 and 2015 with drought affecting approximately 49 million people. The second and third ranking disasters in terms of people affected were the parasitic disease and riverine flood which affected approximately 7 million and 2 million people respectively. When ranked in relation to number of occurrences, riverine floods were the first with 35 recorded events while bacterial disease and drought were second and third with 18 and 14 recorded events respectively (Table 6.1). While drought had the third highest number of occurrences, it affected the highest number of people in the country. The Government of Kenya (2016a) affirms these results by citing drought as the single most important natural hazard in Kenya. The government reiterates that drought shatters livelihoods, causes hunger and leads to nutrition related disease and even death. In addition, droughts have been associated with a decline in food production as well as disturbing the migratory patterns of pastoralists. This may exacerbate resource-based conflict, and cause substantial loss of assets, triggering acute food insecurity among vulnerable households and placing a heavy strain on both the local and national economies.

The occurrence of drought places huge financial strain on households and the economy in general. As an example, the 2008-2011 drought resulted in a loss of approximately US$ 12.1 billion. Out of this, approximately US$ 11.3 billion was attributed to lost income flows across all sectors of Kenya's economy (Government of Kenya, 2013). To address drought effects and manage both pre and post drought impacts, the Government of Kenya established the National Drought Management Authority (NDMA) in 2011 as the key institution tasked with enhancing adaptive capacity. In addition, NDMA is mandated to establish mechanisms to ensure that drought does not become famine and that impacts of climate change are addressed (Government of Kenya, 2016a).

Table 6.1: Summary of Natural Disasters in Kenya from 1960 To 2015

Disaster type	**Disaster subtype**	**Events count**	**Total deaths**	**Total affected**
Drought	Drought	14	196	48,800,000
Earthquake	Ground movement	1	-	-
Earthquake	Tsunami	1	1	-
Epidemic	*	4	1,273	22,538
Epidemic	Bacterial disease	18	1,474	51,987
Epidemic	Parasitic disease	5	1,595	6,807,533
Epidemic	Viral disease	5	514	3,396
Flood	*	7	228	961,200
Flood	Flash flood	7	113	49,500
Flood	Riverine flood	35	1,121	2,206,222
Landslide	Landslide	3	36	20
Landslide	Mudslide	1	20	6
Storm	Convective storm	1	50	-

* Not specified. (Source: Guha-Sapir et al., 2016)

To further address the drought hazard, the government set up emergency relieve funds as well as Drought Response and Emergency Relief policies and strategies. Similarly, the private sector and other development partners have been providing various services including capacity building as well as development of financial products such as index-based insurance to help farmers hedge against these risks.

To support these initiatives by the government and its partners, it is important that the drought risk be estimated more accurately. In this section, we present the results from our estimation of risk exposure to maize farmers in Kenya. The direct impacts of drought (changes in yield) were used to estimate the risk. Specifically, the financial technique (VaR) was applied to crop yield variation to evaluate the risk exposure to maize farmers in Kenya. This approach builds on works by Xu et al. (2011) and Wang et al. (2015) who explored the use of financial models on agricultural yield to estimate drought risk in China. These authors these models are now applied in Kenya which is a developing economy in East Africa.

6.3 Relationship Analysis of the Maize Crop Production Per Ha and Rainfall

To gain an understanding of the relationship between weather variables and maize yield. The national yield and rainfall data for Kitale region from 1961 to 2014 was obtained and plotted on a graph. To enable an in-depth examination of the total growing period rainfall and the maize crop yield for patterns, standardization was performed on the two differing scale attributes of rainfall and maize in order to facilitate a simultaneous sequence chart plot as shown in (Figure 6.1). This method is similar to the one that was adopted by Vagh (2012) who investigated the effect of stochastic annual rainfall on crop yields in South Western Australia.

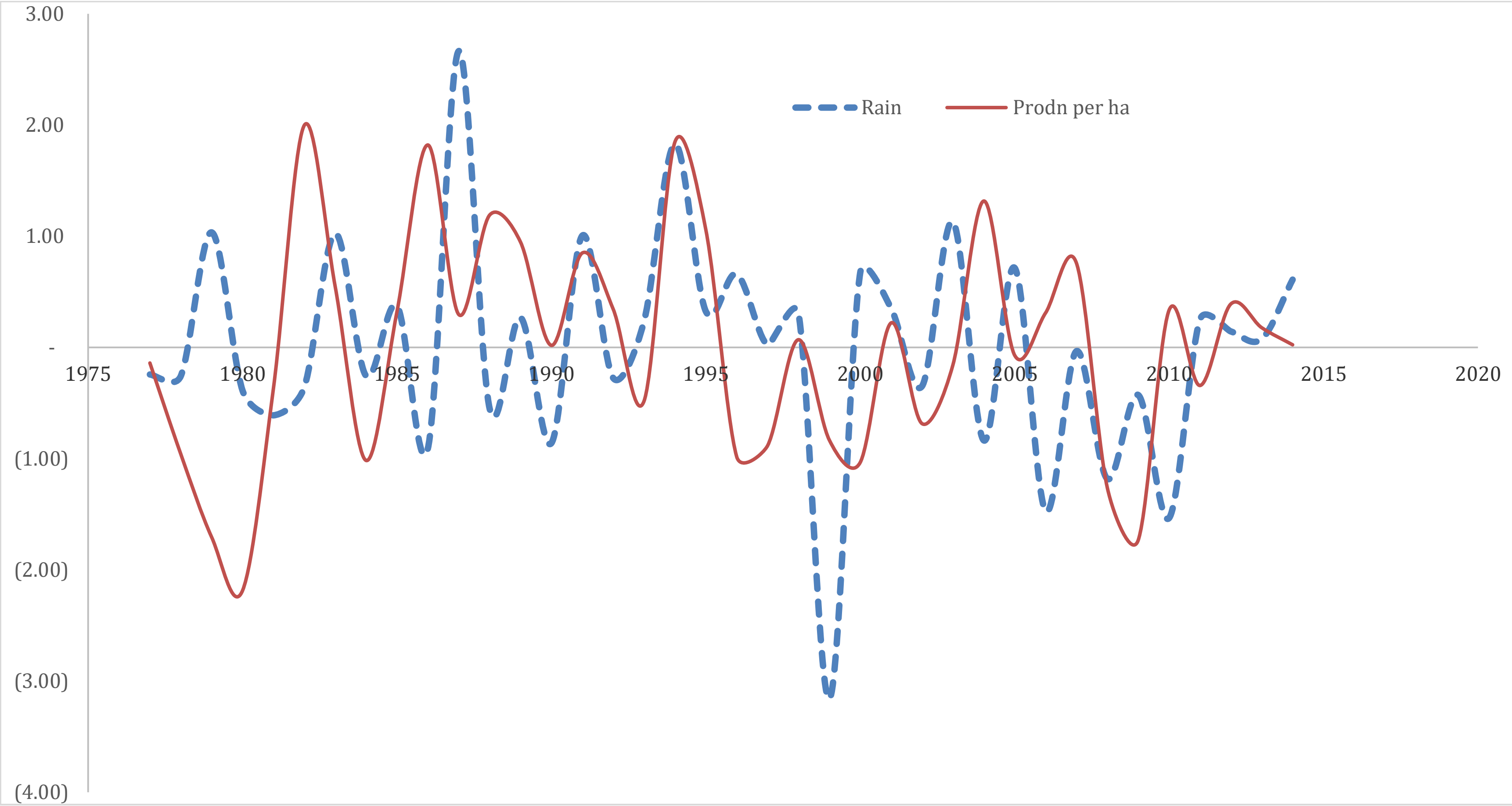

Figure 6.1: Trend Analysis of the Standardised Rainfall and Maize Yield from 1977 - 2014

(Source: Own analysis using data from Food and Agriculture Organization (2017) and (National Oceanic and Atmospheric Administration, 2019))

A visual comparison of the graph enabled a comparative analysis which showed the relationship between the total growing period rainfall and the maize yield across the selected years. It is observed that periods of low rain fall were characterised by low yield and periods of high rainfall leading to higher yields. As an example, the low rainfall during the 1980s and 1990s had a corresponding low yield. The presence of a positive relationship between yield and rainfall is probably because most of the farming in the region is by rain dependent farmers whose production is highly affected by the weather.

Surprisingly, there was a period between 1975 and 1980 when despite the rainfall having a positive index, the yield had a negative index indicating that there was a negative relationship between the rainfall and the yield. This could imply that during this period, there were other factors other than rainfall that influenced the yield. Similarly, some periods between 1985 and 1990 had high rainfall that corresponded to lower yields. The lower yields during times of high rainfall could be as a result of flooding events which as explained by Devereux (2007) do trigger harvest failures.

To conduct a robust check of the relationship between rainfall and yield, the decadal mean, standard deviation and coefficient of variation were calculated and plotted on Figure 6.2. The top figure represents the coefficient of variation, while the diagrams on the right represent the minimum rainfall and yield respectively. On the left-hand side of the diagram, the maximum rainfall and yield are displayed.

Figure 6.2: Relationship between Yield and Rainfall

(Source: Own analysis using data from Food and Agriculture Organization (2017) and National Oceanic and Atmospheric Administration (2019))

It is observed that the coefficient of variation is greatly influenced by the minima values of both the rainfall and the yield. This is because the coefficient of variation diagram mirrors that of the minima values of both the yield and the rainfall. The strong influence of the coefficient of variation by the minima values means that the volatility in yield and rainfall was more because of the periods of low rainfall and yield. Consequently, it is inferred that drought events are the major causes of weather variability during the period under study. In the same way, lower than expected yield is the main cause of yield variability during the period under study. An evaluation of the relationship between the Coefficient of Variation (CV) of rainfall and yield confirms that the periods of low rainfall and very high rainfall (floods) resulted in lower yield.

6.4 Analysis of the Changes in Maize Yield, Rainfall and Prices

After obtaining the results on the relationship between the yield and rainfall, this study then establishes the relationship between the growing period precipitations, maize prices and yield. The data used in this section was obtained from the Central Bank of Kenya (for maize prices), Food and Agriculture Organization Statistics (FAOSTAT) and NOAA (for weather data).

Data relating to producer prices was only available from 1991 to 2014 thus this analysis was limited to this period when all data is available. The annual data on maize yield was in (tonnes/ha), rainfall in (mm) while the producer price of maize was in US dollars. Thus, to ensure ease of comparison across the data sets, the data was standardised and the results plotted on a bar-graph Figure 6.3.

It is observed that lower yields did not always result in higher prices as would have been expected based on the laws of demand and supply. As an example, in 1999 the rainfall was way below average, leading to lower yields; the prices were however below the expected prices. Similarly, in 2002 all the three variables namely, maize yield, price variations and rainfall were all below expectation. This could imply that the price of maize is influenced not only by production but by other factors such as quality of the produce. However, when a correlation analysis was performed, the results indicated that there existed an overall positive relationship of 0.31 between the rainfall and yield. Thus, the overall impact of rainfall on yield is seen to be positive with increase in rainfall expected to result in higher yields. Further, a negative relationship is observed between rainfall and the price of the produce (0.12), meaning high rainfall resulted in lower prices.

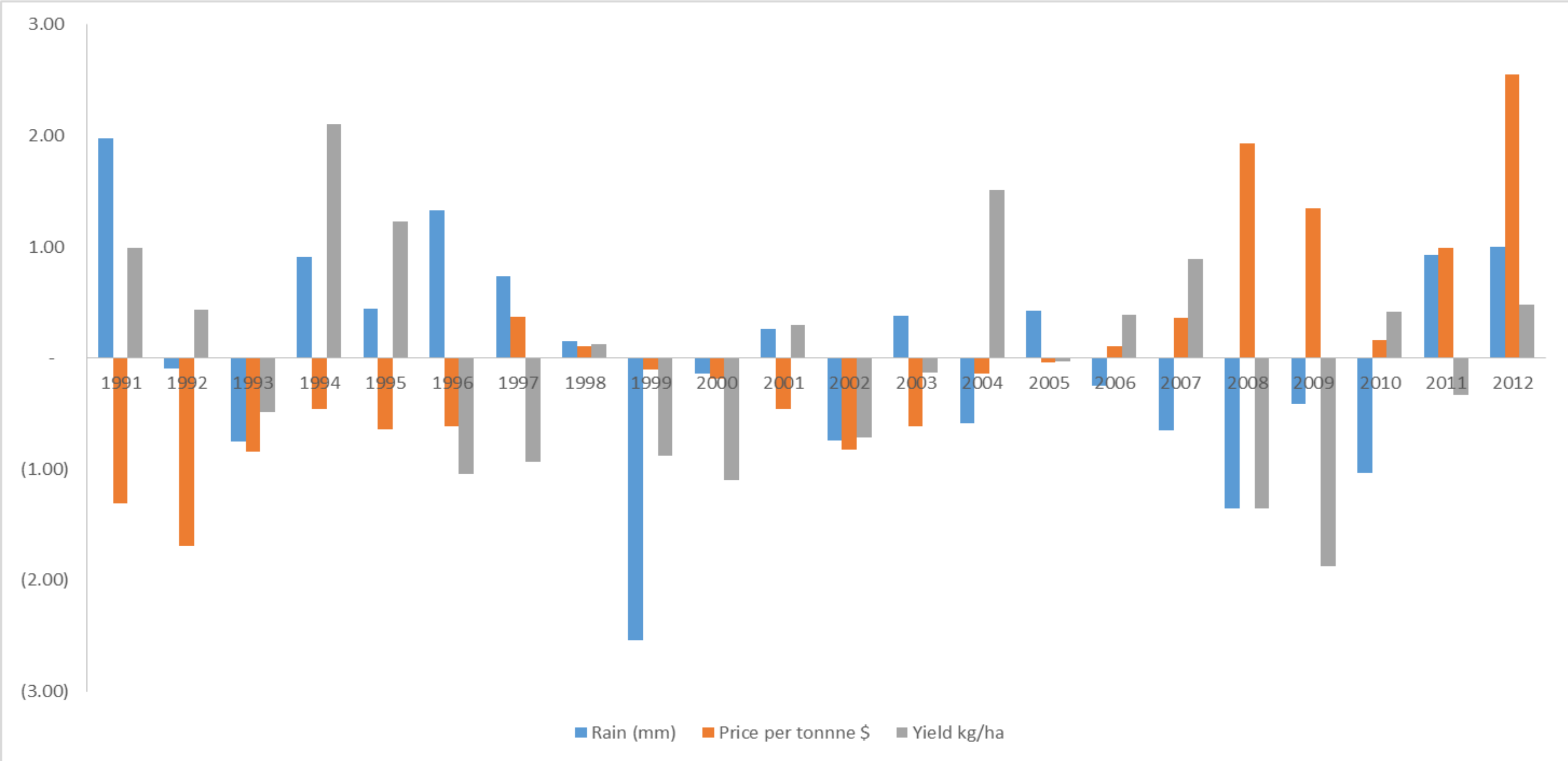

Figure 6.3: Relationship between Maize Yield, Rainfall and Prices

(Source: Own analysis using data from Food and Agriculture Organization (2017))

Finally, the correlation between yield and price is (0.30) which indicates that an increase yield resulted in a reduction in produce price. Overall, an increase in rainfall led to higher yields and lower prices, this could be as a result of the oversupply of the produce during the periods of abundance. Consequently, measures that help farmers manage extra produce during periods of over supply would be helpful during periods of scarcity.

6.5 The Maize Yield Analysis

In order to make accurate and reliable predictions about food production and food availability, an accurate description of yield trends and inter-annual variability is needed (Schauberger et al., 2018). This section analyses Kenya's national maize yield trends and variability by plotting these values on a time series graph as shown in Figure 6.4. A clear and steady increase in annual maize yields is observed from 1963 to 2012 with the period of strongest increase being in the 1980s. This was followed by a period of decline in yield from the 1990 thorough to the years 2000. The observed increase in yield can be attributed to a number of factors such as improvement in technology over time, better farming techniques among others.

A further analysis was conducted in order to compare and evaluate the yield trends across decades. This was achieved by calculating the decadal mean, standard deviation and the coefficient of variation. This approach is similar to that adopted by Schauberger et al. (2018) when analysing crop trends and variability in France. The obtained decadal yield variability as represented by the standard deviation and coefficient of variation are presented in Figure 6.4. The results reveal that the variability in maize yield differed over the decades but largely mirrored the annual maize yields trajectory. Similar to the annual yield, the standard deviation and the coefficient of variation increased from the 1960s until the 1980s where a negative growth trajectory is observed.

