FARMERS ACCESS TO CLIMATE AND WEATHER INFORMATION AND ITS IMPACT ON MAIZE AND WHEAT PRODUCTION IN UASIN GISHU COUNTY, KENYA

BY

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DECLARATION AND APPROVAL

DECLARATION BY CANDIDATE

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DEDICATION

This work is dedicated to my beloved children; Ikram Chemutai Murgor and Andrew Kiprop Murgor.

ABSTRACT

The prevailing climate variability has distorted the order and seasons known to maize and wheat farmers in Kenya over time hence farmers have incurred great losses during farming. Although adaptation strategies require good quality climatic information on a spatial scale and time series known; the information is not readily coordinated, shared or disseminated in a timely way due to adaptability, format and timing challenges of the information in Uasin Gishu County. This study therefore seeks to address these challenges. The main objective of this study was to determine the types, the accessibility and utilization of climate and weather information by maize and wheat farmers in Uasin Gishu County with the intention to recommend and provide a reliable cost effective climate and weather information dissemination approach with a feedback mechanism. The study was conducted in Moiben, Kesses and Soy sub counties of Uasin Gishu County selected purposively. Also, the study adopted stratified and random sampling procedure to be able to capture representative sample of farmers. A minimum of 399 farmers were included in the present study in addition to 12 key informants interviewed. A pre-tested semi-structured questionnaire and an interview schedule were the main data collection tools. Chi-square and independent sample t-test were employed in the analysis using SPSS (V.16). Results were considered significant at $\alpha=0.05$. The participants were 83% male and 17% female with 39.6% of them having attained primary level of education. More than half of the farmers stated that their sources of climate and weather information include Agricultural Extension Officers and their fellow farmers. Indigenous knowledge systems are other sources of information that informs a farmer's decision in maize and wheat growing as affirmed by 45% of farmers. About 60% of the farmers do not access climate and weather information although KMS produces agro-meteorological information and (>50%) were not aware of any organization producing such information. The findings portray a vulnerable group that need urgent intervention measures that include access and use of climate information in farming decisions. There is a significant relationship however between access and usage of information *(Chi = 87.263, P < 0.001).* Access to climate information is generally farmer led and agricultural shows, farmer's field/demonstrations and agricultural value chains are other information outlets that farmers use to access climate information. Education level is significantly related to access to climate and weather information (*Chi = 17.957, P = 0.001*). While Radio and Television were the common means of receiving climate and weather information, farmers also preferred use of mobile phone (51.4%) to receive climate updates. Delivery of agro-meteorological services is poorly coordinated and one of the challenges is the format and media used in disseminating this information to the farmers. Farmer's indigenous knowledge system indicators and experience greatly influences their decision in maize and wheat growing; they have particular dates that activities commence in the farm as stated by (84.9%). Use of indigenous knowledge system alone in farming decision may make farmers fail to capitalize fully on beneficial weather conditions prevailing then, but also frequently buffer poorly against negative effects of climatic variability. Farmers however attach value to use of climate and weather information with a significant relationship thus existing between value attached to information and its usage *(Chi = 10.325, p = 0.016).* Farmers have inculcated coping strategies like crop diversification to mitigate climate variability in their farming practice although this needs to be supported through policy enhancement on crop diversification. Despite the ability to mitigate, farmers remain vulnerable to climate variability due to lack of timely climate and weather information. There was no significant relationship however between access to climate information and production per acre

($p>0.05$). Mobile phones were accessible and convenient to majority of farmers as 92.2% owned a mobile phone. Farmers also use their mobile phones to receive text messages (SMS) as stated by 93.9% of the farmers and 96.3% preferred to receive or get updates on climate and weather information through the mobile phone. I-farm application model: an agro-weather tool for climate-smart agriculture is a web based application developed to deliver climate and weather information to farmers using mobile phone SMS alerts. Based on the findings and conclusions herein, I recommend that the KMS and Directorate of Agriculture in the counties empower Agricultural Extension Officers and farmers with good quality climate and weather information in. This can be done through effective outreach programs and educational initiatives on climate and weather information utilization by farmers. There is need to integrate both traditional knowledge systems and practices with access to climatic information to synergise the two to be able to cope with the prevailing climatic variability and its impact. There is need to repackage climate and weather information to formats accessible and easily understood by farmers and to deliver it in a timely way to be able to create ownership and sustainability among the users of the information. Agro-meteorological services should target the use of mobile phones especially messaging service to disseminate their products and services to the farmers as they are widely accessible to farmers. The development of I-farm model; a web based SMS system to disseminate information to farmers through their mobile phones and relay feedback from users is a noble innovation that could be replicated in other agricultural sectors and propagated in other counties of Kenya to help empower farmers with information to maximize benefits in the farming enterprise.

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ACRONYMS

ACMAD - African Centre of Meteorological Applications for Development

AEWACS - African Early Warning and Advisory Climate Services

AfDB - African Development Bank

AWS - Automatic Weather Stations

CCAFS - Climate Change and Food Security

CGIAR - Consultative Group on International Agriculture

ClimDevAfrica - Climate for Development in Africa

ECMWF - European Centre for Medium Range Weather Forecasting

GHF – Global Humanitarian Forum

GOES - Geostationary Operational Environmental Satellites

GTS – Global Telecommunication Systems

ICPAC - IGAD Climate Prediction and Applications Centre

IGAD - Inter-Governmental Authority on Development's

IPCC - Intergovernmental Panel on Climate Change

IVRS - Interactive Voice Response System

JJA – June to August

KFSSG - Kenya Food Security Steering Group

KMS – Kenya Meteorological Services

KNBS - Kenya National Bureau of Statistics

KNCHS - Kenya National Census and Household Surveys

NCEP - US National Centre for Environmental Prediction

MAM - March to May

NEWU - National Early Warning Units

NIMET – Nigerian Meteorological Agency

NMHS - National Meteorological and Hydrological Services

NWPM - Numerical Weather Prediction Models

OND – October to December

SSTAs - Sea Surface Temperature Anomalies

SWFDP - Severe Weather Forecasting Demonstration Project

UKMO - United Kingdom Meteorological Office

WIFA - Weather Information for All

WMO - World Meteorological Organization

WCC-3 - World Climate Conference

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Thank you Lord for granting me abundant life and good health in all times; "Y*ou oh Lord is worthy of all praise, honour and thanksgiving. For when I was sick, you healed me. When I was discouraged and downcast, you lifted me up. When I felt hopeless, you encouraged me and gave me hope*". Glory is to your name for blessing this work.

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CHAPTER ONE

INTRODUCTION

This section of the study will give general background information to the study, some operational definitions used, statement of the problem, aim of the study and the specific objectives. The hypothesis, research questions and justification for the study are provided in this chapter as well.

1.0 Background of the study

Frequent climate variability in areas where farming is done depresses crop growth and productivity. Increasing climate variability and associated risk jeopardize crop production and further decrease farmer investment in the agricultural enterprise. Hence, knowledge and technology required for adaptation include understanding the patterns of current and projected climate variability. Adaptation practices require data and climate and weather information and agricultural systems at a spatial scale that is meaningful for planning. A good understanding of historical trends of climate variables and current climatic variability can provide a sound basis for assessing climate-related risks and identifying measures to reduce them (World Bank, 2010).

Food and Agricultural Organization (FAO) classifies the effects of climate change on African agriculture into two categories namely; biophysical (include changes in growing conditions and animal productivity arising due to rising temperatures and highly variable precipitation) and socio-economic which include falling incomes from agriculture, higher risks and greater vulnerability for the rural people due to changes in their livelihood and ultimately the slide to poverty) (Chemnitz & Hoeffler, 2011).

Climate variability is one of the main sources of uncertainty and risk in many agricultural systems around the world and the impacts are greater among communities with limited coping strategies. Since agriculture is at most weather-dependent human activity, production decisions directly or indirectly involve a consideration of climatic factors (Oram, 1989). Similarly, investments for the generation of climate-related information for planning and decision-making purposes need to be complemented by investments in customizing information for the final users that is the farmers and in effective dissemination channels that will facilitate timely access to climate and weather information by those who need it.

Ensuring household food security in rain-fed agricultural livelihood systems requires availability of climate and weather information that will reflect onset of seasonal rains and absence of the same in the production year. The use of climate and weather information in crop production planning and production process is fundamental if improved and sustained high wheat and maize yields are to be attained in a rain-fed agricultural system. Such information is critical in the determination of relative calendar of activities with respect to timing of farm preparation; planting; application of fertilizer as well as pesticides and herbicides control. Information on climate is concerned with indispensable climatic and weather elements including; precipitation, humidity, temperature, sunshine, cloud cover, wind and pressure as well as the soil moisture content. These data are useful for interpretation of physical processes in the lower atmosphere and upper soil layers, which are of great importance to agricultural production (Anuforo, 2009).

The necessary climate and weather information for appropriate planning of agricultural activities may include data and or information pertaining to (i) annual rainfall prediction and socio-economic implications information (this will indicate onset dates of the rainy season, cessation dates of the cropping season, length of the rainy season, total amount of rainfall expected for the season, and socio-economic implications of the expected rainfall pattern and advisories to farmers), (ii) annual climate review information which will contain observed changes in climatic parameters, (iii) Dekad (10 day) information on rainfall anomaly and amount, comparison of normal with actual rainfall, soil moisture condition, maximum temperature anomaly and its values; predictions of onset and end of growing season; weather data (rainfall, potential evapotranspiration, maximum & minimum temperatures) and, (iv) Farmers' guides which are handbooks that all investors in agriculture rely on for advisory on what to plant, where to plant, how to plant and when to plant. It contains the elements (onset and cessation dates of the rains, length of the rainy season, average annual rainfall (mm) (Lathore, 2006).

1.1 Definition of Weather and Climate

The terms are sometimes used interchangeably but do not mean the same thing altogether. The meteorological community tends to separate "weather" from "climate".

The Intergovernmental Panel on Climate Change (IPCC), the World Meteorological Organization (WMO) and the German Weather Service (DWD) share the same definition hence the IPCC defines “climate “as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years (Flotow & Ludolph, 2013). The term “climate” therefore, is always directed towards timeframes of several months. The term “weather“ on the other hand describes the physical state of the atmosphere at a certain time or within short timeframes ranging from minutes to about 15 days (Flotow & Ludolph, 2013).