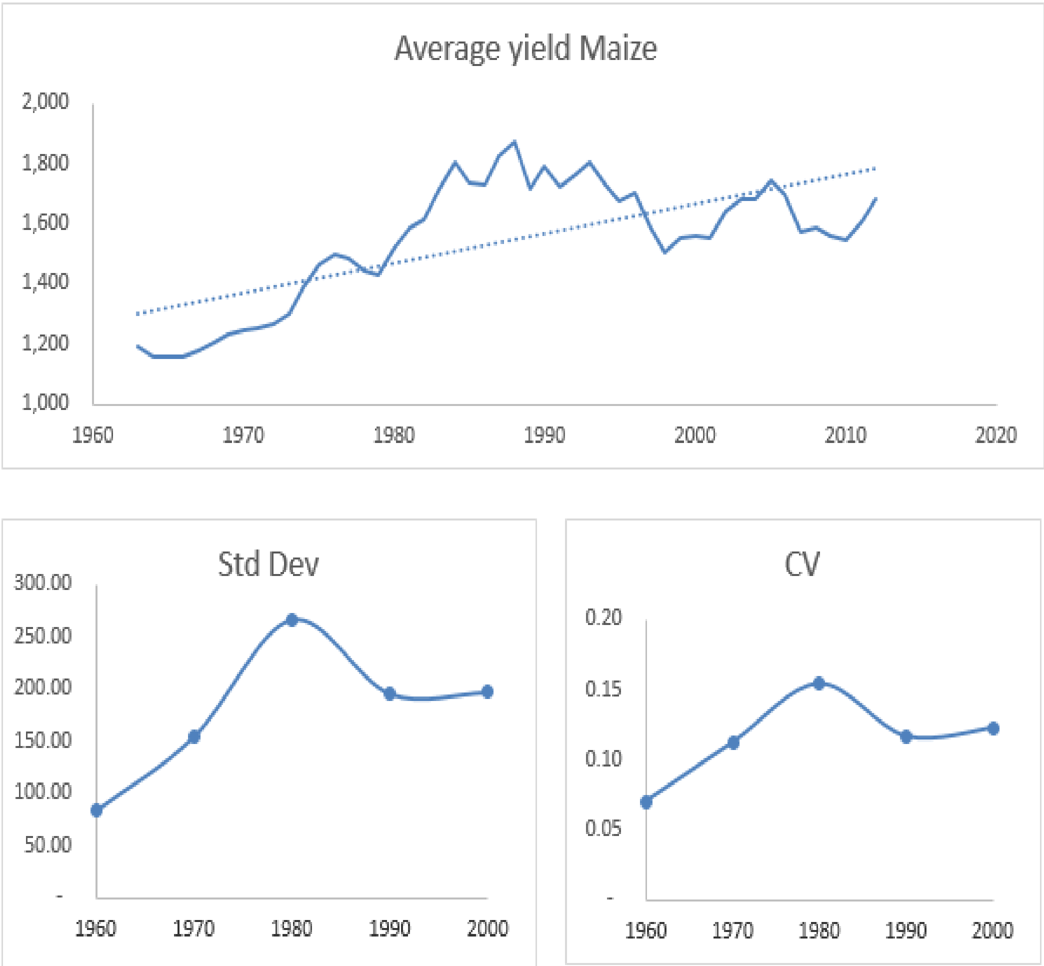

Figure 6.4: Trend and Decadal Maize Yield Analysis

(Source: Own analysis using data from Food and Agriculture Organization (2017))

After analysing the maize trends, the maize yield loss from 1961 to 2014 was estimated using Equation 5.1 and analysed. The yield loss for a given year t, was calculated as a percentage of the yield difference from the normal/average yield. The normal yield was calculated as the average yield starting from period t-2 to t+2. Table 6.2 presents the obtained yield losses.

The obtained results reveal that the actual yield was less than the expected yield during approximately half of the study period. Specifically, 27 out of the 50 years that the variations were calculated had yields that were below the normal yield. The highest losses of 20% and 21% were recorded in 1980 and 1984 respectively. These periods coincide with the drought event of 1984 which was cited as a widespread drought throughout the country while the 1980 drought mainly affected the Turkana region of Kenya. Furthermore, the results show that most of the period that the yield was below the expected yield were periods when a drought event had been recorded or immediately after a drought event. As an example, during the drought in year 2008 and 2009 there was a yield loss of approximately 12% and 17%.

However, even though there was no drought in years 1993 and 1996, a yield loss of approximately 13% and 14% was suffered. Although no drought had been recorded in these years, these were the periods immediately after the 1991/92 and 1994/95 drought events (Table 6.2). There are two possible explanations to these results. First, it could be that the soil moisture content was still low owing to the previous year's drought which affected the yield. Secondly, the farmers may not have fully recovered from the drought event that had happened in the preceding years. A possible reason for this is that the drought-related shocks have been recurring rapidly leaving the farmers with insufficient recovery time before the next shock occurs. In addition, since the farmers may not have had insurance covers, they could have resulted to borrowing during the periods of low production and did not have enough cash at their disposal when the weather conditions improved. As a result, these years may experience a reduced the scale of production and use of farm inputs due to diminished resources. Furthermore, farmers who mostly depend on the sale of surplus crop to acquire inputs for the following season may have been unable to do so during periods succeeding the drought periods owing to poor coping capacities (Government of Kenya, 2012). In view of this provision of products that increase their resilience would be key in managing the duration of time taken to return to their normal production levels.

Table 6.2: Summary of the Maize Yield Losses from 1961 to 2014

Year	Variation %	Year	Variation %	Year	Variation %
1965	-7.20	1980	-21.11	1997	-7.46
1966	-6.57	1981	-0.33	1999	-4.58
1970	-1.59	1984	-20.15	2000	-7.75
1971	-2.76	1985	-0.87	2002	-7.83
1972	-0.97	1987	-5.90	2003	-3.50
1973	-1.09	1990	-7.56	2005	-5.99
1974	-3.07	1992	-2.02	2008	-12.36
1975	-3.29	1993	-13.90	2009	-17.13
1979	-9.22	1996	-14.75	2011	-1.40

(Source: Own analysis using data from Food and Agriculture Organization (2017))

6.6 Modelling the Agricultural Yield Losses

After obtaining the agricultural yield losses, two approaches were used to fit the obtained yield loss series into a probability distribution. The results from the two approaches were compared and the best suited model was selected. The first approach involved fitting the obtained yield losses into various models using the easy fit software and the highest ranked model picked there from. When this process was applied, the best ranking model was the Generalized Extreme Value distribution (GEV).

In the second approach, the R programme was used to fit the yield grain losses into a probability distribution based on the Point Over Threshold (POT) method. First the grain losses were fitted into a Mean Residual Life (MRL) plot so as to determine the optimal threshold (Figure 6.5). Selection of an optimal threshold involves a delicate balance between two competing forces namely bias and variance. If the threshold is too low, the tail satisfies the convergence criterion less, which will result in large bias and incorrect result. Then again, if the threshold is too high, little data above the threshold will lead to high variance and unreliable result (Yang, Zhang, & Ren, 2018). When the MRL approach is used, the optimal threshold is chosen to be the lowest level where all the higher thresholds-based sample mean excesses are consistent with a straight line. (Scarrott & MacDonald, 2012). Following this approach, the threshold in this study was set at 7 because the mean excesses of the yield losses after this threshold has been attained is close to a straight line.

After determining the threshold, the POT method was applied so as to model the data above the set threshold. Subsequently, the MLE approach was used to select the most appropriate model. Using this way, the best suitable model was the Generalised Pareto Distribution (GPD).

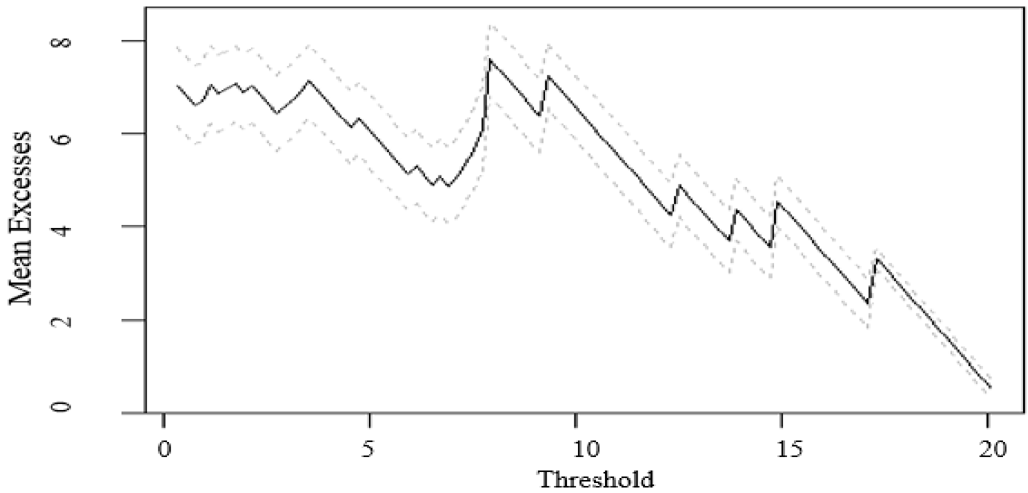

Figure 6.5: Mean Residual Life Plot of the Maize Losses

(Source: Own analysis using data from Food and Agriculture Organization (2017))

The GEV and GPD parameters were determined based on the threshold by use of R Programme. To determine the best suited model between GEV and GPD, the diagnostics for the two probability distributions were plotted and displayed alongside each other with the Quantile-quantile plot at the top, density plots in the middle and return level plot at the bottom of Figure 6.6.

The quantile plot displays quantiles of the empirical data plotted against model quantiles. According to Hasan, Ahmad Radi, and Kassim (July, 2012), a quantile plot that does not deviate greatly from a straight line indicates that the model assumptions may be valid for the data plotted. A visual inspection of the results reveals that the plotted points on the quantile plots are close to linear and also close to the diagonal line for both models. However, the GEV plots are seem to be more linear and closer to the diagonal line compared to those of the GPD. Thus, since the GEV plots are more linear and closer to the straight line compared to those of the GPD distribution, the GEV model was seen to be a better fit compared to the GPD.

Secondly, the density plots were plotted and analysed to aid in choosing the better fitted model for our yield loss distribution. A density plot visualises the distribution of data over a continuous interval or time period. The peaks of the density plot are at the locations where there is the highest concentration of points. R programme was used to fit the yield losses into a density plot. The density plot displays the model distribution (blue dashed line) against the actual yield losses (black solid line). It is observed that the Probability Density Function (PDF) does not follow a normal distribution. This is indicated by the presence of a heavy tail to the right showing that there were some observations that were not normally distributed. Once again, the density plots indicate that GEV distribution provides a better fit compared to the GPD distribution. This is because the model distribution and the empirical distribution are closer aligned in the GEV compared to the GPD distribution.

Finally, the return level plot shows return level against return period. The central line on the graph is the return level for the fitted model, and the pair of outer lines the corresponding pointwise 95% confidence limits. The points are the empirical return levels, based upon the data, and should lie between the confidence limits if the model fits the data well. As with the quantile plot, a significant number of points contravening these limits indicates poor model fit. The analysis reveals that the return level curve asymptotes to a finite level as a consequence of the positive estimate of ξ. Further it is observed that the model points for the GEV distribution fit within the two outlier lines that indicate the confidence interval. Based on the above observation, this study concludes that the return level plots indicate that the GEV distribution is a better fit to our distribution.

In both the GEV and GPD diagnostics results showed good agreement that the data followed an extreme value distribution. However, while using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) showed that the GPD was a better fit for this distribution. The rating and raking 14 different models show that the GEV model was a better fit. This finding is supported by the analysis of the two distributions diagnostic plots which suggest that the GEV is a better fit. This is probably because that AIC and BIC impose a penalty for including more information in the model, in this case more data points (Pinheiro & Grotjahn, 2015). Furthermore, while each of the methods has its advantages and issues GPD method based on POT requires some subjective decisions e.g. during threshold determination and therefore the GEV was selected as the best suited model for the yield losses.

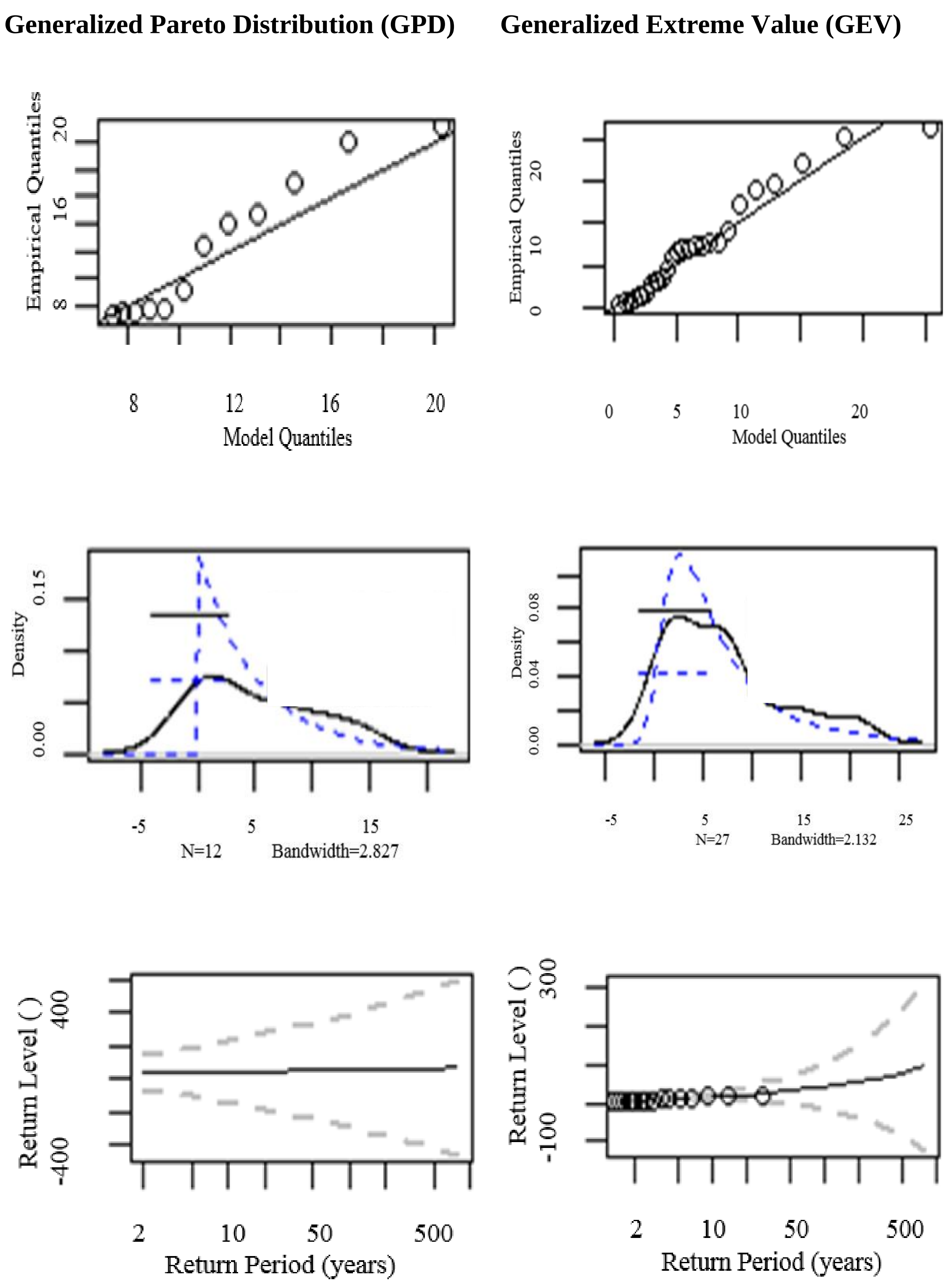

Figure 6.6: The Characteristics of the Maize Losses in Kenya

(Source: Own analysis using data from Food and Agriculture Organization (2017))

6.7 Assessing the Risk

After selecting the model, the R software was used to estimate the model parameters. These are then used to model the Cumulative Density Function (CDF) and the Quantile functions. Successively, VaR technique is applied to calculate the agricultural drought given various scenarios when suffering agricultural drought event of 10 years (α=10%), 20 years (α=5%), 50 years (α=2%) and 100 years (α=1%) for a return period. The calculated VaR was approximately 21%, 21%, 24% and 24% for the 10, 20, 50 and 100 years return periods respectively. This is particularly high especially for the 50 year and 100 year return periods as it implies that the farmers would loss approximately a quarter of the expected yields. These levels of loss are close to those experienced in 1980 and 1984 (20 and 21% losses) which affected approximately 40,000 and 600,000 people respectively.

Similar findings are echoed by Schlenker and Lobell (2010) who found that by mid-century, the mean estimates of aggregate production changes in SSA to be −22, −17, −17, −18, and −8% for maize, sorghum, millet, groundnut, and cassava, respectively; and those of Barron, Rockström, Gichuki, and Hatibu (2003) who evaluated the effects of dry spell on maize yields for two semi-arid locations in East Africa and found that occurrence of dry spells during the growing season negatively affected the maize yield in all the location in the study. The highest yield reductions occurred in the flowering stage and secondly in the grain filling stage for both locations all seasons.

While there is a consensus that dry spells will negatively impact the crop yield in SSA, the effect of different drought intensities on yield risk has not been explicitly accounted for. The findings in this study provide an insight on the probable yield risk under the different drought intensities which would be useful for drought risk management. However, this study is limited by the crop datasets which is only available at the national level. We note that impacts at the country-level mask differences between regions and farmers within country, which arise from diversity in access to factors such as land, credit, markets, technology, as well as differences in the baseline climate. (Schlenker & Lobell, 2010), Thus, future work with finer scale data, as well as different approaches would help to clarify the fine scale differences which may be important for many adaptation decisions. Nonetheless, the patterns depicted in this study should be useful for a set of decisions made at broader scales, such as how much to invest in drought risk preparedness and response or how to invest in agricultural development and adaptation in Kenya

6.8 Conclusion

This chapter sought to estimate the drought risk for Kenya's maize farmers as a result of weather variability. First an in-depth analysis of the maize yield data was undertaken with a view to gaining an insight on the yield trends over time. This was achieved by use of time series graphs for the annual yields and decadal variance analysis. From the analysis it was found that there was a general increase in yield for 1960s up to the 1980s after which a decline in yield is observed. This was confirmed by robust check using Standard Deviation and Coefficient of Variation as shown in Figure 6.4. It was also found that periods of exceptionally high or low rainfall led to a lower yield. The overall variability in yield and rainfall was largely as a result of the minima values. This implies that drought (which is as a result of inadequate rainfall) had a bigger impact the overall yield (low yield).

Secondly, the annual yield, rainfall and prices were examined so as to gauge the relationship between the three variables. The analyses revealed that lower yield did not always result in higher prices. During some drought years e.g. 1999 and 2002 the maize prices were low despite the yield being lower than expected. However, the overall correlation between rainfall and yield was positive indicating that higher rains resulted in higher yields and vice versa.

In order to estimate the yield risk in Kenya's agriculture, the annual yield losses were calculated using Equation 5.1. The overall results that the annual yield was below the expected yield in more than half of the period under study. The highest losses of 20% and 21% were experienced in 1980 and 1984. Furthermore, majority of the years that had yield losses coincided with years that the country experienced drought episodes. This is probably because Kenya's agriculture is dominated by smallholder rain dependent farmers whose production is highly susceptible to the changes in weather. Interestingly, some of the years succeeding the drought periods experienced lower than expected yield.

Then after obtaining the yield loss series, they were fitted into a statistical model and the yield/production risk was estimated using the VaR method. The results indicate that the estimated risk for the 10 years, 20 years 50 years and 100 years return period to be 21%, 21%, 24% and 24% respectively. These values are high considering that similar losses in 1980 and 1984 affected approximately 60,000 and 600,000 people respectively.

The obtained results confirm that the weather changes pose a threat to maize production in Kenya with periods of drought leading to low yield. It is therefore important for the government and other stakeholders to invest in weather risk management in the sector in order to reduce the possible losses arising from weather variability. The following chapter explores the viability of weather derivatives in hedging against drought risk in Kenyan agriculture.

Chapter 7: Hedging Drought Risk in Kenya with Weather Derivatives

7.1 Introduction

This chapter presents the results of an empirical evaluation on the viability of a drought index for pricing weather derivatives. A description of data in this study is provided in section 5.4 while a detailed description of the process adopted to price the option contract is presented in section 5.6. This chapter has four sections. First, an overview of weather variability and the use of financial products is evaluated. This is followed by a presentation of the option pricing process using rainfall data in section 7.3 followed by the results from the use of the SPEI index as the underlying index when pricing the option contracts in section 0.

7.2 Overview of Weather Risk Management

Extreme weather events coupled with limited coping capacity have led to increased financial losses in various economic sectors denoting the need for adaptation measures (Aakre et al., 2010). In particular, the agricultural sector in developing economies such as those in Sub Saharan Africa (SSA) has been extremely vulnerable. This is due to the sectors strong dependence on weather whose variability is projected to rise (Kotir, 2011; Mirza, 2003). Significant financial resources are needed to enhance mitigation and adaptation to these extreme weather conditions (African Development Bank, 2011). Climate finance provides an opportunity to mobilise financial resources needed for adaptation and mitigation. In particular, weather based financial instruments can be used not only to mobilise climate finance resources, but also as a hedging tool for managing climate risks posed by unpredictable weather, especially the extreme weather events (Little et al., 2015).

Weather risk markets are among the newest and most dynamic for weather risk sharing. These markets have experienced rapid growth with emergence of new, weather-based risk management tools (Paulson & Hart, July, 2006). Since 1996, weather derivative or weather contract have been introduced and gained popularity especially in the energy sector (Brockett et al., 2005; Cyr et al., 2010). Weather Derivatives represent a recent type of financial product developed to hedge against weather risks. Although similar to weather insurance, they differ in many ways as outlined in Table 7.1 and can provide for the effective mitigation of the financial impact of weather-related risks.

While weather insurance covers events with a low probability of occurrence but have higher risks exposure, weather derivatives cover events with a high probability of occurrence but a lower risk exposure. In addition, Weather derivatives have several advantages over the traditional insurance. Unlike the traditional crop yield insurance, the design and administration processes of Index Contracts helps to reduce costs. Their payoffs are based on a widely available and objectively measured index which eliminates the need for farm-level loss adjustment. This significantly reduces the index contracts transaction costs relative to crop yield insurance (Geyser, 2004; Isakson, 2015; Vedenov & Barnett, 2004). Furthermore, the problem of adverse selection or moral hazard does not arise in the case of index contracts mainly because the value of the underlying index is independent of the individual actions of market participants (Isakson, 2015). And finally, since index contracts are designed to provide efficient means of risk transfer rather than risk pooling, systemic risk is not a problem. In fact, index contracts work even better when the risk being transferred is somewhat systemic (Vedenov & Barnett, 2004).

Table 7.1: Difference between Weather Derivatives and Insurance Contracts

Description		Weather Insurance	Weather Derivatives
1	Events covered	High risk, low probability events	Low risk, high probability scenarios.
2	Pay-out	Pays a once-off lump sum that may or may not be proportional to loss and as such lacks flexibility.	The pay-out is designed to be in proportion to the magnitude of the phenomena.
3	Pay-out trigger	Proof of damage or loss	Predetermined index value is passed/exceeded.
4	Monitoring of the contract	Not possible to monitor performance of an insurance contract during its life	It is possible to monitor the performance of the hedge during the life of the contract.
5	Costs	Can be relatively expensive and requires a demonstration of loss.	Less costly in comparison to insurance, require no demonstration of loss.

(Source: Geyser, 2004)

In light of the above, this study modelled the possible use of weather derivatives as a hedging tool for maize farmers in Kenya. To achieve this, two approaches were adopted. The first approach involves pricing of option contract using rainfall as the underlying index while the second approach used the SPEI index as the underlying index. This chapter provides the study's findings.

7.3 Results from Burn Rate Analysis

The first approach that was adopted to price a Weather Derivative for Kenya's maize farmers was the burn rate analysis. Rainfall data from Kitale region was used to construct an underlying index that was used to price the option contract. This method adopts a simplified approach to valuing contingent claims often employed in the insurance industry (Cyr & Kusy, 2007). It involves pricing the option contract based on the discounted average of the contract payoff that would have been observed in the previous years based on the historical values of the underlying variable. While the burn rate analysis has the advantage of being simple and easy to use, it’s has also been cited as overly simplistic which may lead to undervalued option contracts. Even so, this popular method has been used in the insurance industry due to its simplicity and ease of use.

This section details the results of the option price calculation for Kitale region using rainfall as the underlying index. Similar to Cyr et al. (2010), we use the growing season rainfall for western Kenya as the underlying index. The period of the study was from 1961 to 2014. The rainfall data was grouped into four categories in line with the crop of interest which is maize and the rainfall seasons in Kenya which are the long rains May to September and the short rains in the month of December and January (Food and Agriculture Organization, 2018). The four categories are, the growing season for the long rains, the growing season for short rains, the combination of the two growing seasons and the annual rainfall. Since the risk in our study would be that of significantly less than average rainfall. If the cumulative amount of rainfall is set at value K, (strike level at maturity) then the option would pay out a value α (tick size) per millimetre rainfall below the strike level (Equation 7.1).

$$X = \alpha \min [CRGP_j - K_0] \qquad \text{Equation 7.1}$$

Usually, the determination of the strike level and tick size is a vital step in estimating the price of an option contract. (Cyr et al., 2010) explains that these parameters are typically determined by the producer after considering their specific idiosyncratic operations. This study however, did not focus on the determination of these parameters. An arbitrary process was chosen to set these values with the strike level being considered at three possible levels. The first is the average rainfall, this is chosen on the assumption that the farmers make their choice of the appropriate farming inputs based on the expected levels of rainfall. Then, three more strike levels are determined at an interval of 5mm rainfall less than the previous strike level which gives four strike levels of 4.95mm, 9.95mm, 14.95mm and 19.95millimetres respectively. Further, the tick size was also chosen at an arbitrary level of Ksh. 2,000 per millimetre of growing period total rainfall that exceeds the strike level. We further assumed that the contract was a European option entered into at the beginning of the season and held till the end of the season. In line with the two seasons in Kenya, this implies that the option contracts would be held for 6 months.

The possible pay-outs were calculated for the set strike levels and discounted at an interest rate r. To estimate the interest rate r, the weighted average rate of the 91 day Treasury bill was obtained from the Central Bank of Kenya (CBK). The 91 day Treasury bill was selected because it provided the longest dataset period of 21 years. The interest rate r was valued as the grand average of the weighted average rate from 1997 to 2017. The 20 year period was selected as it represents all the data that was available on the Central Bank of Kenya (CBK) data base. The annual weighted interest rate for the 20 year period is 10.50%, see Table 7.2.

Table 7.2: The Treasury-Bill Interest Rates

Year	**Annual Weighted Average**	**Year**	**Annual Weighted Average**
1997	22.55	2008	7.70
1998	23.33	2009	7.43
1999	13.25	2010	3.62
2000	12.14	2011	7.98
2001	12.72	2012	12.79
2002	8.92	2013	8.92
2003	3.67	2014	8.93
2004	2.86	2015	10.85
2005	8.44	2016	8.65
2006	6.83	2017	8.35
2007	6.79		
Grand Average			**10.50**

(Source: Central Bank of Kenya, 2018)

Table 7.3 displays the results from the burn analysis using the growing period rainfall as the base index. It is observed that if farmers had bought the option contracts they could benefit in years of drought. As an example, in 1999, the farmers would have received a pay-out at all the strike levels that have been evaluated. This period coincides with the 1999/2002 drought which was declared as a country wide drought. Additionally, by purchasing a call option with a strike level of 15mm for the price of Ksh. 1,237 annually, the farmers would have hedged against the possible losses in 1999, 2004, 2006, 2008 and 2010. Note that in 1999 Kenya experienced a severe drought that was classified as having being a national wide drought while the other years namely 2004, 2006, 2008 and 2010 had drought occurrences that were declared as wide spread drought. In essence, farmers would have been cushioned against losses during these periods of drought. These periods also coincide with the periods documented by Huho and Mugalavai (2010) as having a national disaster being declared as a result of drought. However, the 1994/1995 period would not have resulted in a pay-out to farmers. This implies that there is need to carefully estimate the parameters used to price the option contracts to ensure that all the relevant factors are catered for.

A further analysis shows that hedging at the lower levels of 5mm and 10mm did not result in significant benefits to the farmers as the only year that had an option pay-out at these strike levels was 1999 with the rest not having a positive pay-out. This implies that the best level to hedge at would be 5mm lower than the average growing period rainfall.

Table 7.3: Burn Rate Analysis: 1997 - 2015 Growing Seasons Call Option Terminal Values

Year	**Total Growing Period Rainfall**	**Strike Value (mm of cumulative growing period rainfall)**			
		5	**10**	**15**	**20**
1977	18	-	-	-	2,915
1978	18	-	-	-	3,095
1979	26	-	-	-	-
1980	18	-	-	-	4,675
1981	16	-	-	-	7,375
1982	18	-	-	-	4,295
1983	26	-	-	-	-
1984	18	-	-	-	3,075
1985	22	-	-	-	-
1986	14	-	-	995	10,995
1987	36	-	-	-	-
1988	17	-	-	-	6,635
1989	22	-	-	-	-
1990	15	-	-	415	10,415
1991	26	-	-	-	-
1992	18	-	-	-	3,295
1993	21	-	-	-	-
1994	31	-	-	-	-
1995	22	-	-	-	-
1996	24	-	-	-	-
1997	20	-	-	-	-
1998	22	-	-	-	-
1999	1	8,355	18,355	28,355	38,355
2000	24	-	-	-	-
2001	22	-	-	-	-
2002	18	-	-	-	4,195
2003	27	-	-	-	-
2004	15	-	-	115	10,115
2005	24	-	-	-	-
2006	11	-	-	7,835	17,835
2007	20	-	-	-	375
2008	13	-	-	4,315	14,315
2009	17	-	-	-	5,155
2010	11	-	-	8,595	18,595
2011	21	-	-	-	-
2012	21	-	-	-	-
2013	20	-	-	-	-
2014	24	-	-	-	-
2015	19	-	-	-	1,475
Average	**20**	**214**	**471**	**1,298**	**4,287**
Value of call		**204**	**449**	**1,237**	**4,086**

Source: Own analysis using data from National Oceanic and Atmospheric Administration, (2019)

7.4 Results from SPEI Index

As noted earlier, one of the advantages of the burn rate analysis method is that it is quick and simple to perform as it involves using the historical payoff of equivalent derivatives, and calculating an average return which is assumed to be the fair value of the derivative (Lee & Craine, 2012). This method is widely used by analysts due to its ease and simplicity. Nonetheless, the results from this method are likely to be heavily influenced by particular years in the period under analysis making it unsuitable to value extreme events, (Lee & Craine, 2012; Mungai et al., 2015). Consequently, the results from burn rate analysis should be interpreted with caution.

Secondly, the underlying index used in the above analysis is based on rainfall only and does not account for the effect of temperature on the crop's growth. In view of these concerns, the application of Standardized Precipitation Evapotranspiration Index (SPEI) for pricing the option contracts was explored. This index has the advantage that it takes into consideration both the rainfall and evapotranspiration during its estimation. The SPEI indices are obtained and modelled for use in pricing the option contract. A total of 660 SPEI06 monthly indices were obtained from January 1960 to December 2014. Further, only periods that had negative SPEI during the growing period were considered. This reduced the number of observations to 159.

After obtaining the negative indices, the R programme was used to determine the distribution type. It was found that the drought series followed the Weibull distribution type. After determining the distribution type, the SPEI indices were fitted into a PDF, the obtained results represents the values of Q in the equilibrium model (Zhu et al., 2012). Thirdly, Equation 5.7 was applied on the negative SPEI indices to determine those that were below the set strike level K which was set at -1. As specified in Table 3.5, indices lower than 1 indicated different intensities of drought. Subsequently, if the farmers' hedge against drought in each of the month, then it is implied that they would have received a positive pay-out for every month that the levels of dryness were lower than 1. After obtaining these values, the Equilibrium model as specified in Equation 5.9 was applied to calculate the final monthly put option prices as displayed in (Table 7.4). The assumption was that the farmers issued a put option at the beginning of the season and held it for the 6 months duration of each season.

It is observed that out of the total 159 observations, only 51 of them would have resulted in a positive pay-out. This implies that the SPEI in those months was lower than the set strike level indicating that some level of drought was experienced during these times. Therefore, if the farmers had bought put options to hedge against the possibility of drought during this time, they would have received a positive disbursement and therefore their losses would have been reduced.

Table 7.4: Final Monthly Put Options Values Using SPEI Index

Date	Season	Option price	Date	Season	Option price	Date	Season	Option price
Jan 1960	short rains	0.02	Aug 1982	long rains	0.12	Jun 1992	long rains	0.01
May 1961	long rains	0.07	Jun 1983	long rains	0.07	Aug 1992	long rains	0.04
Jun 1961	long rains	0.00	Jul 1983	long rains	0.11	Jul 1993	long rains	0.01
Jun 1965	long rains	0.07	Aug 1983	long rains	0.04	Aug 1993	long rains	0.10
Jul 1965	long rains	0.10	May 1984	long rains	0.11	Dec 1993	short rains	0.12
Aug 1965	long rains	0.10	Jun 1984	long rains	0.11	Jan 1994	short rains	0.10
May 1971	long rains	0.07	Jul 1984	long rains	0.11	Aug 1995	long rains	0.06
Jul 1973	long rains	0.02	Aug 1984	long rains	0.11	Jan 1997	short rains	0.11
May 1976	long rains	0.04	Dec 1984	short rains	0.02	Jul 1999	long rains	0.02
Dec 1979	short rains	0.09	Dec 1985	short rains	0.03	Aug 1999	long rains	0.02
Jan 1980	short rains	0.04	Jan 1986	short rains	0.08	May 2000	long rains	0.08
Aug 1980	long rains	0.00	May 1986	long rains	0.01	Jun 2000	long rains	0.08
Dec 1980	short rains	0.09	Dec 1986	short rains	0.08	Jul 2000	long rains	0.08
Jan 1981	short rains	0.09	Jan 1987	short rains	0.09	Jul 2002	long rains	0.10
Dec 1981	short rains	0.12	Dec 1987	short rains	0.07	Aug 2002	long rains	0.12
Jan 1982	short rains	0.09	Dec 1990	short rains	0.06	Dec 2002	short rains	0.03
Jul 1982	long rains	0.07	May 1992	long rains	0.06	Aug 2009	long rains	0.03

(Source: Own analysis using data from spei.csic.es/database.html)

The study further sought to estimate the price of the options during the growing season. To achieve this, it was necessary to estimate the drought magnitude during the growing period. SPEI index can be used to determine the drought duration, drought magnitude and drought intensities. The drought duration is defined as the longest period of consecutive months with the values < 0 while the sum of the index values represents the drought magnitude and finally, the drought frequency is determined by the number of months with values < 0 during the main crop growth stages (Chen, Xia, Liu, Chen, & Chi, 2016; Rawat & Tripathi, 2016; Yevjevich, 1967). Thus, following these authors, the drought magnitude which was estimated as the sum of all SPEI during the growing period was calculated and used to estimate the put option values during the growing period. Two strike levels were set i.e. -1 and -1 times the number of months in the growing period. The long rains comprised of the totals of SPEI for the month of May June July August, while the short rains SPEI was for the month of December and January.

Table 7.5 displays the estimated drought magnitude values. A total of 110 values were estimated. Of these, 54 seasons had a negative value of SPEI. This implies that these periods experienced drought at various intensities as determined the total SPEI values. The 54 observations account for almost half of the total observations. This can be interpreted to mean that approximately half of the time, the region experienced dry conditions during the growing period. Furthermore, these dry periods are distributed across 41 years out of the 54 years. This corresponds to approximately 76% of the entire time. Only 13 years out of the 55 years did not experience dry spell in either of the two growing seasons. Further evaluation reveals that 25% of the time, the region experienced dry conditions in both seasons.