This differentiation regarding different time horizons has respective validity for the differentiation between climate and weather forecasts and climate and weather information. Both terms (weather and climate) may be directed towards the description of states or changes in states of meteorological parameters in geographical areas of different sizes. The terms “meteorological data” or sometimes referred to as “monitoring data”, are used for historical weather or climate information without explicit reference to timescales in this thesis.

1.2 Global Climate Change

Evidence of climate change has been observed at global, regional and national levels over the past 100 years. There is a strong scientific consensus that the global climate is changing and that human activity contributes significantly to the changes experienced. Human-induced climate change is caused by greenhouse gas emissions from industry, transport, agriculture and other vital economic sectors (WMO, 2013). In spite of the complexity and degree of uncertainty of climate models and projections, data suggest that regional climatic variations and seasonal changes are expected to increase and be manifested in more vulnerable livelihoods and ecosystems, scarce water resources, heightened food insecurity, new health threats, weakened infrastructure and human habitats, among others (ITU, 2014). According to the contributions of IPCC Fifth Assessment Report, Working Group I; they identified that "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia.

The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentration of greenhouse gases has increased". According to ITC, 2014 report mainly quoted from the IPCC Fourth Assessment Report (AR4), 2007, greenhouse gas (GHG) emissions have increased by 70% between 1970 and 2004, mainly due to the combustion of fossil fuels. Scientific evidence indicates that with the current patterns of economic growth, global GHG emissions will continue to increase over the next few decades. Climate change is linked to changes in precipitation patterns, rain and drought periods, to an increase in average temperature and the frequency of hot days and hot nights, to an increase in extreme weather events such as intense tropical cyclones, heat-waves and heavy rainfall, to the decrease of mountain glaciers and snow cover areas around the globe, and to changes in seasonality and ecosystem processes, among others (ITU, 2014).

The IPCC Fifth Assessment Report indicates that “each of the last three decades has been successively warmer at the Earth’s surface than any preceding decade since 1850”. According to ITU, 2014 report, scientific evidence presented in the report also suggests that the average temperature of the earth’s surface (land and ocean) show a warming of 0.85°C, over the period 1880 to 2012. Temperature is expected to increase between 1.8°C to 4°C by the year 2100 if no action is taken. The same report reveals that in many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality. Glaciers continue to shrink almost worldwide due to climate change affecting runoff and water resources downstream (ITU, 2014 quoted from IPCC, 5AR 2013). Interactions among changes in rainfall, temperature, extreme climatic events, atmospheric carbon dioxide concentration and pests and diseases are largely unknown and could substantively affect impacts on crops and their yields in ways that are not yet understood.

1.2.1 Climate variability and impact on agriculture in Kenya

There is clear evidence that climatic variability has been manifested in Kenya just like many other regions of the world. At the regional level, analysis by the Intergovernmental Panel on Climate Change (IPCC) using general circulation models projects that East Africa will likely become wetter (Parry et al., 2012). Mean annual precipitation in East

Africa is projected to increase by 7 per cent by the decade of 2080 to 2090, though projections range from a decline of 3 per cent to an increase of 25 per cent particularly during the rainy seasons (Parry et al., 2012).

Analyses focused on Kenya project that a general decrease in mean annual precipitation will occur within the country, although wetter conditions are likely during the short rains of October to December (Parry et al., 2012; Funk et al., 2010; Gikungu, personal communication, March 29, 2012). Temperatures have risen throughout the country and rainfall has become irregular and unpredictable, and when rain falls, the downpour is more intense. Extreme and harsh weather is now a norm in Kenya. More specifically, since the early 1960s, both minimum (night time) and maximum (daytime) temperatures have been on an increasing (warming) trend. The minimum temperature has risen generally by 0.7 – 2.0^{o} C and the maximum by 0.2 – 1.3^{o} C, depending on the season and the region (GoK, 2010b).

With regard to rainfall, the most visible feature is the increased variability year to year, and during the year. The Kenya National Climate Change Response Strategy executive brief of 2010 reveals that there is a general decline of rainfall in the main rainfall season of March-May (the “Long Rains”) in the country. This means that drought in the Long Rains Season is more frequent and prolonged. Similarly, there is a general positive trend (more rains) during September to February. This suggests that the “Short Rains” (October-December) season is extending into what is normally hot and dry period of January and February (GoK, 2010b). These variations have caused major challenges in the agricultural sector where rainfall is the predominant parameter in crop growing and farmers have incurred losses in most periods.

Kenya's agricultural sector is vulnerable to climate variability and extreme weather events such as droughts and floods, the impacts of which have led to crop damage, food shortages, rising food prices and damage to the national economy. This vulnerability stems in part from the country's considerable inter- and intra-annual variability in rainfall and dependency on rain-fed agricultural production (Parry *et al*., 2012). Climate change is expected to adversely affect the stability of Kenya's agricultural sector with particular concern being raised regarding the vulnerability of the country's millions of smallholder farmers. The current understanding according to Parry *et al.*, 2012, points to the need for investment in adaptation measures such as development of drought-tolerant crops, income diversification, and improved access to climate and weather information, and conservation of water resources.

The National Climate Change Response Strategy 2010b suggests that the changing climatic (rainfall and temperature) patterns have had adverse impacts on Kenya's socio-economic sectors. Moreover, current projections indicate that such impacts will only worsen in the future if the world does not implement measures that result in deep cuts in anthropogenic Green House Gas (GHG) emissions, which are responsible for climate change (GoK, 2010b).

Although Kenya has put in place climate monitoring systems, the country's capacity for climate change is limited by inadequate data, the relatively short duration of available climate records and/or missing values in the records, as well as changes in instrument types and routines. These problems make it difficult to detect and attribute climate change signals (Ojwang *et al*., 2012). This means that climate change detection and attribution are mostly based on statistical analyses of past trends in rainfall, temperature, stream flow, lake levels, mountain glaciers, paleo-climatological records and variability in biomass production.

1.2.2 Provision of climate and weather information to farmers in Kenya

The Kenyan Meteorological Services provides comprehensive and specialized information for farmers that include rainfall data from over 32 stations country-wide. The Kenya Meteorological services explains further that in Kenya, there are two types of agro-meteorological stations referred to as Grade A and Grade B stations. Grade A stations are operated and manned by Kenya Meteorological Services (KMS) staff, while Grade B stations are run by other organizations like Ministry of Agriculture, Universities and Agricultural Research Institutions. Currently there are 13 agro-meteorological stations in the country (11 Grade A and 2 Grade B) (Kenya Meteorological Services, 2014).

The observations made in the 32 stations spread throughout the country are normal meteorological parameters that are measured on a daily basis and the data conveyed to the Agro-meteorological Section of Kenya Meteorological Services after every 10 days. The parameters include air temperature in degrees Celsius (maximum, minimum, wet bulb, dry bulb, dew point); soil temperature in degrees Celsius at 5, 10, 20, 30, 50, 100 cm depths; Sunshine duration in hours; radiation in mega-joules per meter square; wind speed in meters per second at 2 meters height; calculated relative humidity (%) at 0900 Hrs. and 1500 Hrs., pan evaporation in millimeters per day; calculated potential evapotranspiration in millimeters per Dekad (10 - day period) and rainfall in millimeters per day.

In addition, specific crop data is obtained from the 13 Agro-meteorological stations. The data include the variety of grown crop, stage of development attained by the crop, general assessment of crop performance, damage by pests, diseases and adverse weather, state of weeding in the farm, plant density and soil moisture together with 10-day summaries of crop and weather advisories. All these parameters are important information necessary for the farmers operation (Kenya Meteorological Services, 2014).

According to information available at Kenya Meteorological Services website, the expected yield of Kenya's staple crop (maize, wheat and beans) in the season is assessed visually at the end of each 10 days and along with the meteorological data from the 32 stations, the data is communicated to the agro-meteorological section of the Kenya Meteorological Services to facilitate crop-weather impact analysis. The crop data submitted in the report highlights the stage of crop development, general assessment of crop performance and yield expected (visual) from the farmers farms on the basis of what they see from nearby farms and oral interviews with farmers they come across from areas far from their reach.

1.3 Statement of the problem

Although climate scientists today are able to use sea surface temperatures as scientific indicators to forecast rainfall amounts of above normal, normal and below normal averaged over a period of three months; the primary climatic information needs of the farmers is knowing in advance the expected onset of seasonal rains so that they can prepare early in readiness for planting of the crops in their respective regions. The prevailing climate variability today brought about by climate change has distorted the order and seasons known to farmers over time. There has been a shift in seasons and rainfall variation from the norm making farmer's knowledge and experience difficult to comply with as the case has always been.

There is inadequate or non-access to climate and weather information to aid the farmers in their farming decisions at the farm level which further compounds the problem. According to the World Bank (2010), in many low and middle-income countries of the world, good quality climatic and agronomic data and information are lacking. Time series of climate information may not be available to planners and farmers, either because monitoring systems do not exist or may not function properly, or information is not readily coordinated, shared or disseminated in a timely way. The same is true for Kenya and its counties, Uasin Gishu included. The information may be available from the Kenya

Meteorological Services but may not be readily accessible to the farmers in the right format and time. The information has not been downscaled to meet the needs of farmers.

There is lack of a strong link that includes feedback loops between scientists, advisory agents and farmers in communicating crucial climate information. Facilitation of access to such information by the local communities that include farmers has been a major challenge as farmers usually do not know what climatic conditions to expect in the following growing season. They have evolved conservative cropping strategies based on their experience that not only may fail to capitalize fully on beneficial conditions prevailing then but also frequently buffer poorly against negative effects of climatic changes.

The use of climate and weather information in crop production planning and production process is fundamental if improved and sustained high wheat and maize yields are to be realised in Kenya and more particularly in Uasin Gishu county; the area of focus of the study. At the moment there is a major access challenge to climate and weather information by farmers in Uasin Gishu County. Farmers do not largely integrate climate and weather information in their farming decisions due to adaptability, format and timing challenges of the information. Where such information is available, it fails in quality in terms of its appropriateness for use by farmers. In most cases available information may be poorly channelled and its timing, format and modes of communication may not enhance farmers' planning and farming efficiency. There is therefore, a continued non-use ethic of the information at different farming stages among farmers in Uasin Gishu

County, which has resulted in farming systems that generally ignore the worth of climate and weather information to the detriment of the entire farming enterprise.

In the recent past, for example, frequent crop failures have plagued the region causing a general decline in maize and wheat production in most parts of the North Rift region, Uasin Gishu County included, due to erratic rainfall that has disrupted planting, growth and harvesting phasing. According to the Directorate of Agriculture in Uasin Gishu County, there were 3,378,000 bags of Maize produced in 2008 compared to 2,551,960 produced in 2009. Similarly in 2008, the county produced 1,021,215 bags of wheat compared to 349,472 bags of wheat produced in 2009. The 2009 long rain season maize production was about 1.84 million MT, which was 28 percent below normal (Kenya Food Security Steering Group, 2009). In 2012, maize production in Uasin Gishu County realized 343,795 tonnes while that of wheat production was 88,116.7 tonnes. This is in comparison with production in 2013 where maize harvest increased to 406,728 tonnes while that of wheat dropped to72, 962 tonnes (GoK, Uasin Gishu County Profile, 2013).

This study has been designed to help explore and understand the stated challenges discussed herein that include the apparent lack of requisite climate and weather information that is accessible to the farmer, and by extension how available information has been utilized or otherwise in determining the farming enterprises in the county with the aim of providing evidence based recommendations. Similarly, the understanding of the farmers experience overtime and their traditional knowledge system of weather prediction is important so as to be able to integrate both methods for the betterment of the farming enterprise especially with the prevailing climatic variability.

1.4 Aim of the study

The main goal of this study is to determine the access levels of climate and weather information and its usage by farmers in maize and wheat production. Understanding farmers experience in maize and wheat production is important as this can leverage the attainment of improved production of crops that depend heavily on rainfall hence being able to sustain lucrative crop production in Uasin Gishu County.

1.5 Objectives of the study

The main objective of this study is to determine the type, the accessibility and utilization of climate and weather information by maize and wheat farmers in Uasin Gishu County of Kenya. The specific objectives are to:

(i) Determine the types and sources of climate and weather information accessible to maize and wheat farmers in Uasin Gishu County of Kenya.

(ii) Identify the modes of communicating climate and weather information to farmers;

(iii) Determine the perception of the farmers towards using climate and weather information and the influence of their indigenous knowledge systems in maize and wheat production;

(iv) Examine the influence of climate and weather information in maize and wheat production in the County;

(v) Determine acceptability of use of mobile phone technology to relay climate and weather information to farmers in the community and

(vi) Develop a model to relay climate and weather information to maize and wheat farmers in Uasin Gishu County.

1.6 Research Questions

The study was guided by several questions. These are

(i) What are the types and sources of climate and weather information accessible to maize and wheat farmers?

(ii) What are the modes of information communication utilized to relay climate and weather information to the farmer?

(iii) What are the perceptions of farmers towards the use of climate and weather information?

(iv) Do farmers agree that there has been climatic variability in the recent years that has affected their crop production and what mitigation measures have they undertaken to minimize losses related to climate variability?

(v) How has farmer’s traditional knowledge systems in weather prediction influenced their farming decisions?

(vi) How has use of climate and weather information by farmers influenced their crop production outputs in the county?

(vii) Can maize and wheat farmers embrace use of mobile phone technology to receive climate and weather information in Uasin Gishu County?

1.7 Justification and significance of the study

Being able to translate climate data into applicable information for decision-making is crucial to the survival of maize and wheat farming practice in Uasin Gishu County. In agricultural production, climatic information is particularly relevant because farmers are bound by growing seasons and would like to have advance information about important climate factors such as rainfall, hail, temperature, wind and their extremes. While climatic information is expected to be used by the farmers, many National Meteorological and Hydrological Services (NMHSs) around the world have no adequate mechanisms in place to obtain user feedback hence help in meeting the farming community perceived needs. Greater feedback from the users in improving the dissemination and communication of climatic information is essential.

Climate and weather information can only be useful if it is timely and relevant to actions, which potential users can incorporate into production decisions to improve potential outcomes (wheat and maize) production. This study thus seeks to address such inherent challenges by leveraging the missing climate information link between the providers of climate information and the intended recipients who are the farmers. The study has explored all issues related to farmer's decision making to commence their land preparation, planting of wheat and maize and the relationship of this to the use of climatic information with the ultimate aim of integrating both scientific and traditional knowledge systems in production practices. This will facilitate realization of potential benefits from the farming enterprise as risks are mitigated through provision of timely climate and weather information.

Several country assessments of modes of climate information communication and dissemination to farmers in Southern African countries showed that there were still challenges in delivering such information to the farmers. The problems identified included weak dissemination and poor informational flow from meteorological service through extension workers to the farmers. Too much reliance on radio as a tool for information dissemination was felt to be inadequate for agricultural applications as farmers were not able to ask further questions regarding the information provided due to the ‘one-way’ nature of the communication device.

Timely issuance of climate and weather information remains a key weakness in climate information systems especially for communications passed on the National Early Warning Units (NEWUs) (Ziervogel, 2004). The same applies to the situation in Uasin Gishu County of Kenya. Farmers seem to rely on their experience over the years to set the farming calendar. There is weak dissemination and poor informational flow from meteorological service through extension workers to the farmers and the modes of communicating this information appears to be no longer favorable especially use of Radio, TV and newspapers in comparison with relaying the information through a farmers mobile phone.

The order of seasons known to farmers has been distorted over the last few years and more so during the 2009 period when the rains were completely erratic. There has been delayed onset of rains. In some instances, it has been erratic and inadequate. The unpredictable nature of such rains in a rain-fed agricultural system is catastrophic and has led to declines in the production of maize and wheat over the years compounded by unpredictable markets for the same crops. All the fore mentioned challenges requires that a farmer is adequately aware of such variations in advance to be able to make informed decisions on the farm through availability of climate and weather information delivered in a timely way.

The development of climate information communication model for effective relay of climatic information to farmers in the community with user feedback mechanism has come at the right time to support farmer's decisions. Communication of climate information to farmers is useful both at National and County levels as this will support policy in agricultural sector. Similarly, this study supports the National Climate Change Response Strategy 2010 which is focused on developing a comprehensive and robust adaptation and mitigation interventions to address the adverse impacts of climate change in the country. This strategy promotes integrating meteorological information into farming activities as a mitigation measure.

The model developed has the capability of using the Short Text Messaging to address not only climate and weather information but other farmer's challenges that may include delivering marketing and pricing information to the farmers in order for them to realize profits in their farming enterprise. This will also help address the impact of climate change in the agricultural sector in general as this model can serve other sectors of agriculture as well. The information derived from this study thus is useful to the farmers, the government in policy streamlining, the Meteorological Department and all the stakeholders in food security and livelihood enhancement sectors who may include the UN, Bilateral organizations, International NGOs, Local NGOs/Community Based Organizations and the private sector.

1.8. Scope and limitation of the study

This study was conducted in three Sub-County areas of Uasin Gishu County that exhibit maize and wheat production. There are other areas within the county who grow only maize meaning the survey did not cover them hence missing out on other potential concerns that would have been raised by farmers. This study is limited to climate and weather information as a significant factor of production now with the prevailing climatic variability. There are other factor that are important in high yield production in maize and wheat which this study did not address. Also, there are very few studies that have been conducted nationally on the same thematic area. In fact, most of the studies are pilot projects aligned to the global and regional scale and have been downscaled to the local situation. Use of mobile phone to relay climate and weather information is still at the pilot stage as well and gaining ground now as an emerging effective and efficient information dissemination channel that can access rural based population majority of whom are farmers.

1.9 Operational Definition of Terms

Climate: Climate in a narrow sense is usually defined as the 'average weather', or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The classical period of time is 30 years, as defined by the World Meteorological Organization (WMO).

Climate Change: Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

Climate system: The climate system is defined by the dynamics and interactions of five major components: atmosphere, hydrosphere, cryosphere, land surface, and biosphere. Climate system dynamics are driven by both internal and external forcing, such as volcanic eruptions, solar variations, or human-induced modifications to the planetary radiative balance, for instance via anthropogenic emissions of greenhouse gases and/or land-use changes.

Climate Prediction / Climate Forecast: The IPCC (2007b: 78) emphasizes the probabilistic nature of these terms: “A climate prediction or climate forecast is the result of an attempt to produce an estimate of the actual evolution of the climate in the future, for example, at seasonal, inter-annual or long-term time scales. Since the future evolution of the climate system may be highly sensitive to initial conditions, such predictions are usually probabilistic in nature.

Climate and weather information: Climate information as used in this study covers a broad spectrum of types of climate related information: Information about climatic conditions or changes in these conditions within a certain geographic area and timeframe. Other categories of climate information are empirical information on past climate or predictions on future climate. Both empirical information and predictions may refer to very different timeframes, ranging from months to years up to decades and centuries.

Shorter timeframes are covered by the term weather information. The information can be of spatial nature and can refer to climate of a country or of a single city, or, in the case of empirical information, to a single monitoring station. Similarly, the information may refer to a single climatic parameter, e.g. temperature, amount of precipitation and others or to multiple parameters. Further information, such as observed or predicted socio-economic impacts of changing climatic conditions, information on the individual climate-related vulnerabilities of natural or socio-economic systems, as well as information about recommended adaptation measures to those changes are all classified as climate information in a wider sense.

Climate information Service/Product: Climate services is the provision of climate products to assist user's decision-making and planning in climate sensitive activities while climate product is the result of a process of synthesizing climate data and information. Climate services encompass a range of activities that deal with generating and providing information based on past, present and future climate and on its impacts on natural and human systems. Climate services include the use of simple information like historical climate data sets as well as more complex products such as predictions of weather elements on monthly, seasonal or decadal timescales, also making use of climate projections according to different greenhouse gas emission scenarios. Climate information service may comprise empirical data and climate projections and also information on climate impacts and adaptation.

Rainfall: This is the main source of moisture supply to crops. Its onset & cessation dates help to determine the growing season and water requirement of the crop for efficient crop performance, while a good distribution enhances crop growth, development & yield.