Table 7.5: Summary of the Total SPEI Each Growing Season – Drought Magnitude

Year	**Long Season**	**Short Season**	**Year**	**Long Season**	**Short Season**	**Year**	**Long Season**	**Short Season**
1960	(2.4236)	(1.5512)	1980	(3.1750)	(2.6826)	2000	(5.0862)	0.8547
1961	(1.7971)	2.5071	1981	5.1539	(3.5776)	2001	(1.9418)	0.4409
1962	4.3801	3.2183	1982	(3.6960)	(1.5661)	2002	(4.7770)	(1.3869)
1963	3.9423	1.4164	1983	(3.9161)	0.4533	2003	5.4783	(1.3495)
1964	(0.2628)	1.7749	1984	(7.4255)	(0.6762)	2004	(0.5412)	(0.6215)
1965	(4.9611)	(0.1510)	1985	6.2236	(1.9807)	2005	(1.4922)	(0.1212)
1966	2.2037	0.8415	1986	(3.1497)	(2.8632)	2006	(1.8312)	0.3315
1967	5.0185	1.9224	1987	2.1438	(2.8633)	2007	2.6692	2.8988
1968	1.6690	(0.2316)	1988	0.9585	1.1854	2008	(2.6836)	2.7761
1969	1.8813	(0.3831)	1989	2.6632	2.3514	2009	(1.8242)	1.4162
1970	2.2161	0.3455	1990	3.3779	(0.2636)	2010	6.1819	0.8105
1971	(2.1618)	(0.4616)	1991	1.2372	(0.6712)	2011	(1.3730)	0.5436
1972	(1.0162)	0.0280	1992	(4.4259)	(0.1580)	2012	1.3805	2.3307
1973	(2.7049)	0.3879	1993	(0.0797)	(1.1738)	2013	6.4778	4.0472
1974	0.4569	1.2340	1994	1.1288	(1.2342)	2014	(1.9677)	2.0987
1975	3.0201	(0.1392)	1995	(2.9757)	(0.1929)			
1976	(2.6420)	(0.6617)	1996	3.0573	(0.8061)			
1977	3.7818	0.6336	1997	0.4966	(0.1528)			
1978	0.6389	2.4662	1998	3.4689	2.5958			
1979	5.2476	(0.2030)	1999	(3.8323)	1.3495			

(Source: Own analysis using data from spei.csic.es/database.html)

Since the study seeks to price the option during the dry conditions, only the seasons with negative SPEI magnitude are taken for further analysis. This leads to 56 observations, 28 during the long rains and 28 during the short rain seasons. These are then fitted into an extreme value distribution. Using Equation 5.11, the resulting variables were then used to calculate the option prices for each season.

Table 7.6 displays the estimated contract prices using the drought magnitude as the underlying index. The analysis is made at two strike levels. The first strike level is at the value of -1 while the second level using the season length was calculated as 4. It is observed that a strike level of 1 leads to a positive pay-out in 41 seasons out of the 56 seasons. When a strike level of 4 is selected i.e. the season length (i.e. the number of months in the season) is used, the results are different. The farmers would have received compensation in 18 seasons out of the 56 seasons. When the season length is used to estimate the strike level, the times that the option contracts would have been beneficial coincide with the periods that have been documented as drought years e.g. 1981, 1985, 2003, 2010, 2008 with some years such as 2007, 1979 2012 being those that are immediately succeeding the drought period. However, some years that the option contract would have received a payoff have not been documented as drought years e.g. 1989, 1961, 1962 and 1967. This could imply that although no drought was declared in these years, the SPEI was low enough to warrant a payoff under the contract agreement.

It is however interesting to note that although some years had been declared as drought years e.g. 1987, 1985 and 1980, the option contracts would not have resulted in a payoff. This suggests that the strike level using the season period is high and may result in some dry periods not benefiting from the option contracts. Therefore, a more detailed analysis should be carried out to establish the most appropriate strike level that would reflect conditions on the ground.

Table 7.6: Terminal Values of the Option Contracts by Season

Year	**SPEI 06**	**Season**	**(E_Q)**	**Strike of 1**	**Price**	**Strike 4**	**Price**	**Year**	**SPEI 06**	**Season**	**(E_Q)**	**Strike 1**	**Price**	**Strike (2)**	**Price**
1962	4.3801	Long R	0.0125	3.3801	0.0409	0.3801	0.0046	1961	2.5071	Short R	0.0815	1.5071	0.1208	0.5071	0.0406
1963	3.9423	Long R	0.0194	2.9423	0.0552	0	0	1962	3.2183	Short R	0.04	2.2183	0.0873	1.2183	0.0479
1966	2.2037	Long R	0.1104	1.2037	0.1285	0	0	1963	1.4164	Short R	0.2426	0.4164	0.0993	0	0
1967	5.0185	Long R	0.0066	4.0185	0.02565	1.0185	0.0065	1964	1.7749	Short R	0.1695	0.7749	0.1292	0	0
1968	1.669	Long R	0.1884	0.669	0.1219	0	0	1967	1.9224	Short R	0.1463	0.9224	0.1327	0	0
1969	1.8813	Long R	0.1524	0.8813	0.1299	0	0	1974	1.234	Short R	0.2911	0.234	0.067	0	0
1970	2.2161	Long R	0.109	1.2161	0.1282	0	0	1978	2.4662	Short R	0.0849	1.4662	0.1224	0.4662	0.0389
1975	3.0201	Long R	0.0488	2.0201	0.0953	0	0	1988	1.1854	Short R	0.3056	0.1854	0.0557	0	0
1977	3.7818	Long R	0.0228	2.7818	0.0613	0	0	1989	2.3514	Short R	0.0952	1.3514	0.1265	0.3514	0.0329
1979	5.2476	Long R	0.0053	4.2476	0.0218	1.2476	0.0064	1998	2.5958	Short R	0.0746	1.5958	0.1171	0.5958	0.0437
1981	5.1539	Long R	0.0058	4.1539	0.0233	1.1539	0.0065	1999	1.3495	Short R	0.2594	0.3495	0.0891	0	0
1985	6.2236	Long R	0.002	5.2236	0.0101	2.2236	0.0043	2007	2.8988	Short R	0.0551	1.8988	0.1029	0.8988	0.0487
1987	2.1438	Long R	0.1172	1.1438	0.1296	0	0	2008	2.7761	Short R	0.0623	1.7761	0.1088	0.7761	0.0475
1989	2.6632	Long R	0.0697	1.6632	0.1121	0	0	2009	1.4162	Short R	0.2426	0.4162	0.0993	0	0

Table 7.6: Terminal Values of the Option Contracts by Season

Year	**SPEI 06**	**Season**	**(E_Q)**	**Strike of 1**	**Price**	**Strike 4**	**Price**	**Year**	**SPEI 06**	**Season**	**(E_Q)**	**Strike 1**	**Price**	**Strike (2)**	**Price**
1990	3.3779	Long R	0.0341	2.3779	0.0784	0	0	2012	2.3307	Short R	0.0972	1.3307	0.1272	0.3307	0.0316
1991	1.2372	Long R	0.2902	0.2372	0.0666	0	0	2013	4.0472	Short R	0.0175	3.0472	0.0524	2.0472	0.0352
1994	1.1288	Long R	0.3234	0.1288	0.0403	0	0	2014	2.0987	Short R	0.1226	1.0987	0.1325	0.0987	0.0119
1996	3.0573	Long R	0.0470	2.0573	0.0935	0	0								
1998	3.4689	Long R	0.0312	2.4689	0.0745	0	0								
2003	5.4783	Long R	0.0042	4.4783	0.0182	1.4783	0.006								
2007	2.6692	Long R	0.0693	1.6692	0.1119	0	0								
2010	6.1819	Long R	0.0021	5.1819	0.0105	2.1819	0.0044								
2012	1.3805	Long R	0.2515	0.3805	0.0925	0	0								
2013	6.4778	Long R	0.0015	5.4778	0.0079	2.4778	0.0036								
Max	6.4778			5.4778	0.1299	2.4778	0.0065		4.0472			3.0472	0.1327	2.0472	0.0487
Min	1.1288			0.1288	0.0079	0	0		1.1854			0.1854	0.0524	0	0
Std Dev	1.6780			1.6780	0.043	0.83	0.0026		0.7831			0.7831	0.0263	0.5608	0.0209

(Source: Own analysis using data from spei.csic.es/database.html)

7.5 Conclusion

This chapter explored the possibility of using a drought index as the underlying index when pricing a weather derivative. Two approaches were adopted. The first approach priced an option contract using rainfall as the underlying index while the second method involved pricing option contracts using SPEI drought index. The results from these analyses are presented in section 7.2 and 7.3 respectively.

The findings reveal that rainfall-based option contract would have been beneficial to farmers in Kenya especially during periods of drought. Specifically, when the strike levels are set close to the average rainfall, the more likely the option is to get a pay-out. As an example, the average growing period rainfall from 1977 to 2015 was 20ml. when the strike level was set at 20, the option contract was in the money 19 years out of the total 38 years under study. Furthermore 10 out of these years were periods when drought episodes had been experienced in the country. However, there are some years where even though a drought episode had been experienced, the option contracts were not in the money. Consequently, an in-depth study needs to be undertaken in order to establish a strike level that captures all the drought period. Furthermore, using the specific regional data may produce more accurate results.

Section 7.3 modelled the use of SPEI drought index to price weather derivatives for farmers. First the option contracts were priced using the monthly SPEI indices. Out of the 159 months, only 51 months qualified for a pay-out. However, in the real farming world, farming outcomes are better estimated at the end of the farming season. Thus, the option contracts were priced for each of the farming seasons using the growing period SPEI indices. This required that the SPEI index be modelled for each season. The obtained results are presented in Table 7.5. The study finds that 54 out of the 110 seasons experienced drought episodes. This accounts for approximately half of the total times under consideration. Furthermore 14 of the 55 years had drought episodes during the two seasons. These findings support the results in chapter 6 where the average yield was found to be below the expected yield in more than half of the period under study. This implies that the agricultural production was greatly influenced by the weather conditions affirming the need for weather risk management in agriculture. Due to the implied the need for weather risk management in the agricultural sector, this chapter sought to price weather derivatives for use in hedging against risk loss in agriculture. Consequently, using the obtained seasonal SPEI data, the option contracts were priced and evaluated. The results are displayed in Table 7.6. The study shows at a strike level of 4, the positive pay-outs would have been in 18 seasons out of the 108. The majority of these seasons coincided with the drought years. However, further studies should be carried out in order to scientifically set the strike levels. These findings strongly support the view that weather contracts could benefit farmers if bought to hedge against drought events. Further studies are necessary to determine the optimal strike levels for the option contracts.

Chapter 8: Efficiency of Weather Based Derivatives

8.1 Introduction

This chapter presents the results of empirical analysis of the efficiency of weather-based derivatives in hedging against drought risk in Kenya's agriculture. Section 5.4 provides details on the sources of the data used for this analysis while section 5.7 explains the process used to evaluate the efficiency of the weather derivatives. This chapter is organised as follows. First, a brief background on weather derivatives and the importance of determining the efficiency of weather derivatives is deliberated. Then, the results from modelling the underlying index for use in pricing the option contracts are presented. This is followed by the evaluation of the efficiency of the option contracts in section 8.4.2 and finally, the conclusion is provided in section 8.5.

8.2 Overview on the efficiency of weather derivatives

Weather contracts present several benefits for the insurer namely, reducing the transaction costs of verifying losses, resolving the problem of 'moral hazard' and alleviating the problem of 'adverse selection' (Geyser, 2004; Isakson, 2015; Vedenov & Barnett, 2004). Weather Derivatives have been advocated for as a pro-poor initiative that expands opportunities to smallholders who are often excluded from insurance markets. This is because the buyers of index policies are not required to prove ownership of assets. In addition, index-based policies eliminate the need for loss adjustments which lowers transactions costs making it more affordable to insure small plots of land (Isakson, 2015). These professed benefits have seen several development actors such as the World Bank advocate for the adoption of Weather Contracts for weather risk management (Isakson, 2015). As a result, there has been a rise in the use of Weather Contracts especially in the agricultural sector. As an example, some Canadian provinces have used these contracts to cross-hedge forage production risk (Vedenov & Barnett, 2004; Vroege, Dalhaus, & Finger, 2019). Similarly, the state agricultural Reinsurance Company in Mexico used weather derivatives to transfer part of its weather-related crop insurance risk while Argentina and Morocco have developed and used rainfall index instruments in the agricultural sector (Vedenov & Barnett, 2004).

The majority of the financial benefits that have been cited seem to address the insurer's needs and less of the producer's needs. According to Vedenov and Barnett (2004), prospective buyers of weather derivatives are also concerned with the performance of the derivatives in reducing their risk exposure. For the buyers of financial weather derivatives (WD), their main aim is to hedge against weather risk by balancing their incomes to avoid fluctuations due to weather changes (Manuela & Ruyuan, 2015). The question then arises, how beneficial are weather contracts to the insured? A study on the efficiency of WD would help address concerns that are specific to the potential purchasers of weather derivatives such as the performance of these contracts in reducing their risk exposure. The farmers risk exposure is reduced if their revenue variability with the contract is lower than when the contract is not purchased.

Previous studies have applied VaR, standard deviation, Certainty Equivalent Revenues (CERs) and Measured by Mean Root Square Loss (MRSL) to evaluate the efficiency of weather derivatives (Manuela & Ruyuan, 2015; Štulec, 2017; Vedenov & Barnett, 2004). This study applied the VaR to measure the efficiency of weather derivatives in reducing farmers risk expose to weather variations. This chapter presents estimates of the efficiency of weather derivative contracts in Kenya. A European call option was priced and assumed to have been bought by maize farmers in western Kenya. The purchase of the option contracts was aimed at shielding the farmers by reducing their revenue fluctuations. This study uses the Standardized Precipitation Evapotranspiration Index (SPEI) as the underlying index. This index is calibrated from a scale of 2 to -2 with 2 being extremely wet and -2 being extremely dry (Miah et al., 2017). To price the contracts, the cumulative SPEI index during the growing period was used. After pricing the contracts, VaR was used to evaluate the efficiency of index-based weather derivatives.

8.3 Results and Discussions

8.3.1 Results of the Underlying Index for Option Price Calculation

This study applied Equation 5.11 on the cumulative SPEI index during the two growing seasons to estimate the option contracts prices. In order to be used to price the option contracts, the SPEI index had to be modelled in such a way that it would be suitable for option price calculations. This is done by determining the drought impact which is calculated as the total SPEI during the period under investigation (Chen et al., 2016; Rawat & Tripathi, 2016; Yevjevich, 1967). The results of this analysis are presented in Table 8.1.

Table 8.1: Summary of SPEI for Each Season

Year	Long Rains	Short Rains	Year	Long Rains	Short Rains	Year	Long Rains	Short Rains
1960	-2.42	-1.55	1978	0.64	2.47	1996	3.06	-0.81
1961	-1.80	2.51	1979	5.25	-0.20	1997	0.50	-0.15
1962	4.38	3.22	1980	-3.18	-2.68	1998	3.47	2.60
1963	3.94	1.42	1981	5.15	-3.58	1999	-3.83	1.35
1964	-0.26	1.77	1982	-3.70	-1.57	2000	-5.09	0.85
1965	-4.96	-0.15	1983	-3.92	0.45	2001	-1.94	0.44
1966	2.20	0.84	1984	-7.43	-0.68	2002	-4.78	-1.39
1967	5.02	1.92	1985	6.22	-1.98	2003	5.48	-1.35
1968	1.67	-0.23	1986	-3.15	-2.86	2004	-0.54	-0.62
1969	1.88	-0.38	1987	2.14	-2.86	2005	-1.49	-0.12
1970	2.22	0.35	1988	0.96	1.19	2006	-1.83	0.33
1971	-2.16	-0.46	1989	2.66	2.35	2007	2.67	2.90
1972	-1.02	0.03	1990	3.38	-0.26	2008	-2.68	2.78
1973	-2.70	0.39	1991	1.24	-0.67	2009	-1.82	1.42
1974	0.46	1.23	1992	-4.43	-0.16	2010	6.18	0.81
1975	3.02	-0.14	1993	-0.08	-1.17	2011	-1.37	0.54
1976	-2.64	-0.66	1994	1.13	-1.23	2012	1.38	2.33
1977	3.78	0.63	1995	-2.98	-0.19	2013	6.48	4.05
						2014	-1.97	2.10

(Source: Own analysis using data from spei.csic.es/database.html)

The Standardized Precipitation Evapotranspiration Index (SPEI) facilitates the measurement of drought and wet events with drought being represented by negative values while the positive values represent wet periods (Xu et al., 2018). The results presented in Table 8.1 confirms that the farmers experienced drought episodes (negative SPEI) in approximately half of the time under study. Specifically, years 1965, 1971, 1976, 1980, 1986, 1992, 1993, 1995, 2004, and 2005 had a negative cumulative SPEI value in both seasons indicating that these years experienced drought conditions during the two seasons of the year. Some years experienced drought conditions in the same season in consecutive years e.g. 1971-1973, 1982-1984 1999-2002 and 2004-2006 experienced drought conditions during the long rains while other periods experienced prolonged drought conditions that lasted over several years e.g. dry conditions were experienced for five consecutive seasons starting from the short rains season in 1991 to the short rains of 1993, similarly, dry conditions starting from the short rains of 2003 lasted for six consecutive seasons starting from short rains of 2003 to the long rains of 2006. Given that studies such as those by (Xu et al., 2018) show that there is a correlation between the SPEI index and the yield, then it is expected that farmers experienced losses during these seasons and probably endured harder times during the periods of consecutive dry periods. In the following section we use the obtained indices to estimate the payoffs that the farmers would have received if they had bought the option contracts.

8.4 Estimated Payoff Amounts

After obtaining the indices, the possible payoff that the farmers would have received during the period under study was estimated. These were calculated by applying Equation 5.10 on the total SPEI index for each seasons' growing period as presented in Table 8.1. The strike level was set at zero because this is the level that indicates normal soil moisture conditions. Thus, for every value of the drought index that was below zero, the farmers received a payoff. Indicating that for any time the farmers experienced drought conditions, then they got paid off if they had purchased the option contract. After setting the strike level, the tick size was set at \$100. Consequently, the total pay-out was equivalent to the value of the negative SPEI index times \$100. The obtained results are presented in Table 8.2.