Potential Evapotranspiration: This measures the rate of water loss (transpiration & evaporation) from short green crops/vegetation. It shows water availability for crop and therefore gives reliable hydrologic growing/potential growing season. It also aids planning with respect to irrigation in the event of water shortage.

Solar Radiation: Solar radiation provides the light required for photosynthesis and thermal conditions for normal physiological functions of plants. It also provides the energy used for evaporation and transpiration. Its amount and distribution sets limits for the dry matter production of crops.

Temperature: Biological and biochemical processes which determine crop growth and development are temperature driven, and so both the air and soil temperatures therefore affect all the growth and developmental processes of crops. Temperature also helps to determine the choice of cultivars given the close link between temperature and photosynthesis.

Weather: According to WMO, weather is the atmospheric condition at any given time or place. It is measured in terms of such things as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation. In most places, weather can change from hour-to-hour, day-to-day, and season-to-season. Definition 2; The term “weather “describes the physical state of the atmosphere at a certain time or within short timeframes ranging from minutes to about 15 days.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter gives an account of how climate and weather information utilization by maize and wheat growing farmers may help them avoid losses as a result of the prevailing climatic variability due to climate change phenomena witnessed globally and at the local level in the community. It is important to understand farmer's utilization of their indigenous knowledge in their farming calendar activities and how this can complement climate and weather information provided by national meteorological departments in an effort to mitigate the impacts of climatic changes on farmers growing rainfall dependent crops. The theoretical and conceptual framework underpinning this study is explored. The study is hinged on the three theories that support the idea of delivering information to support people in need hence changing their livelihood system. The theories are the systems theory, vulnerability adaptation framework and communications theory which have the underlying variable as dissemination of information to mitigate on the challenges experienced by the community of interest.

2.2 Overview

Agriculture practice is quite sensitive to any climatic variation thus it is the most vulnerable sector to inherent weather and climate risk. Risks affecting the agriculture sector can be minimized by making adjustments with the coming season through timely and accurate weather forecast (Zendera, 2011; Mannava *et al*., 2007). Accurate forecasts of weather 3–6 months ahead of time can potentially allow farmers in agriculture to make decisions in order to reduce unwanted impacts or take advantage of expected favorable climate (Hansen, 2002). Weather forecasts for agriculture can be grouped into short range, covering a period of 12-72hrs, medium range covering a period of 3-10 days and long range forecasts covering a period of a month to a season (Ramamasy, 2007).

Farmers and farming communities throughout the world have, in most instances, survived and developed by mastering the ability to adapt to widely varying weather and climatic conditions. However, the dramatic growth in human population is imposing enormous pressure on existing farming production systems. In addition, farmers are expected to manage the more insidious effects of long-term climate change that may now be occurring at an unprecedented rate against the very unfavorable economic scenarios of the last decades. Farmers have been struggling to maintain their income by continuously trying to increase yields in their production systems. Such increased productivity may be associated with increased economic and environmental risk as the farming system becomes more vulnerable to climate variability and climate change (World Meteorological Organization, 2014). Such existing pressures will demand the development and implementation of appropriate methods to address issues of vulnerability to weather and climate. These will be needed to assist farmers to further develop their adaptive capacity with improved planning and better management decisions.

More targeted weather and climate information can increase preparedness and lead to better economic, social, and environmental outcomes for farmers. However, weather and climate forecasting is just one of many risk management tools that play an important role in farming decision-making. More effective approaches to the delivery of climate and weather information to farmers may need the incorporation of a more participatory, cross-disciplinary approach that brings together research and development institutions, relevant disciplines, and farmers as equal partners to reap the benefits from weather and climate knowledge (World Meteorological Organization, 2014).

In South East Asia and many other countries of the world for example, Hansen (2002) argues that information on climate variability and change is not readily available or widely used at the community level by non-governmental organizations up to the national and regional levels. Typical weather and climate information dissemination systems generally follow linear, top-down approaches, in which the information is released without considering who the end users are, how they will be using the information, and the time frames and contexts within which they need the information to be communicated.

Climate and weather information is often released without conveying the probabilistic nature of the forecasts, for example the range of likely variability in a seasonal forecast of the Indian Ocean monsoon. In his observation and analysis, Hansen (2002) reveals that the prerequisites for potential benefits of meteorological and climatological forecasts if they are to be realized by farmers include first ensuring that these types of forecasts have to address a need for farmers that is ‘real and perceived’. Climate and weather forecasts have to be a relevant component of the climate or weather system at an appropriate farming spatio-temporal scale. Importantly, Hansen points out that the benefit also depends on the existence of decision options for the farmer which are sensitive to the particular incremental information that the forecasts provide and which are compatible with the farmer’s goals (Hansen, 2002).

2.3 Policy context on climate change and climate information in Kenya

The basis of a climate change governance framework stems from the provisions of the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC and corresponding Kyoto Protocol put the onus for early action on industrialized countries, citing common but differentiated responsibilities for their participation (Heinrich Böll Stiftung, 2013 cited from Ashton *et al.,* 2003). Climate change governance also calls for action that shifts societies towards establishing active mitigation and adaptation policy regimes that confront and prepare for the impacts of climate change. To signify its commitment to address the issue of climate change, Kenya ratified the UNFCCC in August 1994 and the Kyoto Protocol in February 2005.

Kenya has been integrating climate considerations into various legal and governance instruments for some time. Notably, there has been progress made in planning and implementing policies, projects and programs in key economic sectors in order to align Kenya with the international community’s approach to reducing greenhouse gas emissions and promote climate resilience. The scope of climate change governance is reflected in various policy and regulatory frameworks that guide the coordination of various sectors dealing with management of climate sensitive natural resources. According to the Kenya National Climate Change Action Plan, 2013, significant efforts have been taken to commence Kenya's policy response to climate change, including the development of the National Climate Change Response Strategy (NCCRS) in 2010 which is focused on developing a comprehensive and robust adaptation and mitigation interventions to address the adverse impacts of climate change in the country.

Agriculture's vulnerability to climate change is also addressed in the government's National Climate Change Response Strategy of 2010. This strategy promotes integrating meteorological information into farming activities. Similarly, the development of the National Climate Change Action Plan (NCCAP) 2013 – 2017, will help in the implementation and operationalization of the NCCRS 2010. The process is on-going for the development of a Climate Change Policy and mainstreaming climate change into Vision 2030 especially it's Mid Term Plan (MTP) 2013 – 2017. This has increased recognition of climate change as a development challenge and policy priority, and has resulted in the establishment of several climate change-related institutions and policy instruments albeit fragmented.

The enactment of the Environmental Management and Coordination Act, No. 8 of 1999 (EMCA); the key legislative authority on environmental coordination and management in Kenya is in place. The development of a National Environment Policy, in its 5th draft as of July 2012, and the development of Kenya Climate Change Authority Bill 2012, a private members Bill that was presented to Parliament in 2012 are some of the policy instruments being finalized by the Government (Heinrich Böll Stiftung, 2013; GoK, 2013). Although the Constitution, Vision 2030 and the Environmental Management and Coordination Act (EMCA 1999), provide some legal foundation for climate change, more specific policy and legislative instruments are required that effectively acknowledge the severity of potential climate change impacts and address the importance of climate change response (GoK, 2013). Government bodies established to coordinate Kenya's response to climate change include the National Climate Change Activities Coordinating Committee, the Environment and Climate Change Coordination Unit and the Climate Change Secretariat, which is housed within the Ministry of the Environment and Mineral Resources (MEMR) (Parry *et al*., 2012). While MEMR has lead responsibility for coordinating and supervising climate change efforts across government, numerous other ministries and parastatal organizations are also actively engaged in climate change actions.

2.3.1 Climate Change Authority Bill 2012.

This is a legislation to provide a framework for coordination, mitigation and adaptation to the effects of climate change on various sectors of the economy through the establishment of an authority and to provide for the development of response strategies to the effects of climate change. According to Heinrich Böll Stiftung (2013), the proposed Bill weaves together the institutional and conceptual issues of reduction of Green House

Gas (GHG) emissions at a national level, as well as provides mechanisms for the financing, coordination and governance of matters of climate change. The proposed Authority will advise the National and County governments on legislation and other measures on mitigation and adaptation to climate change, including emission reduction targets; coordinate between government and non-state actors on issues of climate change, among other functions, including carrying out public awareness programmes; and manage a climate fund, which is proposed within the Bill to facilitate the development of climate change projects. The various national climate change actions are geared towards addressing the drivers of vulnerability, building response capacity, managing climate risk and planning for extreme events.

2.3.2 Climate information flow in Kenya

Within Kenya, historical climate data, forecasts and information is provided through the Intergovernmental Authority on Development Climate Prediction and Applications Centre (ICPAC). ICPAC supports the national and regional climate risk reduction strategies of seven countries in the Greater Horn of Africa (Djibouti, Eritrea, Ethiopia, Kenya, Somalia, Sudan and Uganda), and facilitates access to climate information by Burundi, Rwanda and Tanzania (Parry *et al*., 2012). The Regional Centre collects, processes, stores and offers access to climate and remote-sensing data, provides early warning of climate-related hazards, identifies climate change adaptation options, and supports capacity-building in the generation and application of climate tools and information. It monitors past climate parameters (including temperature and rainfall) in the Horn of Africa on 10-day, monthly and seasonal time scales in order to detect historic anomalies, and it monitors and assesses current climatic conditions and predicts conditions based on statistical models for these same time scales (ICPAC, 2014).

The Kenya Meteorological Services (KMS), which is housed within Ministry of Environment and Mineral Resources, is responsible with disseminating climate and weather information to the stakeholders in the country. The reliability of KMS's forecasts, including seasonal forecasts, has increased in recent years, and they are generally accurate (Parry *et al*., 2012 cited from Ndegwa *et al*., 2010). Continuous improvement, though, would address emergent concerns such as human resource constraints, restricted capacity to collect and disseminate data, the need for greater real-time data collection and transmission and a lack of regional modeling capacity. The Central Bureau of Statistics, the Department of Resource Surveys and Remote Sensing and a variety of institutions outside of government collect and analyze this data. However, their work remains largely uncoordinated, and gaps remain in the availability, accuracy and accessibility of such data (Parry *et al*., 2012 cited from GoK, 2008).