It is observed that the farmers stand to get a pay-out in 17 years out of the 20 years under study i.e. 85% of the time. This coincides with all the seasons that experienced drought conditions during the 20 years under study. The 85% pay-out rate implies that the farmers experienced a lot of dry conditions during the period under study and would have been cushioned against possible losses if they had bought the option contracts. Note that during all the periods that drought episodes were declared a positive pay out would have been made to the option contract holders. In fact, the highest pay-outs i.e. amounting to $200 and above were made in 1992, 1995, 1999, 2000, 2002, 2008 which fall within the periods cited as drought disaster years.

Table 8.2: Option Contract Pay-Out for Each Season

Year	**SPEI Long Rains**	**SPEI Short Rains**	**Payoff Short Rains**	**Payoff Long Rains**	**Total Per Year**
1991	1.24	(0.67)	0	67	67
1992	(4.43)	(0.16)	443	16	459
1993	(0.08)	(1.17)	8	117	125
1994	1.13	(1.23)	0	123	123
1995	(2.98)	(0.19)	298	19	317
1996	3.06	(0.81)	0	81	81
1997	0.50	(0.15)	0	15	15
1998	3.47	2.60	0	0	0
1999	(3.83)	1.35	383	0	383
2000	(5.09)	0.85	509	0	509
2001	(1.94)	0.44	194	0	194
2002	(4.78)	(1.39)	478	139	617
2003	5.48	(1.35)	0	135	135
2004	(0.54)	(0.62)	54	62	116
2005	(1.49)	(0.12)	149	12	161
2006	(1.83)	0.33	183	0	183
2007	2.67	2.90	0	0	0
2008	(2.68)	2.78	268	0	268
2009	(1.82)	1.42	182	0	182
2010	6.18	0.81	0	0	0

(Source: Own analysis using data from spei.csic.es/database.html)

8.4.1 Price of the Call Option

After determining the possible pay-outs, the next step involved the estimation of the option contract price. To achieve this, the cumulative SPEI index during the growing period was used to calculate the option prices. First, the cumulative SPEI needs to be fitted into suitable distributions and the best suited distribution selected there from. The easy-fit programme was used to fit the cumulative SPEI into different distributions and rank them according to the Anderson-Darling (A-D) test, Kolmogorov-Smirnov (K-S) test, and Chi-square () test. The ranking of the models may differ when from one test to another. This is owing to the differences between these kinds of test methods. Then individual ranking results using the different methods were used to obtain an overall ranking for the models. In this study, if all three or two of three test results are consistent, we are accept the results; if the three test results are not the same, we average the ranking of results and obtained the results as presented in Table 8.3.

The highest ranked distribution using the average is then selected as the best suited model for our index. This approach is similar to that of Wang et al. (2015) who studied the drought risk in China's agriculture. They modelled the yield losses using eleven different distributions and used the Anderson-Darling (A-D) test, Kolmogorov-Smirnov (K-S) test, and Chi-square () to select the best ranked model as the most suitable model for the yield losses. From the analysis the best suited model for the cumulative SPEI was the Generalised Extreme Value (GEV) distribution.

Table 8.3: Goodness of Fit Summary

		Kolmogorov Smirnov		Anderson Darling		Chi-Squared		
Srl No.	**Distribution**	**Statistic**	**Rank**	**Statistic**	**Rank**	**Statistic**	**Rank**	**Average**
21	Gen. Extreme Value	0.07	3	0.18	3	0.23	1	2
40	Lognormal (3P)	0.08	4	0.23	7	0.25	3	5
30	Johnson SB	0.06	1	0.15	2	0.60	15	6
41	Nakagami	0.07	2	0.25	10	0.44	7	6
7	Dagum	0.08	11	0.13	1	0.58	14	9
3	Burr (4P)	0.08	9	0.30	13	0.26	5	9
59	Weibull (3P)	0.08	10	0.31	14	0.26	4	9
18	Frechet (3P)	0.08	5	0.23	6	0.79	20	10
2	Burr	0.09	13	0.32	16	0.24	2	10

Note: the entire table including the ranking is attached in the Appendix.

After selecting the best suited model, the R programme was used to obtain the models parameters. The obtained parameters are used to simulate 100 distributions for each year under study. The Probability Distribution Function (PDF) and the Cumulative Distribution Function (CDF) of the simulated distributions is determined. Then Equation 5.7 was used to estimate the option prices for all the 100 simulated distributions for each year under study. The option price for each year is calculated as the average of all the 100 simulated values in that year. The results are presented in Table 8.4.

Table 8.4: Estimated Option Prices

Year	**Annual Price**
1991	93.09
1992	93.55
1993	93.03
1994	91.57
1995	91.55
1996	90.62
1997	92.50
1998	94.73
1999	92.02
2000	91.90
2001	93.41
2002	94.56
2003	93.61
2004	86.56
2005	91.84
2006	95.44
2007	93.22
2008	93.98
2009	92.39
2010	92.64

(Source: Own analysis using data from spei.csic.es/database.html)

8.4.2 Efficiency Analysis

In order to analyse the efficiency of the option contracts bought by the farm producers in western Kenya, we follow the approach taken by Vedenov and Barnett (2004) and Manuela and Ruyuan (2015) who analysed the performance of weather derivatives in protecting farmers' income by comparing their production revenues with and without options. To achieve this, we estimate the de-trended yields from 1991 to 2010. De-trending of the farm yield is based on the notion that production yield has a significant positive autocorrelation with time mostly due to technology advancement and as a result, a process to separate the technology influence on total yield is needed in order identify weather's contribution to yields' variability (Manuela & Ruyuan, 2015). The de-trending process starts with a regression between yield and time which produces the predicted yield and the yield residuals. According to Vieira, Carvalho, Ceddia, and González (2010), the predictions from the analysis will form a straight line that can be taken as the trend line for the dataset. The residuals from the analysis represent the de-trended form of the dataset and are obtained by calculating the difference between the actual data and the predicted data (Vieira et al., 2010).

Since the de-trended data set has positive and negative values, we added a constant to the de-trended data to make all the data positive. This approach is similar to that adopted by Manuela and Ruyuan (2015). These authors added a constant value C to make sure that the de-trended yield positive. The constant value that was used was equal to the mean of predicted yield depending on time.

After obtaining the de-trended yield, the next step was to determine the price of the produce. This study assumes that the maize price p was constant over time. The price used in this analysis was USD 224.38 per tonne, this was calculated as the average price using maize producer price per tonne from 1991 to 2016 Table 8.5. This period was used because it encompasses all the producer price that was available from the FAO database. By using the average prices, we ignore the effect of supply and demand on the crop price, this is because the aim of the study is to determine the influence of the contract on the total revenue.

Table 8.5: Annual Producer Prices for Maize in Kenya (USD)/Tonne 1991 – 2016

Year	Price	Year	Price	Year	Price
1991	104.30	2001	169.40	2011	281.50
1992	74.40	2002	141.50	2012	401.80
1993	139.70	2003	157.50	2013	363.80
1994	169.50	2004	193.80	2014	377.40
1995	155.60	2005	201.70	2015	292.30
1996	157.60	2006	213.00	2016	292.50
1997	233.80	2007	232.70		
1998	212.80	2008	353.50		
1999	197.10	2009	309.10		
2000	190.30	2010	217.20		
Average Price					**224.38**

(Source: Food and Agriculture Organization, 2017)

The de-trended yield and the obtained prices were used to construct the revenue function with and without the option contracts Table 11.6. Then, using Equation 5.5 the VaR technique was applied on the estimated revenue functions to calculate the efficiency of SPEI based options contract in hedging against drought risk. The results from these calculations are presented in Table 8.6.

Table 8.6: Calculated Value at Risk (VaR) at 95% Confidence Level

	Without Option	**With the option**
Calculated VaR	4.74%	4.80%

(Source: own calculations using data from Food and Agriculture Organization (2017))

The results indicate that the option contracts did not perform well in reducing the risk of revenue fluctuations for maize farmers in western Kenya. In contrast the risk increased when the option contract was purchased compared to when the contract had not been purchased. This is contrary to the finding of Manuela and Ruyuan (2015) who studied the efficiency of WD for the Chinese agriculture and found that the use of option contracts reduced the revenue risk for maize and wheat farmers in the cities of Beijing and Shanghai. Similar results were found by Zong and Ender (2016) who studies the efficiency of temperature derivatives in hedging revenue risk for farmers in the Chinese agricultural sector. However, Vedenov and Barnett (2004) found that use of option contract did not necessarily result in lower risk for the farmers. In addition, he found that even when the option contracts resulted in lower risk exposure in the within sample analysis, this did not necessarily translate to lower risks in the out of sample. In some instances, the risk was reduced in the in sample and increased in the out of sample analysis.

Previous studies have demonstrated that the basis risk has an extraordinarily high influence on the hedging effectiveness of option contracts. For instance, Musshoff et al. (2006) demonstrates that the distance between the site of agricultural production and the nearest reference weather station (e.g. 39 km in their study), considerably reduced the hedging effectiveness of the option contracts. He further shows that the correlation between the reference underlying index and the yield had an influence on the hedging effectiveness of these contracts. Thus, the results of our analysis may have been influenced by various factors that were not considered in the study. Therefore, we recommend further research to be conducted on setting optimum strike price and strike level when using SPEI index is recommended. Additionally, the effect of basis risk and location of the weather reference point should be considered in determining the effectiveness of the option contracts.

8.5 Conclusion

Chapter 6 of this study estimated yield risk in Kenya’s agriculture and found that the risks was high especially for the 50 year and 100 year drought return period. Consequently, the subsequent chapter sought to contribute to weather risk management by evaluating the viability of SPEI drought index in pricing weather derivatives. It was found that the SPEI index was a viable index for use in pricing weather-based option prices. However, the buyers of the weather derivatives would be very interested in evaluating how well the purchased contracts protect them from the risk of loss due to weather changes. Consequently, this chapter explored the efficacy of weather derivatives in hedging against drought risk for maize farmers in Kenya. First the underlying index to be used for pricing the weather derivatives is modelled and presented in Table 8.1**.** Then the estimated payoff and premium from the option contracts were calculated and presented in tables 18 and 20 respectively. Finally, the revenue function with and without the option contracts was modelled and used to evaluate the efficiency of option contracts. The obtained results are presented Table 8.6. The study finds that estimated risk with the option contract was higher than the risk without the contracts. This is contrary to the expectation as the option contracts are meant to reduce the risk exposure to the farmers. It is therefore important that further studies be conducted to scientifically determine the model parameters in order to determine the efficiency of the contracts. Furthermore, the use of regional agricultural production data could better refine the results.

Chapter 9: Kenya's Readiness for Climate Finance

9.1 Introduction

The KNAP 2015-2030 shows that there is a climate finance deficit across all the sectors in Kenya. As a result, the country needs to increase flows of climate finance from private capital and ensure more effective leveraging of public capital from domestic and international sources. The effectiveness and the distributive fairness of international climate finance to developing countries depends on the availability of a variety of financing resources and increasingly on the capacity of recipient countries and especially the most vulnerable ones, to absorb, manage, and implement the money flows (Bécault, Koenig, & Marx, 2016). The latter has been described as Climate Finance Readiness (CFR) which can be broadly defined as the capacity to plan for, access, deliver, monitor and report on climate finance from both international and domestic sources in ways that are catalytic and fully integrated with national development priorities and achievement of development goals (Vandeweerd, Glemarec, & Billett, 2012). A country's readiness for climate finance is greatly influenced by its capacity to establish a stable policy framework, develop realistic climate financing and investment strategies at all government levels as well as deploy effective planning, monitoring and reporting systems (Agbemabiese, Nyangon, Lee, & Byrne, 2018). This chapter evaluates Kenya's CFR by reviewing the country's policies and legislation, institutional frameworks as well as the mechanisms put in place to enhance climate finance oversight.

9.2 Evaluating Kenya's Readiness for Climate Finance

Previous studies have adopted different approaches to evaluate CFR. Some studies take on a more specific approach by evaluating the country's readiness in respect to a particular source of climate finance. As an example, Maniatis et al. (2013) focused on Congo Basin's readiness for climate finance from REDD+. To achieve this, they reviewed the regions national forest monitoring systems that included GHG Measurement, Reporting and Verification (M&MRV). This approach has the advantage of providing feedback specific to REDD+. Of importance to note is that REDD+ is just one of the components/sources of climate finance. Consequently, the results from such an approach may not apply to the general climate finance readiness.

In contrast, some studies assess CFR by considering the systems and processes in place in order to understand the actions and supporting policies that would assist countries in adapting to and mitigating climate change and the role that finance can play in supporting such efforts (Van-Rooij, Brown, Nakhooda, & Watson, 2013). Most studies however, assume a more general approach by considering CFR's core components of planning, access, delivery, monitoring and reporting with their performance indicators being the activities and/or capacities needed to build enhanced readiness for climate finance (Bécault et al., 2016). Under this approach readiness can be evaluated as a static state or a work in progress with most studies assuming that CFR is an ongoing process.

This study assesses CFR as an ongoing process and evaluates Kenya's readiness by reviewing the systems and processes that are in place. Special attention was paid to the policies, institutional frameworks and oversight mechanisms and their possible contribution towards Kenya's readiness for climate finance. This was achieved by reviewing reports by development cooperation organisations, research institutes, published papers as well as Kenya's policies, strategic plans and reports on climate change.

9.3 Policies

The national policies and strategies of a country play a big role in driving and shaping the evolution of functions, forms, mechanisms and vehicles that attract climate sensitive finance and investments (Agbemabiese et al., 2018; Micale, Tonkonogy, & Mazza, 2018). This section examines Kenya's policies and legislation and considers how these contribute towards the country's readiness for climate finance.

The constitution of Kenya which is the supreme law in the country asserts that every person has the right to a clean and healthy environment, which includes the right to have the environment protected for the benefit of present and future generations (Government of Kenya, 2010b). Climate finance plays an important role in enhancing environmental protection by funding climate smart investments. Consequently, the Government of Kenya has set up policies aimed attracting climate finance. Some of these legislation and policies are listed in Table 9.1.

Evidently, the Government of Kenya has taken considerable effort to formulate legislation and policies aimed at managing the impacts of climate change in the country. However, a review of these policies shows that the there are some gaps that have not been comprehensively addressed. For instance, KNAP 2015-2030 highlights a deficit in financing needs for adaptation projects across all the sectors (Government of Kenya, 2016a; The National Treasury, 2017). Despite this, most of the strategies put in place e.g. the NCCRS – 2010 focus more on mitigation finance and not adaptation finance. Besides, the mitigation finance mobilisation strategies as detailed in NCCAP - (2013/2017) focus more on CDM mechanisms which narrows down the possible sources of finances for mitigation. Consequently, there is need for the government to explore non CDM sources of climate finance in order to mobilise more funds for mitigation investments (The National Treasury, 2017). Moreover, since financing has been identified as a major challenge across all the sectors, there is need for a comprehensive strategy on ways to mobilise finances for both adaptation and mitigation including the possibility of introducing additional economic and financial instruments to leverage private sector investments. Further, the government in conjunction with the relevant stakeholders should seek ways of strategically positioning the country in order to tap finance from all the available sources.

Table 9.1: Climate Related Policies and Institutional Frameworks in Kenya

Legislation	Gaps
i. Kenya National Adaptation Plan 2015-2030 ii. The National Climate Change Response Strategy (NCCRS) (2010) iii. The National Climate Change Action Plan (NCCAP) (2013/2017 iv. The National Climate Change Act (2016) The Kenya Vision 2030 v. the National Action Plan among, Submission of the Nationally Determined Contributions (INDC) to the UNFCCC, vi. the Climate Finance Policy, vii. Climate change Policy among others viii. Draft Climate Change Framework Policy (2014) ix. The Third Medium Term Plan (MTP III) (2018-2022) x. Draft National Climate Finance Policy (NCFP) (2016) xi. Establishment of climate change institutional frameworks; xii. Ascension of International Agreements e.g., the Paris Agreement xiii. National policy on climate finance	✓ In-adequate finance across all sectors in the NAP ✓ Strategy on mobilisation and management of climate finance not clearly defined ✓ Need to introduce additional economic and financial instruments to leverage private sector investments. ✓ Guidance on the general institutional framework of climate finance is not provided ✓ Need to provide the general structure of Kenya's climate finance arena ✓ The Vision 2030 does not comprehensively address issues on climate finance ✓ NCCRS – 2010 focusses more on mobilising mitigation finances ✓ There is need for the NCCAP - (2013/2017) to explore non CDM mechanisms ✓ Government score card on climate finance and aid effectiveness not developed ✓ The total cost of adaptation not comprehensively estimated ✓ Need to include stakeholder representatives in the management Board of the Climate Change Fund ✓ Need to bring out the role of stakeholders in mobilizing climate finance ✓ Need to recommend interventions for strengthening PPPs ✓ Communication between the GoK and funding institutions should be strengthened ✓ Ensure a balance between adaptation and mitigation financing ✓ Climate finance related expenditure not coded, this complicates tracking and reporting of climate related budget and expenditure ✓ Need to develop capacity on climate investments at all government levels

(Source: The National Treasury, 2017)

The Vision 2030 is an important blueprint document that comprehensively details the development objectives of the government of Kenya. The overall vision is supported by three pillars namely the economic, social and political pillars. The social pillar of the Vision 2030 undertakes to provide social development in a clean and secure environment. Climate finance has the potential to enhance the clean environment through funding of climate smart investments. However, the Vision 2030 document does not comprehensively address climate finance issues. There is a need to provide some guidance on the general structure and institutional framework of climate finance clearly detailing the role of the various stakeholders in mobilising climate finance from all sources (Ongugo et al., 2014; The National Treasury, 2017). This would provide an exclusive and comprehensive climate change policy and legislative framework for the country. Kenya's national policy on climate finance addresses this gap. It provides the general structure of climate finance detailing the target sectors, the proposed government intervention, governance structure as well as the financial needs to implement the strategy (The National Treasury, 2016). There is evidence of implementation of some of the policy recommendations as an example, the financing mechanism – the green climate fund has been established and the government has taken measures to enhance governance of climate finance by putting in place measures that enhance the tracking of climate finance. In addition, the government has put in place mechanisms that enhance direct access of climate finance by designating institutions that work with the GEF. More effort needs to be put in place to enhance data collection and ensure availability of the same to interested stakeholders such as the academia for purposes of research. In addition, the role of the various stakeholders in mobilising climate finance needs to be discussed in detail.