2.4 Empirical Review

The Global Humanitarian Forum and World Meteorological Organization report of 2012 indicated that approximately 70% of African population (close to 700 million) people rely on farming for their livelihood and over 95% of Africa's agriculture is rainfall dependent. With the prevailing changes in weather patterns due to climate change, traditional knowledge relating to agriculture otherwise reliable for centuries could be rendered obsolete. This has created a great need for climate and weather information to be delivered to those engaged in farming activities. Similarly, a recent Global Humanitarian Forum report estimated that climate change is responsible for some 300,000 deaths each year and over 100 billion US dollars' worth of economic losses, mainly because of shocks to health and agricultural productivity. Sub-Saharan Africa largely accounts for close to a quarter of these losses, and is the region at the most immediate risk of droughts and floods. Agricultural yields in some areas are expected to fall by 50% as early as 2020 (GHF, 2012).

According to the IPCC, 2001, the projected changes in Africa for the coming decades which could have serious consequences for agriculture include: Temperature increases of +0.2 to +0.5°C per decade, with the greatest warming in interior regions, increases in the occurrence of extreme values for rainfall and temperature, increased variability and decreased reliability for rainfall. Although the magnitude of projected rainfall changes for 2050 is small in most African areas, it may be up to 20% of baseline values. These projected changes could lead to significant decreases in crop yields in some rainfed African agricultural systems, with overall crop yields potentially falling 10–20% by 2050 because of warming and drying. However, this effect will not be uniform – yield losses may be much more severe in some places, while crop yields may increase in others. It may also likely yield increased water stress, coupled with the expansion of arid and semi-arid areas, limiting possibilities of using agricultural expansion to offset lower yields per hectare (CAADP, 2013 cited from IPCC, 2001).

To demonstrate clearly the impact of climate variability on maize and wheat production globally, CCAFS outlined some factual information that will help crystallise this phenomena. The Consultative Group on International Agriculture (CGIAR) research programme in Climate Change and Food Security (CCAFS, 2014; Lobell & Field, 2007) reveal that through historical studies, climate change has already had negative impacts on crop yields. Maize, wheat and other major crops have experienced significant climate-associated yield reductions of 40 mega tonnes per year between 1981 and 2002 at the global level.

The Intergovernmental Panel on Climate Change (IPCC) consensus on the other hand argues that at mid- to high latitudes, agricultural productivity is likely to increase slightly for local mean temperature increases of 1 to 3 degrees Celsius. In tropical areas, there will be productivity decreases. On the other hand, there will be major spatial and temporal variability based on Global aggregate figures derived from using a mean of two climate models and two climate scenarios. Maize production is projected to increase 18% in Kenya but fall 9% in Uganda in the period 2030 (Thornton, 2010).

Yields of maize and wheat are sensitive to temperatures above 30 degrees Celsius. For example, each day above 30 degrees Celsius in the growing season reduces the final yield of maize by 1% under optimal rain-fed conditions and by 1.7% under drought conditions (Lobell, 2011). On the same phenomena, results from simulations of a warmer climate (4 degrees Celsius or more in Africa) indicate that projected increases in the length of the growing period projected for parts of East Africa will not necessarily translate into increased agricultural productivity but rather; maize yields are projected to decline by 19% despite longer growing periods (Thornton, 2011). Due to climate variability, the likely challenge of pests and diseases in the current production areas will be real. Pests and disease that were once minor problems can turn into major constraints and change their range of distribution with climate change hence causing further destruction to livelihoods.

2.5 Types and sources of climate and weather information for farmers

Despite the availability of relatively reliable weather and climate information and products by the late 1990s, farmers seldom use these for farm level decision-making (Hansen 2002; Hammer *et al*. 2001). This is mainly due to lack of adaptability of the information to the locality and difficulties in accessing the information on time and in a format that farmers can easily understand.

During the third World Climate Conference (WCC-3), held from 31 August to 4 September 2009 in Geneva, the declaration saw the establishment of a Global Framework for Climate Services to strengthen the production, availability, delivery and application of science-based climate prediction and services. Climate services in this context is the provision of climate products or climate information to assist user's (farmers) decision-making and planning in climate sensitive activities such as maize and wheat growing.

There are several categories and types of climate information products and services existing in the countries for agriculture and food security support. According to Kadi

(2011); KMS, (2014) the types or products include daily weather forecasts; dekadal agro-meteorological bulletins; monthly climate outlooks; seasonal climate outlooks; climate alerts; observed climate impacts; and tailored information for users (farmers) including various types of climate mean maps on different parameters. The products have been explained more as follows:-

2.5.1 Tailored information for farmers

This is type of information is normally given out on request according to the Kenya Meteorological Services. The major clients for this information are Agricultural Commercial Farmers, Insurance Companies and Community Based Organizations. Some of the climate information required includes onsets and cessation dates for localized places, distribution of rains including amount and time, climatological maps, climate change vulnerability assessment maps; observed climate change indices for specified places, and advice on types of crops to be grown for particular regions among many others.

2.5.2 Daily Weather Forecasts

These are weather forecasts that are issued out to the agricultural communities and general public on a daily basis. They normally contain detailed likelihood of forecasts (possibility of showers and temperature) for the following day for every region in Kenya. They also include detailed daily weather statistics (usually for the previous day), including temperature and precipitation. The information product is usually presented in Newspaper caption, Television and Radio (weather forecast around the country).

2.5.3 Dekadal (10-day) Agro-meteorological Bulletins

The bulletin contains observed climate statistics for the previous 10-days over the country. The statistics include spatial and temporal performance of rainfall within the country, temperature, relative humidity and winds among others. It also gives report on the stage of crop development, general assessment of crop performance and yield expected (by observation) from the farms and some face to face interviews with farmers by Agro- meteorological observers from the 14 Kenya Meteorological Services stations across the country. Other crucial information on general assessment of crop performance is obtained from county Agricultural Officers and the weather forecast for the next ten days provided as well.

2.5.4 Monthly Climate Outlooks

The weather forecast is given out monthly to farmers in all regions of the country. It gives the monthly updates of the rainfall and temperature performance for every climatological zone in the country. It contains statistics on the observed weather parameters like rainfall and temperature against long-term mean. It also gives out probabilistic outlook for the next month in three categories (Above normal, Normal and Below normal) in order to detect the evolution of any significant anomalies that could impact negatively on the socio - economic activities of the region

2.5.5 Seasonal Climate Outlooks

They are weather information products that are given out to the farmers and general public during the three rainfall Seasons of March to May (MAM), June to August (JJA), and October to December (OND) in Kenya. The forecasts have been very crucial in the detection of the evolution of any significant anomalies that could impact negatively on the socio - economic activities of the country. Seasonal Forecast is the downscaled seasonal climate consensus forecast issued by IGAD Climate Prediction and Applications Centre (ICPAC) and NMHSs in liaison with Global Production Centers (GPCs), International Research Institute for Climate and Society (IRI), UK Meteorological Office, the European Centre for Medium-Range Weather Forecasts, among other partners.

The forecast according to Kenya Meteorological Services outlook press release for March to May 2014 is based on the prevailing and expected Sea Surface Temperature Anomalies (SSTAs) over the Pacific, Indian and Atlantic Oceans as well as other Synoptic, Mesoscale and local factors that affect the climate of Kenya. These factors were assessed using various tools including ocean-atmosphere models, statistical models, satellite derived information and expert interpretation (KMS Seasonal Outlook (MAM), 2014).

Expected seasonal rainfall distribution is information contained in the seasonal outlook. Similarly, the distribution, both in time and space, for March to May 2014 “Long-Rains” is provided. Expected onset and cessation date, potential impacts as per sector, weather review for the preceding season October-November-December (OND) 2013 “short rains” season, observed conditions during January-February 2014 and the experienced impacts then. In Figure 2.3, seasonal rainfall distribution is given for the country whereas in Figure 2.4, the probabilistic outlook for the next month in three categories (above normal, normal and below normal) is given. This helps in detecting the evolution of any significant anomalies. In Figure 2.5, expected onset of rainfall for March-May 2014 season is given while Figure 2.6 gives expected cessation dates for March-May 2014 seasonal rainfall.

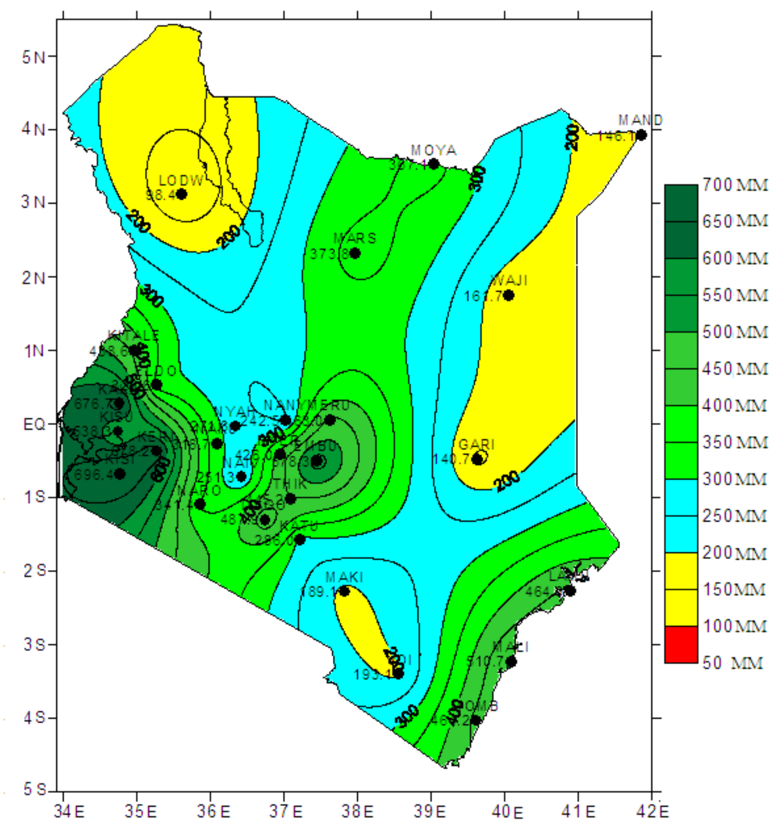


Fig. 2.1: Mean March-May 2014 seasonal rainfall

(Source: Kenya Meteorological Services, 2014)

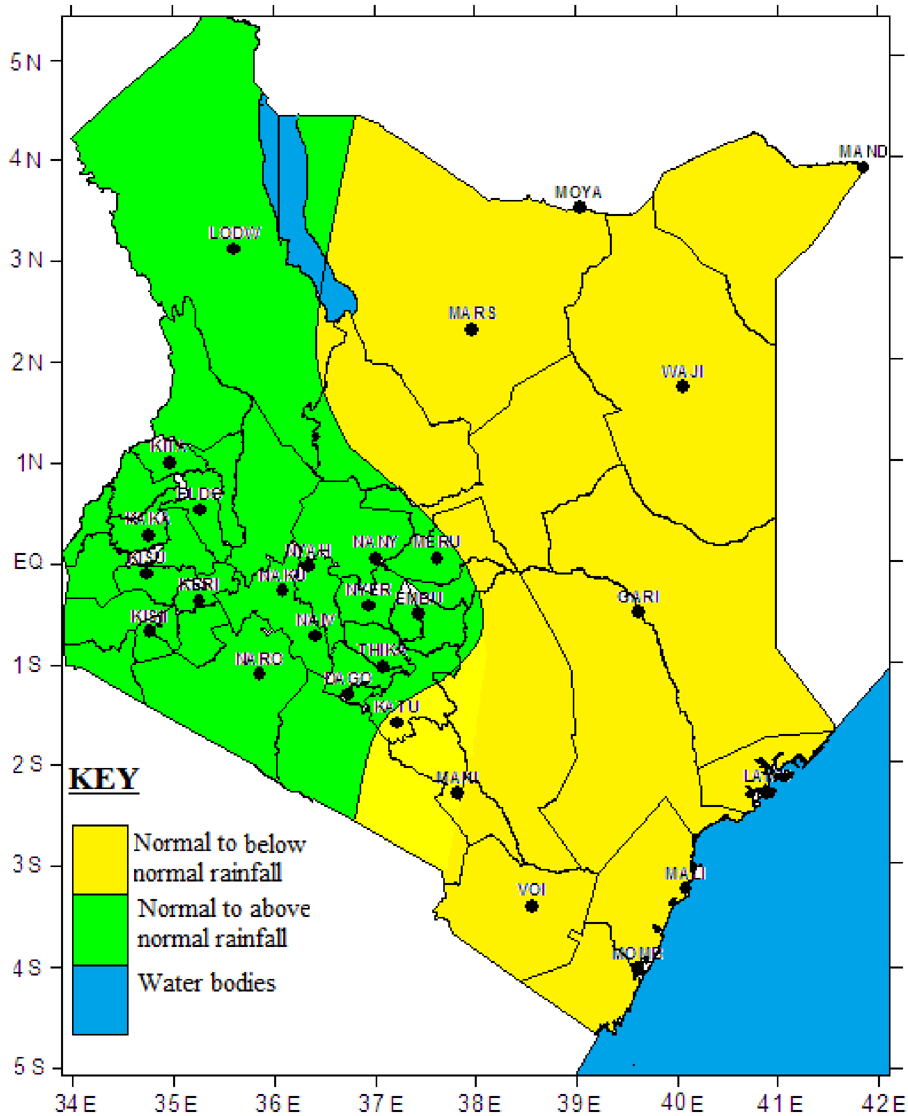


Fig. 2.2: March-May (MAM) 2014 seasonal rainfall

(Source: Kenya Meteorological Services, 2014)

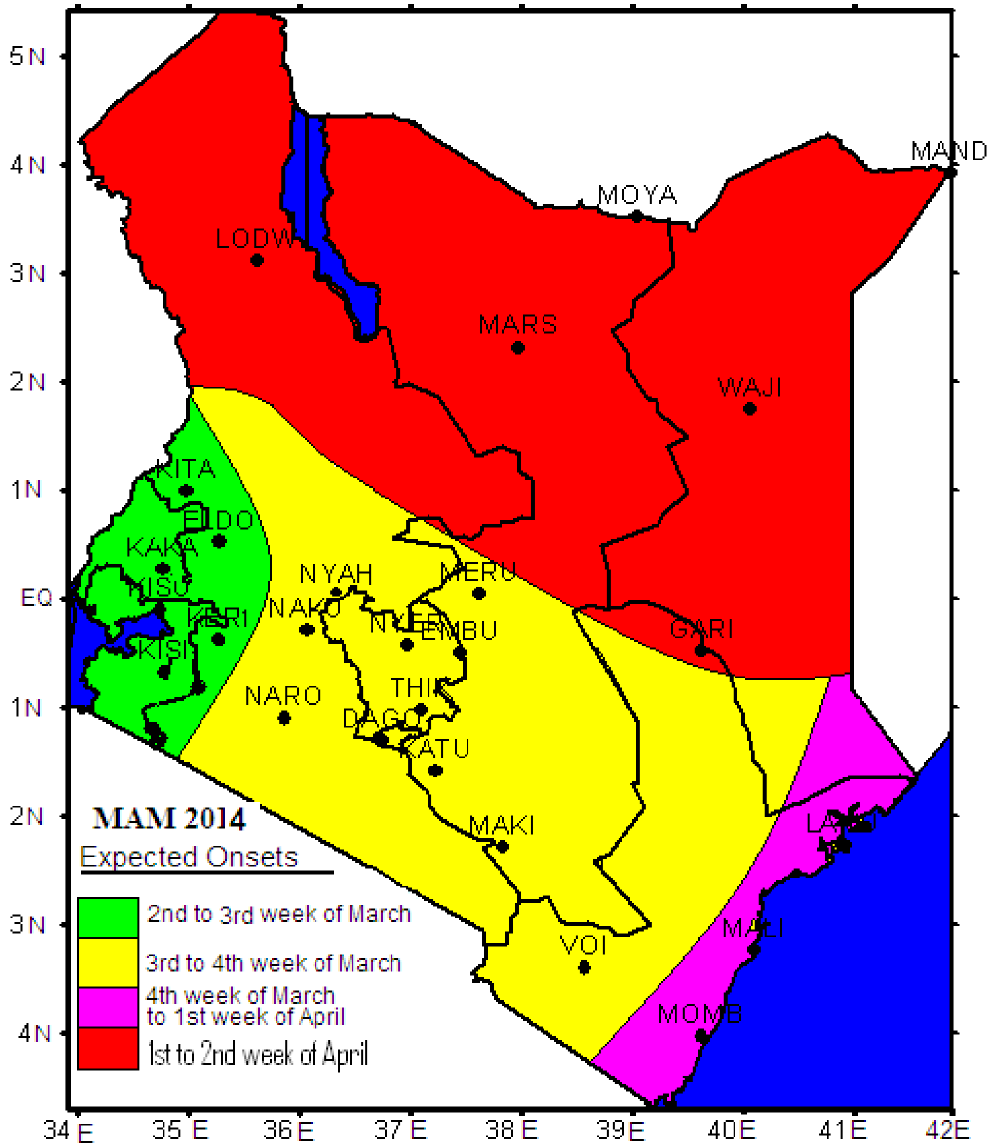


Fig.2.3: Expected March-May 2014 seasonal rainfall onset.

(Source: Kenya Meteorological Services, 2014)

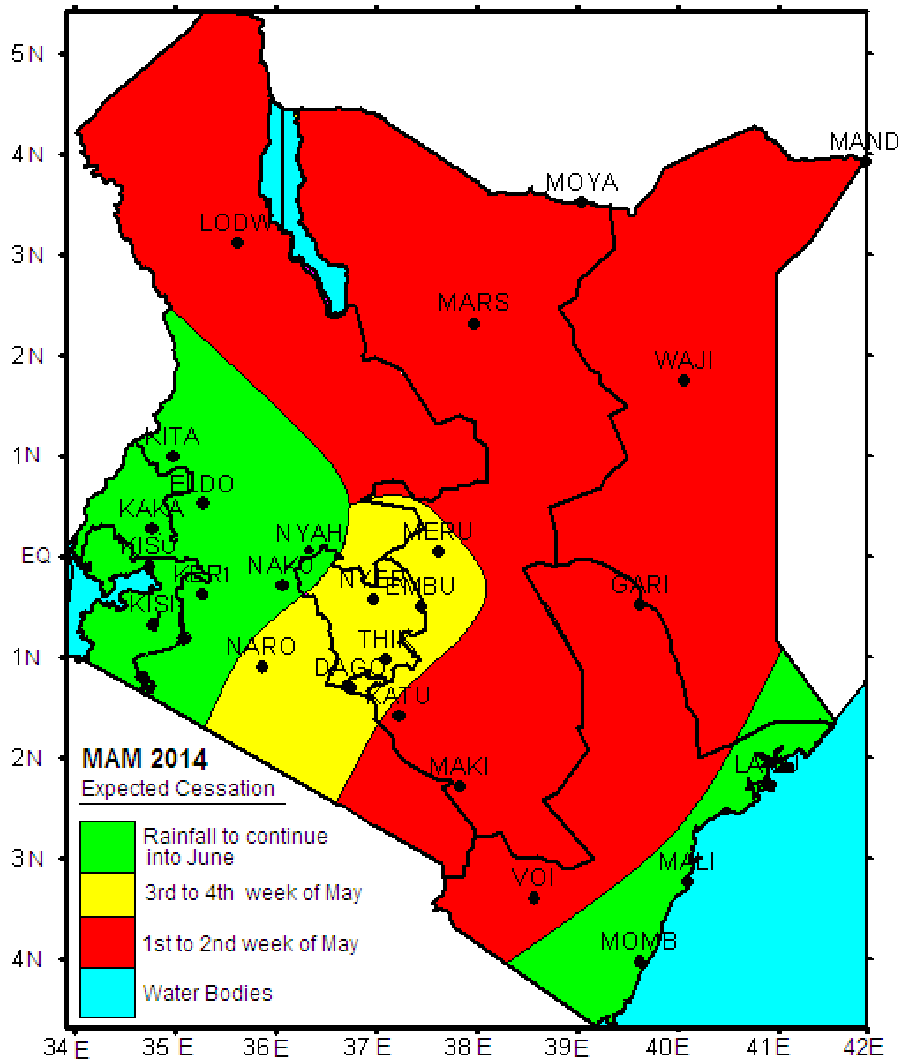


Fig. 2.4: Expected March-May 2014 seasonal rainfall cessation

(Source: Kenya Meteorological Services, 2014)

A World Bank report, (2010) guidance note 6 illustrates that seasonal forecasting can greatly assist in managing climate risks in agriculture, particularly in risk-prone rain-fed environments, by providing planners and farmers with timely information, which allows them to decide upon and shift to the most suitable coping strategies over short time scales. The report explains further that the usefulness of seasonal climate forecasts will largely depend on the capacity of farmers and agricultural extension workers to access and utilize climate information and react upon it in a timely manner. Input and feedback from forecast end-users (farmers) and relevant institutions are crucial to ensure that societal or farmer’s needs are addressed. At the same time, forecasts need to be understandable, credible and trusted in order to have a positive impact. This could be achieved by designing participatory farmer workshops that help farmers become familiar with, better understand and use of weather and climate information.