Devolution is one of the most transformative changes to Kenya's governance system brought about by the Constitution of Kenya, 2010 (Ministry of Devolution and Planning, 2016). This system of government has achieved a number of successes and challenges. In relation to climate finance, devolution brings challenges such as fragmentation of climate finance, compromised quality of existing budget data in addition to the budgets not being broken down by 'source' which makes it hard to determine the source of the finances (Development

Initiatives, 2019). Furthermore, budget categorisation is informed by broader sub-programmes rather than programmatic activities which further complicates the classification of climate finance. To enhance tracking and reporting of climate finance, all climate related expenditures should be coded at all government levels using a consistent/uniform set of codes. While the government has introduced a budget coding system for climate related expenditures, evidence on its implementation is not readily available making it difficult to assess its effectiveness.

This section set out to assess the policies and legislation that enhance CFR in Kenya. It is established that the government of Kenya has put in place various climate related policies and legislation that improve Kenya's readiness for climate finance. The success of these policies in delivering their intended goal depends on how well they complement one another. The following section reviews the various pieces of legislation and policies with a view to understand how well they complement each other in addressing CFR in Kenya.

9.4 Exploring the Linkage between the Policies

The previous section reviewed the policies and legislation associated to climate change in Kenya. It was observed that the government of Kenya has put in place various regulations and policies aimed at enhancing climate resilience in the country. It has been argued that in the majority of circumstances, the use of multiple rather than single policy instruments leads to better regulation (Gunningham, Grabosky, & Sinclair, 2004). To be optimal, these regulations and legislation need to be designed in a way that they complement one another in addressing the issues of interest. This can be achieved by using existing legislation to inform new policies so that issues that may have not been adequately covered by existing legislation are addressed by the subsequent legislation. This section evaluates how the different climate related regulation and policies in Kenya are designed with the aim of understanding how well they perform in terms of addressing the overall goal of enhancing climate resilience in the country. In order to understand the connection between the various pieces of legislation, this study evaluated the available legislation and policies paying special attention on their inter-relationships. A summary of these policies as well as their relevant key supporting policies is presented in Table 9.2.

The vision of the NCCRS is for a prosperous and climate change resilient Kenya while the strategy's mission is to strengthen nationwide focused actions by ensuring commitment and engagement of all stakeholders towards adapting to and mitigating against climate change (Government of Kenya, 2010c). It describes an enabling policy, legal, and institutional framework for climate change and acknowledges climate information had not been comprehensively factored in most of the governments development policies and plans (Oulu, 2015). The NCCAP which operationalised the NCCRS focuses on mainstreaming climate change in Kenya's development. To achieve this, it deliberates on low-carbon development strategies; adaptation and mitigation options; climate finance; enabling policy, legislative, and institutional framework (Oulu, 2015). While this policy outlines the priority low carbon development areas and options, it does not set the governments emission reduction targets. This omission is remedied by the INDC which sets out to reduce the country's GHG emissions by 30% by 2030 relative to the BAU scenario of 143 MtCO2eq (United States Agency for International Development, 2016).

KNAP 2015-2030 which is Kenya's first plan on adaptation to climate change impacts builds on the foundations of NCCRS and the NCCAP. It sets out Kenya's national circumstances, focusing on current and future climate trends, and describes the country's vulnerability to climate change. KNAP also elaborates institutional arrangements, including monitoring and evaluation processes and priority actions based on vulnerability (Government of Kenya, 2016a). But, while the KNAP identifies that the private sector has some responsibility of enhancing the country's resilience to climate change, it does not explicitly state the sectors role or how its participation will be enhanced. A more elaborate strategy detailing the private sectors involvement including the possible responsibilities and incentives for the sector and would better address this gap.

Table 9.2: Climate Finance Related Policies in Kenya

Policy	Additionality	Supporting policies
Kenya National Adaptation Plan (KNAP) 2015-2030	- Provides a guideline on implementation of adaptation projects - Estimates financial needs, does not indicate how these finances will be raised - Does not explicitly state the role of private institutions	- National Climate Change Framework Policy and Act - NCCRS, NCCAP, The Constitution of Kenya, Vision 2030 - Medium Term Plan (MTP) - Medium-Term Expenditure Framework (MTEF)
Intended Nationally Determined Contribution (INDC)	- GHG estimations	- KNAP 2015-2030 - NCCAP 2013-2017 - NCCRS 2010
National Climate Change Framework Policy		- NCCAP 2013 – 2017 - Climate finance strategy
The Kenya National Green Climate Fund (GCF) Strategy	- Explains GCF access modalities - Outlines the stakeholders	- The Constitution of Kenya (2010), The Kenya Vision 2030 - MTP III (2018-2022), NCFP – 2016, NCCRS – 2010, NCCAP - 2013/2017), NAP (2015-2030) - The National Climate Change Act (2016), Climate Change Framework Policy
The National Climate Change Act	- Outlines the funding mechanism (CF)	
National Climate Change Action Plan, NCCAP (2013-2017)	- Clarifies climate change risks and required responses - To operationalise the NCCRS and	
National Climate Change Response Strategy (NCCRS)	- In recognition of climate change challenge	- Climate Change Act

Policy	Additionality	Supporting policies
National Policy on Climate Finance		- The Constitution of Kenya, 2010, The Climate Change Act, 2016 - Public Finance Management Act (amended in 2014) - Kenya Vision 2030, NCCRS, 2010, NCCAP 2013-2017 - MTEF, County Integrated Development Plans (CIDPs) - Environmental Management and Co-ordination Act, 1999 (EMCA), as amended through EMCA (Amendment Act) 2015 - The Forests Act, 2005, The Energy Act, 2006 - Property Rights, Land Act (2012), The Land Registration Act (2012) - Physical Planning Act (Cap 286), Intellectual property - Industrial Property Act (Cap 509), The Standards Act (Cap 496) - Taxation laws, Investment promotion legislation - Treaty Making and Ratification Act (No. 45 of 2012)
Climate Change Budget Codes for the National Treasury Draft Report	- Development of codes for tracking climate finance in the country	- NCCAP (2013-2017), NCCRS, 2010 - Budget Review and Outlook Paper, September 2013 - MTEF Sector Reports 2013, Medium Term Budget Policy Statement, April 2013 - Estimates of Recurrent and Development Expenditure of the National Government for the Year Ending 30th June 2014 - The 2013 Environmental Protection, Water and Housing Sector Reports
The Kenya Vision 2030		- 2010 Constitution of Kenya - MTP I, MTP II & MTP III

The KNAP is the basis for the adaptation component of Kenya's Intended Nationally Determined Contribution (INDC) (Government of Kenya, 2016a). The INDC commits to enhance the Kenya's resilience to climate change by mainstreaming climate change adaptation into the Medium-Term Plans (MTPs) and implementing adaptation actions. It also sets out the country's emission reduction targets but does not provide any specific financing request nor does it provide information on the quality of the data that was used to estimate the country's mitigation and adaptation costs (United States Agency for International Development, 2016).

This section sort to evaluate the inter-relationships between the different policies and legislation in Kenya with a view to understanding how they fit in together towards addressing the overall goal of enhancing climate resilience in the country. It is observed that there is a logical and pragmatic inter relationship between the various legislation that were reviewed with subsequent legislation addressing issues that may have been omitted by the preceding regulations. But even though the current policies and legislation seem to be comprehensively addressing climate issues, their implementation cannot be satisfactorily ascertained. This is mainly because the information on their implementation was not easily available making it difficult to determine their status or their effectiveness.

9.5 Institutional Frameworks

Institutions are systems of rules and decision-making procedures that give rise to social practices, assign roles and guide interactions (Oulu, 2015). They play an important part in facilitating climate investments as well as helping to plan and respond to climate change by structuring the distribution of risks, constituting and organising incentive structures and mediating external interventions into local contexts (Government of Kenya, 2010c; Mubaya & Mafongoya, 2017). Clear and well-defined structures also help to overcome significant obstacles in translating climate change responses from concept to reality (Government of Kenya, 2016b). Furthermore, local institutions have been found to have a great influence on how different social groups gain access to and are able to use assets and resources. (Agrawal, 2008). This section reviews institutional structures in Kenya that are potentially important for CFR. Special attention will be paid to the institutional structures put in place by the government of Kenya. This is because of the crucial role that the state plays in ensuring environmental protection for both the current and future generations.

The government of Kenya has made deliberate efforts to set up institutions and systems that facilitate climate investments in the country. The NCCRS reviewed the institutional frameworks put in place to govern climate change affairs and proposed that an institution that is dedicated climate change be established to help enhance climate change-resilience in Kenya (Government of Kenya, 2016b). NCCRS's proposed institutional structure gives the Ministry of Environment and Mineral Resources (MENR) a dominant role with all the key institutions placed under it (Government of Kenya, 2016b; Oulu, 2015). The challenge with this approach is that ministries of environment are generally viewed as "less powerful" due to low annual budgetary allocation and the late entry of environmental issues on the national agenda. As a result, these ministries generally lack the political influence, financial muscle and convening powers necessary to effectively coordinate and mainstream a crosscutting issue such as climate change across government (Oulu, 2015).

On the contrary, the NCCAP which is responsible for the NCCRS ignores NCCAP's proposed structure and recommends that a high-level National Climate Change Council (NCCC) be established in the Office of the President and be responsible for the mainstreaming of climate change functions by the national and county governments in addition to approving and overseeing the implementation of the National Climate Change Action Plan (NCCAP) (Government of Kenya, 2016a). It further proposes that the NCCC be chaired by the Secretary to the Cabinet, have a secretariat within the Cabinet Affairs Office and report annually to Parliament. In addition, it should comprise lead experts in climate change, representatives of the national and county governments, and involve representatives of civil society, academia and the private sector (Government of Kenya, 2016a; Oulu, 2015). This effectively raises the profile of climate change issues and remedies the weakness in the proposal made by the NCCRS.

In addition to setting up an institutional framework, the government formulated the National Green Climate Fund (GCF) Strategy with the aim of increasing financial flow from the GCF for low carbon investments (The National Treasury, 2017). This strategy offers a roadmap for stakeholders applying for finances from the GCF and recommends mechanisms that strengthen the Nationally Designated Authority - NDA's capacity to implement its functions.

The government has also selected and appointed some institutions to act in various capacities in order to enhance the country's access to GCF. Kenya's national treasury is the NDA for GCF making it the main point of communication with GCF to "ensure that activities supported by the Fund align with strategic national objectives and priorities, and help advance ambitious action on adaptation and mitigation in line with national needs" (The National Treasury, 2017). In addition, NEMA is the National Implementing Entity (NIE) for the Adaptation Fund as well as the Accredited Entities (AEs) for the GCF.

A summary of some of the designated institutions and their corresponding mandate is presented in Table 9.3. The summary also includes other initiatives taken by the Government of Kenya to enhance CFR in the country. While there is evidence of deliberate efforts by the government of Kenya to set up institutions and systems that facilitate climate investments, it is observed that the involvement of the private sector in the climate change space is limited. As of October 2017, no private institutions had been accredited in the GCF with only one application by the Kenya Commercial Bank (KCB) in the pipeline (The National Treasury, 2017). Higher private-sector climate finance for developing countries' climate investments is crucial. Thus, it is important for the role of the private sector in financing climate investments to be reviewed. Furthermore, ways in which the public sector could incentivise private investments should be pursued (Hoch, Friedmann, & Michaelowa, 2018).

Table 9.3: Climate Related Institutions in Kenya

Institutional framework	
i.	Establishment of Kenya's National Treasury as the Nationally Designated Authority for the Green Climate Fund (GCF)
ii.	Establishment of NEMA as the National Implementing Entity (NIE) for the Adaptation Fund
iii.	Establishment of NEMA as Accredited Entities (AEs) for the GCF
iv.	Devolving climate funds through establishment of County Adaptation Funds to support County Governments mainstream climate change adaptation in planning and to access climate finance
v.	Creation of National Climate Change Budget Codes for tracking climate finance flows and expenditure
vi.	Supporting the Climate Public Expenditure and Budget Review
vii.	Supporting the Banking Network (SBN) initiative by the International Finance Corporation (IFC) which supports adaptation financing by micro and small enterprises (MSEs)
In the pipeline	
i.	The GoK plans to establish a Kenya Climate Fund to act as a financing mechanism for priority climate change actions and interventions

(Source: The National Treasury, 2017)

This section reviewed the institutional framework set in place to enhance CFR in Kenya. It was observed that considerable efforts have been taken to set up institutional framework that attract climate finance to the country. Through the NCCRS, the government has set up the National Climate Change Council (NCCC) which is mandated with overseeing climate change mainstreaming in the country. Additionally, the government has set up the green climate fund and appointed various government institutions to work with the GEF in order to facilitate direct access of climate finance. Although the role of climate finance has been discussed in various documents, the policy incentives to enhance the sectors participation are rarely discussed.

9.6 Oversight and Regulation of Climate Finance

Climate finance occupies a significant share of funding under international environmental agreements (Pickering, Betzold, & Skovgaard, 2017). Information on how these funds are utilised improves knowledge on the extent to which the finance available meets demonstrated needs which in turn fosters trust between the financiers and the recipients (Watson, Nakhooda, Caravani, & Schalatek, 2012). That is why it is important for effective monitoring and reporting systems to be put in place in recipient countries to provide oversight and feedback on the climate finance process. As a result, the Government of Kenya has taken initiative to set up mechanisms to enhance tracking and reporting of climate finance. In this regard, the government introduced a budget coding process in 2014 which is aimed at ensuring that all climate finance is correctly recorded at all government levels.

Despite this, tracking of climate investments in Kenya is still problematic. An effort to track climate investments at the county level as at May 2019 experienced challenges associated with inadequate breakdown of budget items at the county levels (Development Initiatives, 2019). From the foregoing, the effectiveness of the introduced climate change budget codes is yet to be realised.

Building robust capacities towards monitoring and tracking climate finance is an arduous task even for developed partner countries (Bécault et al., 2016). The political, technical, and capacity constraints in developing countries make it even harder for these countries to build robust monitoring and reviewing systems for climate finance. However, Rwanda which is a Least Developed Country (LCD) has been successful in setting up thorough MRV procedures and mechanisms to monitor verify and report on climate-related expenditures and financial flows, a fact which is rather commendable for a least developed country (Bécault et al., 2016). A comparative study of the two country’s MRV’s systems would better reveal the key lessons for Kenya to upscale their processes.

9.7 Conclusion

This chapter explored Kenya’s CFR by reviewing climate related policies and institutional frameworks that are in place. The findings reveal that considerable efforts have been taken to enhance Kenya's readiness for climate finance by instituting various legislation and institutional frameworks. A summary of the policies and legislation as well as the established institutional framework is presented in Table 9.1, Table 9.2 and Table 9.3.

A review of the established legislative and institutional framework shows that Kenya has made some impressive progress on climate change response (International Development Law Organization, 2012). This is evidenced by the formulation of various policies and legislation that aim at enhancing Kenya's climate investments and consequently the country's climate resilience. Sustainable development has also been recognised by the constitutional of Kenya which is the supreme law of the country. This gives climate issues the much needed backing that is key for their implementation.

Additionally, a range of institutions that have a specific mandate to address climate change or have substantial engagement with the issue have been created (International Development Law Organization, 2012). These include the establishment of a high-level National Climate Change Council (NCCC) in the Office of the President. This places the NCCC at a high level within the governmental hierarchy and policy-making circles giving climate change high visibility an approach that is similar to that of United Kingdom and Philippines (International Development Law Organization, 2012; Oulu, 2015). Furthermore, the government has nominated institutions to work with the GEF which enables direct access to climate funds. Similar positive progress has been reported in Rwanda a country that has been described as the pioneer country in Africa in relation to enhancing climate finance readiness (Bécault et al., 2016).

Despite Kenya's achievements towards CFR, this study identifies some issues that need closer attention and focus. One such concern is the effectiveness of the introduced climate change budget coding. While the introduction of this process was aimed at enhancing the tracking and oversight of climate related expenditures at all levels, a review by the Development Initiatives (2019) found it difficult to determine climate related expenditures at the county levels. This was attributed to lack of description on the budget expenditures at the county level. It is hard to tell whether the lack of description of these expenditures was due to the budget codes not being implemented or as a result of the introduced codes not being effective. Similarly, while the policy documents acknowledged that the private sector is key in enhancing climate investments, evidence of active support to the sector through policy guidelines or the establishment of institutional structures could not be found. It is important that the necessary support be accorded to the private sector in order to enhance their participation in climate related investments.

Overall, there has been some positive progress towards enhancing Kenya's CFR as evidenced by the relevant policies and institutional frameworks. However, readiness is a continued process which implies that the government needs to constantly updating the existing structures in order to ensure that the country's access to climate finance is at the optimum level.

Chapter 10: Summary and Conclusions

10.1 Introduction

Concerns about the implications of climate change on the livelihood of millions of people has prompted discussions on ways to slow down climate change while at the same time helping the most vulnerable communities to adapt to the negative impacts of climate change. The general consensus is that while the most vulnerable communities have contributed the least towards the factors accelerating climate change, they are the most affected by the impacts of climate change. In particular, the agricultural sector in developing economies is highly vulnerable to the climate change impacts. As a result, the developed countries – who bear the most responsibility to climate change, agreed to set aside funds for climate related investments in developing countries. These funds should be invested in projects that contribute towards climate change mitigation and adaptation. As a result, an insight on the performance of these funds is key in order to justify continued provision of climate funds by the donors. Furthermore, the climate financial needs far exceed the available finances raising the need to evaluate other ways of mobilising and channelling funds towards low carbon investments. This study sought to evaluate the risk exposure in Kenya's agriculture to climate change impacts and the viability of climate finance tools in managing these risks. This chapter highlights the findings of the conducted analysis and summarises the take home messages for the different stakeholders.

The chapter is organised as follows. First an outline of some of the important lessons from the review of climate investments is presented. Secondly using the national yield, maize yield risk at different drought intensities was estimated, the summary of the findings and recommendations are presented in section 10.2.2. Then the inferences on the use of SPEI drought index to price an option contract for maize farmers in Kenya is outlined in section 10.2.3 and finally, the interpretations on the efficiency of SPEI based option contracts in hedging against drought risk are explained in section 10.2.4.

While the use of derivatives provides an innovative solution for managing weather uncertainty, there are other measures that have been put in place to help developing countries cope with the risks. This includes the provision of climate finance for investment in low carbon investments. However, developing countries need to improve their climate finance absorptive capacity in order to access climate finance for their investments. Chapter 9 of this study reviewed Kenya's readiness for climate finance. The findings from this review are presented in section 10.2.5.

The rest of the chapter proceeds as follows. Section 10.3 offers contributions the study makes towards the existing body of literature on climate finance and weather risk management in agriculture. Section 10.4 presents policy implications of the relevant findings while Section 10.5 outlines limitations of the study as a basis for further future research and finally the conclusion of this thesis is presented in section 9.6 concludes the thesis.

10.2 Summary of the findings

The findings reveal that climate finance is positively contributing to the UN's goal of '2 degree' limit of 'global warming. The findings also support the possibility of using a drought index in pricing option contracts for weather risk management in Kenya's agriculture. However, there is need for this to be refined in order to get more accurate results.

10.2.1 Climate Finance

In order to understand the climate related financial flows, this study reviewed the current global climate finance landscape from both the public and private sources. This involved a review of the climate funds in terms of geographic origin, geographic distribution as well as an analysis of the sectors that the funds have been invested in. After that, selected climate financed projects in Africa were analysed with the goal of gaining an insight into the challenges faced by climate investments as well as the opportunities for enhancing more investments. This section outlines the findings of this review.

Table 10.1: Climate Finance Delivery Challenges and Solutions

Challenges	**Innovative solutions**
Access to finance	- Enhance credit rating services e.g. Climate smart credit scoring, private credit bureaus - Adopt mobile technology to provide financial products - PPP, blending of finance e.g. grants, low cost debt to lower the cost of lending to farmers - De-risking of projects
High transaction costs	- Branchless insurance and banking e.g. mobile technology - Index based Insurance
Inadequate enabling environments	- Policy interventions - PPP
Lack of capacity – technical, administrative	- Policy interventions - PPP
Non bankable projects	Ensure bankability through e.g. - capacity building - de-risking the projects - Pooling of small projects
High risk in climate investments	De risking the projects by; - Blending of climate finance (different sources) which have different risk return profile - Insurance, credit guarantee, derivatives

(Source: creation by the author)

While the flow of funds has been growing over time, the mobilised amounts still fall short of the amounts needed to meet the green investment needs. Consequently, addressing some of the identified barriers could catalyse mobilisation of funds to the climate investments. Table 10.1 outlines some of the challenges as identified from literature and outlines some of the innovative ways that these have been managed by different actors.

Figure 3.3 shows that the flow of funds is more skewed towards mitigation investments. Accordingly, measures need to be put in place to catalyse more investments in adaptation measures. Further SSA which accounted for 3% of the global investments will need to put measures in place to increase the flow of funds to the region.

Kenyan government has instituted various policies and strategies that cover climate change adaptation and mitigation. These can be better improved by aligning the strategies to the national and international climate finance landscape. Furthermore, while the governments' climate strategies indicate the financial needs, they do not show the sources of funds and how the government intends to catalyse the flow of funds to green investments.

10.2.2 Estimation of the Agricultural Risk

Agricultural risk is a major concern for investors seeking to venture into agriculture in SSA. Unreliable weather coupled with the low levels of irrigation are some of the factors that make the sector even more volatile. Chapter 6 sought to estimate production risk for Kenya's maize farmers. The yield loss series was estimated and fitted into a probability density function. Then, VaR was applied to estimate the yield risk. The obtained results slow that the estimated risk is high at approximately 21% for the 10year and 20-year return period and 24% for the 50 year and 100-year return period. This is likely to affect thousands of people who depend on agriculture for their livelihood. While the communities have established their own adaptation and coping strategies, the percentage of loss and the frequencies of occurrence could lead to increasing poverty if not well managed. It is therefore important that there is a management strategy that transfers the risks from the farmers to another better equipped party through insurance or other hedging options.

10.2.3 Hedging Drought Risk in Kenya with Weather Derivatives

An understanding of the potential impacts of climate change has led to a heightened awareness for the need to explore methods of adaptation to increasing variability of weather-related risks. The agricultural sector faces a number of such risks which makes the use of weather contracts one of the possible ways of mitigating the financial risks associated with weather.

Chapter 7 explored the use of weather contracts to hedge against financial risks arising due to drought occurrence. As a practical example, growing period rainfall and drought index (SPEI) to model for the western Kenya region. With the possibility of the weather becoming more volatile, the use of weather derivatives will be of greater value to the agricultural sector in Kenya.

The study found the modelled option contracts to reasonably cover the periods of drought episodes. As an example, the season based SPEI contracts as displayed in Table 7.6, show that the farmers would have received compensation in 1981, 1985, 2003, 2010, 2008. These years had been cited as having experienced drought episodes. Similarly, the rainfall-based weather derivatives were beneficial in years 1999, 2004, 2006, 2008 and 2010. However, some years that had drought episodes did would not have qualified for compensation. Further studies that use location specific data, and empirically set strike levels should be used to refine these results.

10.2.4 Efficiency of Option Contracts

Chapter 8 presents the results on the efficiency of SPEI based option contract as a hedging tool against income fluctuations due to drought. Using SPEI based option contract, the revenue functions with and without the option contract are modelled and tested for efficiency using the VaR method. The results indicate that the revenue risk as measured using VaR was 4.74% without the option contract and 4.80% when the option contract was purchased. This is contrary to the expected results where the purchase of option contracts should reduce the risk exposure for the contract holders. However, while the results are contrary to expectation, they are consistent with those of (Vedenov & Barnett, 2004) who found that buying option contracts increased the risk exposure for some out of sample crops/districts.

There are several reasons for such an outcome such as basis risk, however overcoming basis risk would require a more localised contract designs which comes at additional cost and raises questions potential markets for the contracts. There is need for further studies on how to improve the efficiency of the contracts while maintaining low costs and ensuring simplicity of the product.

10.2.5 Kenya's Readiness for Climate Finance

Significant resources are needed in order to cope with the impacts of climate change. While climate finance has been set aside for use by developing countries to invest in investments that enhance their resilience, access and investment of these funds will play a big role in their ability to benefit from these funds. Chapter 9 of this study reviewed the measures that have been put in place to enhance Kenya's readiness for climate finance. The study found that Kenya has made considerable steps towards becoming climate finance ready. This is evidenced by the formulation of legislation as discussed in section 9.3 and 9.4 as well as setting up of institutional frameworks meant to enhance Kenya's readiness for climate finance. However, while considerable efforts have been taken to enhance Kenya's readiness for climate finance, the country could improve its readiness by addressing issues such implementation of the legislation, provision of data for use by relevant stake holders as well as provision of incentives for private sectors in order to encourage them to venture in climate smart investments.

10.3 Contributions

This study main contributes to the existing body of knowledge on climate risk management in agriculture in several ways.

First, it sets a base for estimating financial resources needed to cater for extreme weather events in the agricultural sector. Precisely, while most traditional measures of risk assume that losses are normally distributed (Wang et al., 2015), in reality, some loss distributions may not follow a normal distribution making the results obtained based on these distributions unreliable. This study adopted the extreme value approach there by addressing the issue of losses that may not be catered for if the normal distribution is used. Furthermore, the study also demonstrates the application of VaR in estimating yield risk as a result of changes in weather.

Second, while weather derivatives have received considerable attention in literature as potential risk management instruments for agricultural production, most of the techniques that have been used to model these contracts use one weather variable such as rain or temperature. In this study the use of SPEI drought index as the underlying variable when pricing weather derivatives has been explored. The advantage of the SPEI index is that it considers both precipitation and evapotranspiration. These two parameters are key in determining the growth and performance of crops.

Third, the main foci when designing weather derivatives has been on developing actuarially-fair pricing mechanisms for the contracts and institutional frameworks necessary to introduce weather-based insurance (Vedenov & Barnett, 2004). This approach primarily addresses the seller's side of the market. Thus, this contributes to literature by addressing the buyers side of view on whether purchasing option contracts is efficient in hedging against the revenue fluctuation risk that comes about as a result of weather changes.

10.4 Policy Implications

The findings of this thesis have policy implications for Kenya’s agriculture. In this section, the core policy implications that are relevant to the advancement of agricultural risk management are outlined.

i. For insurance companies, this study provides a quantitative method which although primarily used in the financial sector is relevant in conducting more accurate and quantitative based analysis when determining the insurance premiums.
ii. For the Government, the study provides quantitative measures that would be useful when estimating the probable resources needed as a contingency fund for use during times of extreme weather events. In addition, the information obtained can be used as evidence when bargaining for funds from international funding organisations.

iii. For investors, the risk analysis techniques presented would be useful when making investment decisions. Private investors can use the results to determine their risk exposure when venturing into agriculture.

iv. The risk estimated for 50 year and 100 year return period is high. Thus, the government should consider partnering with the private sector to share the risks by providing re-insurance programmes.

v. Kenya has taken deliberate steps to enhance CFR. This is evidenced by the policies and laws that the government has formulated. This study was however not able to confirm the level of theory implementation or effectiveness found. There is need for information to be easily available to researchers in order to aid in research and decision making.

vi. There is need for the Kenyan Government to institute measures to improve climate finance tracking from both the private and the public sector. In particular, the use of climate change markers within the national budget should be considered.

vii. The results show the kind of information that international donors can obtain from recipient countries. It suggests that donor countries should ensure that in some countries, including Kenya, agriculture should be included in the sectors that have access to climate finance.

10.5 Suggestions for Future Research

This study does have limitations that present opportunities for further research. One of the limitations relates to availability of data on agricultural production. At the time of this study, the agricultural production data that was available was the national production. This reflects the total production from all the regions. This may be different from the yield at the regional levels due to differences in factors such as weather, type of soil among others. Consequently, the findings of this study may differ from the possible results if the analysis was carried out using data from the regions. Thus, further research using data from the regions could provide more accurate result for the different regions.

Secondly, while this study provides insights on risk estimation and management in the face of uncertain weather, it focuses on one country (Kenya) whose circumstances may differ from those of other countries. Undertaking similar studies in other countries would enhance our understanding of agricultural risk as a result of weather and the efficiency of the proposed weather derivatives in managing these risks. Consequently, further studies on the topic in other countries is proposed.

This study did not scientifically determine the strike level and tick price when estimating the option contract prices and pay-out. Determination of the strike level and tick size is usually an important issue and is set after considering distinctive characteristics specific to the issue being reviewed (Cyr et al., 2010). Consequently, future research that scientifically determines the optimal weather parameters such as the tick size and strike level would further refine the results.

Evaluation of the level of CFR in Kenya provided useful information on the policy, legislation and institutional frameworks aimed at improving climate finance readiness in the country. It discusses the linkage between the different legislation and policies and identifies some gaps as observed from the reviewed literature. Due to the very broad scope of this topic and the limited time taken to carry out this analysis, there is likely to be some omissions. Consequently, the findings of this study should provide a stepping stone for future research and analysis.

10.6 Concluding Remarks

Risk management in Kenya's agriculture is vital because of the important role that the sector players as a major GDP earner, the key source of employment as well as the vulnerability of the sector to weather changes. This thesis: (i) demonstrates additional ways of production risk estimation in Kenya's agriculture; and (ii) models the use of a drought index in pricing financial risk management tools for the sector and demonstrates the evaluation of the financial tools in hedging against the risk of revenue fluctuation. Consequently, this research offers insights to researchers, investors and policy makers around the world who are interested in agricultural risk management.

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Appendices

Table A.1: Goodness of Fit Summary

		Kolmogorov Smirnov		Anderson Darling		Chi-Squared		
Srl No.	**Distribution**	**Statistic**	**Rank**	**Statistic**	**Rank**	**Statistic**	**Rank**	**Average**
21	Gen. Extreme Value	0.07	3	0.18	3	0.23	1	2
40	Lognormal (3P)	0.08	4	0.23	7	0.25	3	5
30	Johnson SB	0.06	1	0.15	2	0.60	15	6
41	Nakagami	0.07	2	0.25	10	0.44	7	6
7	Dagum	0.08	11	0.13	1	0.58	14	9
3	Burr (4P)	0.08	9	0.30	13	0.26	5	9
59	Weibull (3P)	0.08	10	0.31	14	0.26	4	9
18	Frechet (3P)	0.08	5	0.23	6	0.79	20	10
2	Burr	0.09	13	0.32	16	0.24	2	10
29	Inv. Gaussian (3P)	0.08	6	0.23	8	0.86	23	12
48	Pearson 6 (4P)	0.09	14	0.33	17	0.29	6	12
36	Log-Logistic (3P)	0.08	7	0.28	12	0.74	19	13
16	Fatigue Life (3P)	0.08	8	0.24	9	0.84	22	13
25	Gumbel Max	0.08	12	0.22	5	1.28	28	15
24	Gen. Pareto	0.10	17	0.21	4	0.91	25	15
20	Gamma (3P)	0.10	18	0.40	18	0.58	13	16
19	Gamma	0.10	15	0.67	25	0.54	10	17
47	Pearson 6	0.11	21	0.44	20	0.56	12	18
22	Gen. Gamma	0.11	22	0.53	23	0.54	9	18
37	Log-Pearson 3	0.10	19	0.25	11	0.94	27	19
52	Rayleigh (2P)	0.11	20	0.31	15	1.28	29	21

Srl No.	Distribution	Kolmogorov Smirnov Statistic	Rank	Anderson Darling Statistic	Rank	Chi-Squared Statistic	Rank	Average
49	Pert	0.14	27	0.87	30	0.52	8	22
56	Triangular	0.10	16	0.88	31	0.94	26	24
42	Normal	0.12	24	0.43	19	1.69	33	25
11	Error	0.13	25	0.47	21	1.76	35	27
58	Weibull	0.16	34	0.70	26	0.81	21	27
44	Pareto 2	0.18	43	0.86	28	0.56	11	27
38	Logistic	0.13	26	0.49	22	2.43	37	28
13	Exponential	0.17	42	0.81	27	0.65	16	28
4	Cauchy	0.16	36	0.86	29	0.89	24	30
10	Erlang (3P)	0.16	38	1.16	35	0.71	18	30
31	Kumaraswamy	0.15	31	1.10	33	1.42	30	31
14	Exponential (2P)	0.16	37	1.74	40	0.71	17	31
27	Hypersecant	0.14	28	0.61	24	3.58	43	32
5	Chi-Squared	0.16	33	1.16	34	1.52	32	33
1	Beta	0.14	30	1.60	38	1.70	34	34
57	Uniform	0.11	23	4.26	49	N/A		36
39	Lognormal	0.17	41	1.25	36	2.11	36	38
32	Laplace	0.16	35	0.90	32	4.91	47	38
23	Gen. Gamma (4P)	0.14	29	4.20	48	N/A		39
28	Inv. Gaussian	0.15	32	5.83	53	1.44	31	39
35	Log-Logistic	0.20	46	1.44	37	2.90	39	41
6	Chi-Squared (2P)	0.19	44	1.73	39	3.26	41	41
26	Gumbel Min	0.19	45	1.74	41	2.47	38	41
51	Rayleigh	0.16	39	2.07	42	3.98	45	42
33	Levy	0.26	48	3.00	44	2.99	40	44
8	Dagum (4P)	0.17	40	4.46	50	N/A		45

Srl No.	Distribution	Kolmogorov Smirnov Statistic	Rank	Anderson Darling Statistic	Rank	Chi-Squared Statistic	Rank	Average
17	Frechet	0.27	49	2.84	43	4.71	46	46
45	Pearson 5	0.30	52	3.32	47	3.83	44	48
15	Fatigue Life	0.30	51	3.13	46	7.37	48	48
50	Power Function	0.24	47	5.44	51	N/A		49
34	Levy (2P)	0.31	53	3.03	45	10.30	51	50
46	Pearson 5 (3P)	0.31	54	5.93	54	3.34	42	50
54	Rice	0.27	50	5.61	52	8.46	49	50
43	Pareto	0.41	56	8.24	56	10.11	50	54
9	Erlang	0.38	55	9.78	57	11.18	52	55
53	Reciprocal	0.42	57	7.26	55	14.22	53	55
12	Error Function	0.55	58	25.73	58	47.87	54	57
55	Student's t	0.69	59	39.36	59	117.17	55	58