2.5.6 Climate Alert Bulletins

These are alerts normally given out when the need arises. The climate alert bulletin provide climate updates as well as timely information on major regional climate stress and impacts associated with extreme climate events such as drought and floods. Some of these climate extremes have been associated with El Niño / La Niña events. It also spells out cumulative associated impacts of previous extreme climate events that are similar to what is evolving (KMS, 2014).

Other products that may be relevant in agriculture and other sectors that have been produced and used in many countries include observed climate change signals; climate change vulnerability assessment maps; advisories/alerts on extreme climate/weather events such as droughts and floods; climatological maps; agro-ecological maps; seasonal distribution maps of onset and cessation of rains; length of growing period maps; maps on chances of dry and wet spell of given lengths; maps on rainfall variability during different seasons; and climate atlases.

2.6 Sources of climate and weather information

The sources of climate and weather information can either be Institutions who may be originators of the information or help in relaying the information and can also be attributed to the media used to relay such information. The institutions that provide climate information products and services include the countries National Meteorological and Hydrological Services (NMHSs) and the IGAD Climate Prediction and Applications Centre (ICPAC) located in Nairobi, Kenya among other institutions in the eastern Africa region. African Centre of Meteorological Applications for Development (ACMAD) also issue dekadal and monthly climate watch bulletins covering the Region (Kadi, 2011).

In Kenya, the farmers get climate information from extension services, daily radio, television, newspapers (Media) and through community interactions whereby fellow farmers share climate and weather information they have come across during their daily routines. According to Kadi, 2011, experience has shown that the majority of farmers prefer indigenous forecasting knowledge more than contemporary forecasting. Their reasons are that indigenous information is more compatible with local culture and it has been tested, tried and trusted. In addition, it is more specific and is in a language that can be understood better by communities passing clear message that integration of indigenous forecasting knowledge into science based climate forecasting will promote effective use and create ownership by communities.

2.6.1 Institutions and organizations generating climate and weather information

The climate and weather information providers are organization established as regional, sub- regional intergovernmental organizations by State governments or at national level by government for the sole purpose of carrying out meteorological and related functions for the benefit of its citizens. The providers of climate and weather information used in Kenya and the East African region are the National Meteorological and Hydrological Services (NMHSs), IGAD Climate Prediction and Applications Centre (ICPAC) and African Centre of Meteorological Applications for Development (ACMAD). ACMAD also issue dekadal and monthly climate watch bulletins covering the Region

2.6.2 IGAD Climate Prediction and Applications Centre (ICPAC)

IGAD Climate Prediction and Applications Centre (ICPAC) is a specialized institution of the Intergovernmental Authority on Development (IGAD) working with the National Meteorological Services, World Meteorological Organization (WMO) and other partners to address regional challenges of climate risks including climate change headquartered in Kenya (ICPAC, 2014). The climate and weather information products produced include: Ten day, monthly and seasonal climate/weather bulletins, climate watch/El Niño updates, and annual climate summaries. The organization produces tailor made forecast depending on requests, perform analysis to predict onset and cessation dates and probability of dry and wet spells during the season, (ICPAC, 2014).

2.6.3 African Centre of Meteorological Applications for Development (ACMAD)

African Centre of Meteorological Applications for Development (ACMAD) is a continental Centre which came into being after the devastating droughts associated with famines of the 1980s in sub-Saharan Africa. It was created in 1987 by the Conference of Ministers of the United Nations Economic Commission for Africa and the World Meteorological Organization (ACMAD, 2014). The organization handles provision of weather and climate information for the promotion of sustainable development of Africa (notably within the context of national strategies for poverty eradication), in the fields of agriculture, water resources, health, public safety and renewable energy. It handles early warning system (EWS) across the African continent. ACMAD runs projects aimed at strengthening African NMHSs and regional Centers' capacities to improve their climate services to meet the increasing demand of users especially in agriculture and food security. The projects being conducted by ACMAD targeting the Eastern Africa include ClimDevAfrica and VIGIRISC:

2.6.4 ClimDevAfrica

Climate for Development in Africa (ClimDevAfrica) is a joint initiative of the African Development Bank (AfDB), the Commission of the African Union and the United Nations Economic Commission for Africa (UNECA). The program was established to create a solid foundation for Africa's response to climate change due to its vulnerability to the adverse impacts of climate change and the apparent lack of appropriate climate-related information and underdeveloped policies on the effective use of the climatic information. The project supports among others, the implementation of adaptation and mitigation programs and projects that incorporate climate-related information to facilitate adoption of evidence based climate change adaptation and mitigation measures. The objective of this Climate Risk Knowledge Management project (AfriClimServ) is to strengthen the capacities of African regional climate centres to generate and disseminate climate information to support economic development in the continent.

2.6.5 VIGIRISC

The ACMAD project also known as African Early Warning and Advisory Climate Services (AEWACS) has focus on adaptation of African countries to climate variability and change by delivering Early Warning Systems (ACMAD, 2014).

2.6.6 Kenya Meteorological Services (KMS)

One of the many functions of KMS is the provision of meteorological and climatological services to agriculture and other allied sectors. Some of the products produced by KMS and touches on crop production include: Daily weather forecasts for rainfall, temperature and areas expected to experience thunderstorms, which may be accompanied by strong winds and in some instances hailstones that can affect crops; Five day forecast containing information on how the weather performed during the last 5 days and how it is expected to be in the next 5 days; Monthly forecast containing review of the current month and the expected conditions during the coming month. The summarized contents of the forecast are; rainfall performance for the month under consideration, prevailing synoptic situation during the month, impacts experienced during month on various socio-economic sectors (KMS, 2014). The short duration forecasts (5 and 10 days) are used in the management of short term agricultural planning activities such as planting, drying grains, applying fertilizer and insecticides (KMS, 2014).

Seasonal Forecast is the downscaled seasonal climate consensus forecast issued by ICPAC and NMHSs in liaison with Global Production Centers (GPCs), IRI, UK Met Office, the European Centre for Medium-Range Weather Forecasts. The forecast is not deterministic but probabilistic and works on the chance of monthly rainfall totals falling into a specified category. Rainfall is predicted to be either below normal, normal or above normal. Seasonal forecasts are based on one of two methods. The numerical approach uses General Circulation Models (GCMs), integrated with sea surface temperatures to give a prediction of how much rain there will be for up to 50 days ahead. The other method uses statistical analyses of past rainfall data. Historical rainfall records are statistically analysed for trends and multi-annual variability that can account for 30% of the rainfall variability (Ziervogel, 2011) as cited in (Washington & Downing 1999).

The KMS also provide Agro-meteorological services (10-Day Bulletin). In all the 13 Agro-meteorological stations of KMS normal meteorological parameters are measured on daily basis and the data is conveyed to the agro-meteorological Section of KMS after every 10 days. The compiled information is released to various users via the Dekadal Crop and Weather Bulletin. The Department gives special alerts when some unexpected event may or a post-mortem of an unusual event if it has occurred. The El-Niño

Command Post set up in 2009 help in issuing El Niño La Niña alerts to the users of the information.

2.6.7 RANET-Kenya

RANET network is being used in communicating weather and climate information to communities. The RANET-Kenya project is based at the Kenya Meteorological Services (KMS) and is part of the global RANET project. It is a rural communications project that seeks to transmit vital weather and climate information to rural communities using Internet and Radio. To achieve this goal, KMS is working with many partners such as government departments, NGOs and CBOs operating in the local communities, addressing challenges that affect them particularly in food security and poverty reduction. There are five installed weather broadcasts and internet stations in Budalangi, Kangema, Suswa, Matuga and Luanda areas in the Country. They broadcast in vernacular languages. Uasin Gishu County is looking for ways to adopt the RANET Model as well (Ramtu, Personal interview, 15 May 2015).

2.6.8 Kenya Food Security Steering Group

The KFSSG acts as a technical and advisory body to all relevant stakeholders on issues of drought management and food security in the country. The steering group provides effective guidelines on methods and approaches for the coordination of both information and appropriate response measures. KFSSG being a multi-agency committee is chaired by Office of the President and World Food Program as co-chair. In attendance of KFSSG meetings are the Department of Drought & Disaster Emergency Response Coordination, Ministry of Livestock development, Ministry of Agriculture, Water Resources, Health, Works, Fisheries and international organizations including WFP, UNICEF, DFID, EC, Oxfam, and Doctors without Borders – Spain. Others are USAID/FEWS, WFP-VAMS, UN OCHA and World Vision (Kadi, 2011).

Seasonal Forecast is given to the Office of the President, similarly, monthly forecast updates and weekly updates is done when extreme events occur such as floods. Once these products are given, a local level analysis is done to produce an early warning bulletin. KMS gives briefs to Office of the President on monthly or weekly basis as need arises.

Other organizations do produce climate and weather information in some instances. The UN and NGOs dealing with food security are of interest. They include Famine Early Warning System Network (USAID/FEWS NET), World Food Program's Vulnerability Analysis and Mapping Unit (WFP-VAMS), UN OCHA UN FAO's Global Information and Early Warning System (GIEWS) and others.