:

Table A.2: The Simulation Codes

gevSim(model = list(xi = -0.35, mu = -0.86, beta = 3.40), n = 100, seed = NULL)

Symbol	**Meaning**	**Long rain value**	**Short rain value**
Xi	Shape parameter	-0.35	-0.30
Mu	location parameter	-0.86	-0.29
Beta	scale parameter	3.40	1.65

gevSim(model = list(xi = -0.35, mu = -0.86, beta = 3.40), n = 100, seed = NULL)

dgev(Longrain) for the pdf

pgev(Longrain) for the cdf

Decade	**Average**	**Std Dev**	**CV**
1960	1,185.66	83.06	0.07
1970	1,376.15	154.42	0.11
1980	1,729.17	266.98	0.15
1990	1,676.24	195.76	0.12
2000	1,606.57	197.18	0.12

Maize yield variation over time:

Table A.3: De-trended yield

Year	Predicted Yield kg/ha	Residuals	Standard Residuals	Yt	Ydet	Year	Predicted Yield kg/ha	Residuals	Standard Residuals	Yt	Ydet	Year	Predicted Yield kg/ha	Residuals	Standard Residuals	Yt	Ydet
1961	1,283	-29.98	-0.14	1,253	1,508	1988	1,543	360.15	1.69	1,903	1,898	1983	1,495	274.42	1.29	1,769	1,812
1962	1,293	-70.70	-0.33	1,222	1,467	1989	1,552	300.13	1.41	1,853	1,838	1984	1,504	-60.7	-0.28	1,444	1,477
1963	1,303	-52.51	-0.25	1,250	1,486	1990	1,562	97.02	0.45	1,659	1,635	1985	1,514	208.19	0.98	1,722	1,746
1964	1,312	-140.73	-0.66	1,171	1,397	1991	1,572	260.41	1.22	1,832	1,798	1986	1,524	510.67	2.39	2,034	2,049
1965	1,322	-250.44	-1.17	1,071	1,288	1992	1,581	145.79	0.68	1,727	1,684	1987	1,533	183.66	0.86	1,717	1,722
1966	1,331	-252.15	-1.18	1,079	1,286	1993	1,591	-36.02	-0.17	1,555	1,502	2010	1,754	-29.25	-0.14	1,725	1,509
1967	1,341	-140.97	-0.66	1,200	1,397	1994	1,601	439.47	2.06	2,040	1,978	2011	1,764	-179.97	-0.84	1,584	1,358
1968	1,351	-96.98	-0.45	1,254	1,441	1995	1,610	265.75	1.25	1,876	1,804	2012	1,774	-36.98	-0.17	1,737	1,501
1969	1,360	-86.09	-0.4	1,274	1,452	1996	1,620	-169.16	-0.79	1,451	1,369	2013	1,783	-90.99	-0.43	1,692	1,447
1970	1,370	-144.81	-0.68	1,225	1,393	1997	1,629	-158.08	-0.74	1,471	1,380	2014	1,793	-132.61	-0.62	1,660	1,405
1971	1,379	-162.02	-0.76	1,217	1,376	1998	1,639	30.71	0.14	1,670	1,569						
1972	1,389	-135.23	-0.63	1,254	1,403	1999	1,649	-166.9	-0.78	1,482	1,371						
1973	1,399	-108.95	-0.51	1,290	1,429	2000	1,658	-218.22	-1.02	1,440	1,320						
1974	1,408	-63.46	-0.3	1,345	1,475	2001	1,668	33.37	0.16	1,701	1,571						
1975	1,418	-4.08	-0.02	1,414	1,534	2002	1,677	-164.84	-0.77	1,513	1,373						
1976	1,427	207.71	0.97	1,635	1,746	2003	1,687	-64.66	-0.3	1,622	1,473						
1977	1,437	189	0.89	1,626	1,727	2004	1,697	232.63	1.09	1,929	1,771						
1978	1,447	8.98	0.04	1,456	1,547	2005	1,706	-65.79	-0.31	1,641	1,472						
1979	1,456	-156.33	-0.73	1,300	1,382	2006	1,716	3.8	0.02	1,720	1,542						
1980	1,466	-265.94	-1.25	1,200	1,272	2007	1,726	87.69	0.41	1,813	1,626						
1981	1,476	103.04	0.48	1,579	1,641	2008	1,735	-342.63	-1.61	1,393	1,195						
1982	1,485	586.03	2.75	2,071	2,124	2009	1,745	-450.44	-2.11	1,294	1,088						

Table A.4: The De-trended Yield

Year	Predicted Yield kg/ha	Residuals	Standard Residuals	Yt	bt	bE(t)	Ydet 1	De-trended Yield 2
1991	1,693.40	138.70	0.78	1,832.10	7,411.35	(6,130.34)	3,113.12	1,785.57
1992	1,689.67	37.43	0.21	1,727.10	7,415.08	(6,130.34)	3,011.84	1,684.29
1993	1,685.95	(131.05)	(0.73)	1,554.90	7,418.80	(6,130.34)	2,843.36	1,515.81
1994	1,682.23	357.77	2.00	2,040.00	7,422.52	(6,130.34)	3,332.18	2,004.64
1995	1,678.51	197.39	1.10	1,875.90	7,426.24	(6,130.34)	3,171.81	1,844.26
1996	1,674.78	(224.18)	(1.25)	1,450.60	7,429.96	(6,130.34)	2,750.23	1,422.68
1997	1,671.06	(199.76)	(1.12)	1,471.30	7,433.69	(6,130.34)	2,774.65	1,447.10
1998	1,667.34	2.36	0.01	1,669.70	7,437.41	(6,130.34)	2,976.77	1,649.23
1999	1,663.62	(181.92)	(1.02)	1,481.70	7,441.13	(6,130.34)	2,792.50	1,464.95
2000	1,659.89	(219.89)	(1.23)	1,440.00	7,444.85	(6,130.34)	2,754.52	1,426.97
2001	1,656.17	45.03	0.25	1,701.20	7,448.58	(6,130.34)	3,019.44	1,691.89
2002	1,652.45	(139.85)	(0.78)	1,512.60	7,452.30	(6,130.34)	2,834.56	1,507.02
2003	1,648.73	(26.33)	(0.15)	1,622.40	7,456.02	(6,130.34)	2,948.09	1,620.54
2004	1,645.00	284.30	1.59	1,929.30	7,459.74	(6,130.34)	3,258.71	1,931.16
2005	1,641.28	(0.78)	(0.00)	1,640.50	7,463.47	(6,130.34)	2,973.63	1,646.08
2006	1,637.56	82.14	0.46	1,719.70	7,467.19	(6,130.34)	3,056.55	1,729.01
2007	1,633.84	179.36	1.00	1,813.20	7,470.91	(6,130.34)	3,153.77	1,826.23
2008	1,630.11	(237.61)	(1.33)	1,392.50	7,474.63	(6,130.34)	2,736.80	1,409.25
2009	1,626.39	(332.09)	(1.86)	1,294.30	7,478.36	(6,130.34)	2,642.32	1,314.77
2010	1,622.67	102.43	0.57	1,725.10	7,482.08	(6,130.34)	3,076.84	1,749.30
2011	1,618.95	(34.95)	(0.20)	1,584.00	7,485.80	(6,130.34)	2,939.46	1,611.92

Year	Predicted Yield kg/ha	Residuals	Standard Residuals	Yt	bt	bE(t)	Ydet 1	De-trended Yield 2
2012	1,615.22	121.38	0.68	1,736.60	7,489.52	(6,130.34)	3,095.79	1,768.24
2013	1,611.50	80.70	0.45	1,692.20	7,493.25	(6,130.34)	3,055.11	1,727.56
2014	1,607.78	52.42	0.29	1,660.20	7,496.97	(6,130.34)	3,026.83	1,699.29
2015	1,604.06	218.94	1.23	1,823.00	7,500.69	(6,130.34)	3,193.35	1,865.81
2016	1,600.34	(171.94)	(0.96)	1,428.40	7,504.41	(6,130.34)	2,802.48	1,474.93

Table A.5: Correlation Matrix

	Year	*Yield Kg/ha*	*Area Harvested (Ha)*	*Yield hg / ha*	*Production / Tonnes*
Year	1.00				
Yield Kg/ha	(0.16)	1.00			
Area Harvested (Ha)	0.92	(0.17)	1.00		
Yield hg/ha	(0.16)	1.00	(0.17)	1.00	
Production/Tonnes	0.76	0.40	0.83	0.40	1.00

Table A.6: Revenue Function

Year	*Predicted Yield kg/ha*	*Residuals*	*Standard Residuals*	*Yt*	*Ydet*	*unit Price*	*Revenue*	*Price of option*	*Payout of Option*	*New Revenue*
1991	1,572	260.41	1.22	1,832	1,798	224	403,536	93.09	67	403,510
1992	1,581	145.79	0.68	1,727	1,684	224	377,820	93.55	489	378,215
1993	1,591	(36.02)	(0.17)	1,555	1,502	224	337,023	93.03	479	337,409
1994	1,601	439.47	2.06	2,040	1,978	224	443,714	91.57	193	443,815
1995	1,610	265.75	1.25	1,876	1,804	224	404,737	91.55	67	404,712
1996	1,620	(169.16)	(0.79)	1,451	1,369	224	307,149	90.62	141	307,200
1997	1,629	(158.08	(0.74	1,471	1,380	224	309,638	92.5	244	309,789
1998	1,639	30.71	0.14	1,670	1,569	224	351,998	94.73	383	352,287
1999	1,649	(166.90)	(0.78)	1,482	1,371	224	307,656	92.02	509	308,073
2000	1,658	(218.22	(1.02)	1,440	1,320	224	296,143	91.9	233	296,285
2001	1,668	33.37	0.16	1,701	1,571	224	352,595	93.41	616	353,118
2002	1,677	(164.84)	(0.77)	1,513	1,373	224	308,119	94.56	135	308,159
2003	1,687	(64.66	(0.30)	1,622	1,473	224	330,599	93.61	145	330,651
2004	1,697	232.63	1.09	1,929	1,771	224	397,303	86.56	200	397,416
2005	1,706	(65.79)	(0.31)	1,641	1,472	224	330,346	91.84	238	330,492
2006	1,716	3.80	0.02	1,720	1,542	224	345,960	95.44	268	346,133
2007	1,726	87.69	0.41	1,813	1,626	224	364,781	93.22	197	364,885
2008	1,735	(342.63)	(1.61)	1,393	1,195	224	268,228	93.98	137	268,271
2009	1,745	(450.44)	(2.11)	1,294	1,088	224	244,038	92.39	14	243,960
2010	1,754	(29.25)	(0.14)	1,725	1,509	224	338,542	92.64	197	338,647

Table A.7: GEF Funded Projects

Project Name	Source of Finance / co finance and type of finance
Strengthening National Capacity in Kenya to Meet the Transparency Requirements of the Paris Agreement and Sharing Best Practices in the East Africa Region	- Government of Kenya - Conservation International (GEF) - GHG MI
Combating Poaching and Illegal Wildlife Trafficking in Kenya through an Integrated Approach	- Government (Ministry of Environment and Natural Resources) - County Government of Taita Taveta - Tsavo Conservation Group - Kenya Wildlife Conservancies Association - Maasai Mara Conservancy Association - CSO Maasai Mara Conservancy Association
Restoration of arid and semi-arid lands (ASAL) of Kenya through bio-enterprise development and other incentives under The Restoration Initiative	- KEFRI
Enhancing Integrated Natural Resource Management to Arrest and Reverse Current Trends in Biodiversity Loss and Land Degradation for Increased Ecosystem Services in the Tana Delta, Kenya	- National Government - County government - Various national agencies
RLACC - Rural Livelihoods' Adaptation to Climate Change in the Horn of Africa (PROGRAM)	AfDB
Sixth Operational Phase of the GEF Small Grants Programme in Kenya	- Community grantee organisations - Other multilateral organisations and donor funds
Developing the Microbial Biotechnology Industry from Kenya's Soda Lakes in line with the Nagoya Protocol	- National Government - local private companies - Multilateral agencies

Project Name	**Source of Finance / co finance and type of finance**
Sound Chemicals Management Mainstreaming and UPOPs Reduction in Kenya	- National Goberment - Civil society organizations – CSOs - Private Sector - Parastatals - UoN - National GVT loans
Food-IAP: Establishment of the Upper Tana Nairobi Water Fund (UTNWF)	- Government of Kenya – In kind - Private sector - county Governmenrs – In Kind - CSO’s - Small holder farmers - International NGO’s – in Kind
Sixth Operational Phase of the GEF Small Grants Programme in Kenya	- Multilateral organizations (cash & In Kind) - CSO (cash & In Kind)
RLACC - Rural Livelihoods' Adaptation to Climate Change in the Horn of Africa (PROGRAM)	- AFDB Loan
SP-SFIF: Kenya Coastal Development Project	- World bank - Borrower /Non world bank loan
SIP: Mainstreaming Sustainable Land Management in Agro-pastoral Production Systems of Kenya	- UNDP - National Government - other partners
Strengthening the Protected Area Network within the Eastern Montane Forest Hotspot of Kenya	- National Government of Kenya - GEF Agency UNDP - Bilateral / Multilateral Aid Agency - Donor Consortiums - Private Sector - NGO
Fifth Operational Phase of the GEF Small Grants Programme in Kenya	- National Government - Grant - GEF Agency - Bilateral Aid Agencies - Grant

Project Name	Source of Finance / co finance and type of finance
	- Private Sector – Soft loan - NGO- in kind - Others – Grant
Support to Kenya for the Revision of the NBSAPs and Development of Fifth National Report to the CBD	- National Government - grants in Kind
Enhancing Wildlife Conservation in the Productive Southern Kenya Rangelands through a Landscape Approach	- Government - Implementing Agency - Non-Governmental Organisations
Capacity, Policy and Financial Incentives for PFM in Kirisia Forest and integrated Rangelands Management	- Co-financing (USD): - Kenya Forestry Service (KFS) - Forestry Research Institute (KEFRI) - Kenya Wildlife Service (KWS) - FAO - Samburu County Government - Community Forestry Associations - Kenya Forest Working Group
Sustainable Conversion of Waste to Clean Energy for Greenhouse Gas (GHG) Emissions Reduction	- The National Government of Kenya - Private funder - other multi-lateral agencies
Scaling up Sustainable Land Management and Biodiversity Conservation to Reduce Environmental Degradation in Small Scale Agriculture in Western Kenya	- national government - agencies - community groups
Removal of Barriers to Energy Conservation and Energy Efficiency in Small and Medium Scale Enterprises	-
Expedited Financing of Climate Change Enabling Activities Part II: Expedited Financing for (interim) Measures for Capacity Building in Priority Areas	(NIL)

Project Name	**Source of Finance / co finance and type of finance**
Mount Kenya East Pilot Project for Natural Resource Management (MKEPP)	- Government of Kenya - Beneficiary - IFAD
Wildlife Conservation Leasing Demonstration	- National Government - NGO
Developing Incentives for Community Participation in Forest Conservation through the Use of Commercial Insects in Kenya https://assembly.thegef.org/project/developing-incentives-community-participation-forest-conservation-through-use-commercial	- IFAD - ICIPE - USAID Nature –Kenya - Viking Limited - EU BCP Arabuko - EU BCP Kakamega - Govt Kenya FBD/Districts, - IDA APL)
Agricultural Productivity and Sustainable Land Management	- Government of Kenya - Rockefeller Foundation - EU - FAO - UNDP
Development and Implementation of a Standards and Labeling Programme in Kenya with Replication in East Africa	- GEF Agency(UNDP) - Government (cash & in-kind) - Private(KAM +Private Sector
Improved Conservation and Governance for Kenya Coastal Forest Protected Area System	- Government of Kenya - Bilateral aid - Multilateral - Private sector Cash Not - NGO Cash
Market Transformation for Efficient Biomass Stoves for Institutions and Small and Medium-Scale Enterprises	- Government - Private sector - End-users

Project Name	Source of Finance / co finance and type of finance
Enhanced Regulatory and Information Systems for Integrated Implementation of Multilateral Environmental Agreements (MEAs)	- National Government - GEF IA/ExA
Adaptation to Climate Change in Arid Lands (KACCAL)	- Government
National Capacity Needs Self-Assessment for Global Environmental Management (NCSA)	- Government of Kenya
Tana River National Primate Reserve Conservation Project	- Government of Kenya
Biodiversity Strategy & Action Plan and First National Report to the CBD	- Co-financing – NIL
Removal of Barriers to Energy Conservation and Energy Efficiency in Small and Medium Scale Enterprises	- Government of Kenya
Enabling Activities for the Preparation of Initial National Communications Related to the UNFCCC	- Government of Kenya
Lake Baringo Community-based Integrated Land and Water Management Project	- Government of Kenya
Western Kenya Integrated Ecosystem Management Project	- Government of Kenya - PHRD - SIDA
Support to the Implementation of the National Biosafety Framework	- Government of Kenya
Enabling Activities for the Stockholm Convention on Persistent Organic Pollutants (POPs): National Implementation Plan for Kenya	-
Development and Implementation of a Sustainable Resource Management Plan for Marsabit Mountain and its associated Watersheds	-

Project Name	Source of Finance / co finance and type of finance
Assessment of Capacity Building to Conserve Biological Diversity Participation in the National Clearing House Mechanism and Preparation of a Second National Report to the CBD (Add On)	- Government of Kenya
Joint Geophysical Imaging (JGI) Methodology for Geothermal Reservoir Assessment	- Duke University (in kind): - KenGen
Lewa Wildlife Conservancy	- Government of Kenya

(Source: http://assembly.thegef.org/projects?f%5B0%5D=field_country%3A