2.7 Farmers perception on climate and weather information use and the influence of indigenous knowledge systems in maize and wheat farming

There is evidence that substantial gain to sustainable food security and national development adaptation strategies can be achieved in Africa through provision and integration of improved climate information and prediction products into decision-making systems (Kadi, 2011). Accurate monitoring, prediction and early warning of seasonal rainfall performance can be used to improve planning and management of various rainfall dependent socio-economic activities like agriculture and the same can be used to enhance the livelihoods of the communities and services and support their resilience to adverse weather conditions.

Information from literature obtained in Anuforo, 2009 has demonstrated that adequate use of climate and weather information conditions by farmers' results in at least 30% increase in crop yields. The utilization of this information reduces farmers' vulnerability to weather related risks, ensures that informed decisions are made on time, and reduces the risk of agricultural losses as well as indicating to farmers the most marketable crop in respective times.

Access to climate information and technologies for adaptation is, therefore, essential to enable actors to anticipate long–term risks and make the appropriate adjustments to increase their resilience. However, despite significant scientific gains in predicting the climate, often there is a lack of climate information available at the local level due to uncertainty in climate projections and seasonal forecasts, or due to lack of information on particular climate indicators, such as rainfall variability (Bryan & Behrman, 2013) cited from (Roncoli *et al*., 2002; Hulme *et al*., 2005; Vogel & O'Brien, 2006). Even when climate information is available, incorporation of scientific climate information into local decision making may not often occur because of the way such information is communicated and disseminated (Vogel & O'Brien 2006). Several studies have shown that there is a need to make climate information more accurate, accessible, and useful for rural communities (Bryan & Behrman, 2013 cited from Hansen *et al*., 2007).

2.7.1 Utilization of downscaled weather and climate information

Agriculture in Kenya's ASALs is being adversely affected by increasingly unpredictable weather, compounding farming communities' vulnerability to food insecurity and declines in human and animal health. These conditions present a growing challenge for development in these regions. To enhance the resilience of ASAL farmers to drought, a pilot project was launched in 2006 in the community of Sakai, located in Mbooni East District. One of its objectives was to improve the provision of downscaled weather information to farmers through a partnership between ICPAC, KMS, the government's Arid Lands Resource Management Project and the Centre for Science and Technology Innovations.

In the past, KMS had delivered information in a manner that farmers were not able to understand. Through the partnership, projections regarding the likely onset, cessation and distribution of the rains, and whether rainfall levels would be above normal, normal or below normal, were translated into agronomic advice for rural farmers (e.g. crop selection, timing of planting and spacing of seeds). This information was delivered to Sakai farmers through radio, printed brochures and agricultural extension workers in an understandable language and in a way that was relevant to their agronomic needs. As a result, farmers were able to make more informed farming decisions and successfully apply climate risk management strategies to cope with weather variability. Based on the successful Sakai experience, a farmers' handbook tailored to the region's agro-ecological conditions was created. In addition, the Ministry for the Development of Northern Kenya and other Arid Lands then required that all of the arid and semi-arid areas of Kenya receive downscaled weather forecasts as part of Kenya's drought-early-warning activities (Parry *et al*., cited from IISD, 2011).

2.7. 2 Value attached to climate and weather information

Adapting to climate change requires improved understanding of the linkages between climatic conditions and the outcomes of climate sensitive processes or activities; agricultural production for example in a certain region could be influenced by the availability of water resources and their management ways. According to (Gunasekera, 2009), there has been a positive effect associated with the use of climate and weather information in agricultural production as seen in some empirical studies carried out. Some of the examples where the use of climate information can have a positive impact as demonstrated by various studies Solow *et al.* (1999) analyzed the effect of improved ENSO predictions on US agriculture. The study estimated that the value of "modest" and "high" skill ENSO forecasts is $240m and $266m respectively per year (1995 US dollars), Lemos *et al.*, (2002) analysed the use of seasonal climate forecasts in drought mitigation strategies (including seed distribution, emergency drought relief and water reservoir management) in Northeast Brazil. This study highlighted the potential to offer considerable opportunity for state/local government level planners to undertake proactive drought relief planning using climate information.

Thornton, (2004) analyzed the economic value of climate forecasts for livestock production in the Northwest Province of South Africa and the study demonstrated that, for the commercial farmers, long term average annual income could potentially be increased through using ENSO predictions (Gunasekera, 2009).

During a World Bank funded workshop in Dar-es-Salaam in 1999 on users responding to seasonal climate forecasts in southern Africa and the lessons learned then, it became apparent that there were communication barriers between the generators of the information and the users of the same information thus there was a need to develop appropriate information channels to relay such information. The second was that there were bottlenecks in the effective use of seasonal climate forecasts by farmers (Walker, 2001; Blench, 1999); (O'Brien, 2000). Users of seasonal climate forecasts have not been able to decode the information disseminated and therefore, users could not make use of the information provided if they did not understand the information provided in the first place (O'Brien, 2000).

Field studies conducted in the southern part of Africa reveal the existence of a considerable gap between information needed by farmers and that provided by meteorological services. There existed a communication barrier as the two parties have been interacting for a long time but probably have not been able to communicate effectively. The farmers know what they want and the meteorological services know what they need to give to the farmers, but there is no "shared meaning" (Walker, 2001; Blench, 1999). Without a shared meaning in communication, the value attached to particular information availed to the user is diminished and may not serve the intended purpose.

2.7.3 Farmers Indigenous knowledge systems in climate and weather monitoring

Indigenous knowledge (IK) is generally defined as "knowledge of a people of a particular area based on their interactions and experiences within that area, their traditions, and their incorporation of knowledge emanating from elsewhere into their production and economic systems" (Boef *et al.*, 1993). Over the years, communities have developed their own systems for monitoring climate conditions, but this information may not be adequate to inform adaptation if the climate changes in unprecedented ways. For example, farmers in Burkina Faso traditionally rely on observation of environmental indicators to predict climate patterns, but they have lost confidence in their ability to predict rainfall given increased climate variability and increasingly seek to incorporate scientific information (Bryan & Behrman, 2013) cited from (Roncoli, Ingram, & Kirshen 2002).

Socio–cultural changes also account for the shift away from traditional practices such as the use of bio–indicators for agricultural production, even when such practices continue to provide useful information (Bryan & Behrman, 2013; Gilles *et al*., 2013). It is thus important to reflect on the traditional knowledge systems of communities as this provides an entry into understanding how a new type of information about the climate might be accepted by the people (Ziervogel, 2001). Many societies and communities have their own ways of interpreting climate and weather patterns developed over years of experience.

In a study on climate forecasting amongst the Basotho in Lesotho, they were asked if there were any ways to predict the coming weather and climate from what they know traditionally and a lot of answers were given that touched on weather conditions (hours and days) rather than climate conditions (weeks to months). The indicators were both environmental and cultural beliefs. Birds and insects were the most common environmental indicators. People mentioned the 'squawk of the *Makara*' bird as being indicative of rain in the coming days. Winds that blow from a certain direction were thought to bring rain. Plants flowering at certain time, the amount and colour of clouds gathering, rising groundwater and frisky animals were all mentioned as indicators of imminent rain (Ziervogel, 2001) cited from (Wilken, 1982; Pepin, 1996).

Among the Nandi of Uasin Gishu County, the majority of those making up the population of the study area in this research, there are indicators or rainfall predictors that have been observed over the years and have been perceived as very important. The indicators can be classified as those related to the plant species, meteorological, animal and universe indicators. According to Kipkorir (2012), some of the meteorological indicators include wind direction blowing eastwards signifying rainfall near onset, clouds thickening at the horizon and wind veering or breaking towards the east and darkens in color; this indicates rainfall onset is near and also cloud movement from eastern to western side of their farms all indicating rainfall near onset. High sunshine intensity during the day and warm nights or high temperatures at night and low temperature in the evening signify onset of rains.

Lightning strikes in near vertical position in three specific locations indicate near onset of rainfall.

Animal indicators include migratory birds that include *(kaptalaminik*) moving or flying towards the north signifying near rainfall onset and when flight changes towards the south, this signifies cessation. Quail bird (*Terkekyat)* in Nandi dialect is known to produces a sound that is interpreted to be telling farmers that it's time to start planting. This signifies rainfall is very near. For plant indicators, three tree species namely *Schrebera* alata (*Kakarwet*) start flowering red with full leaves regained, Bothriocline fusca (*Tepengwet*) starts flowering shading leaves and Flacourtia Indica (*Tungururwet*) start budding is an indicator for rainfall near onset and farmers prepare to do dry planting.

2.8 Communicating climate and weather information to farmers

A World Meteorological Organization (WMO) assessment of the level of member state's public weather service programmes revealed that the mass media is by far the preferred communication channel through which the public could receive weather information, forecasts and warnings disseminated by the National Meteorological and Hydrological Services (Walker, 2001 & WMO, 2000). The Newspapers, radio and television are all very effective means of informing the public as they reach a maximum number of people. The most common means of reception of weather forecasts, warnings and other information is clearly by radio, (100% world-wide), followed by television (93% world-wide). The picture is similar when analyzing the means of dissemination of warnings by

National Meteorological Stations, as survey results indicate global figures of 88% and 79% for radio and television respectively (Walker, 2001& WMO, 2000).

Several modes of disseminating information products are used by Kenya Meteorological Services to its stakeholders. The following are products that were considered important by users of the information: - Monthly brief to National Drought Crisis Steering Committee, done to senior government officers for planning and is located in office of the President; The Director, KMS gives briefs to the cabinet on La Niña phenomena in the country; KMS buys space each month to publish the monthly forecast as well as seasonal forecast once it has been downscaled. Regional Directors of Meteorology hold public gatherings with user communities in each region and disseminate climate information and in the western part of the country the scientific community has teamed up with traditional climate predictors and a “Climate Resource Centre” has been started and both partners issue climate outlooks to the local communities.

2.8.1 Weather Forecasting and Telecommunication Networks

Information Communication Technologies (ICT) helps in advanced weather forecasting and climate monitoring and also essential in disseminating information to large audiences, for example via mobile phones. This can help address major climate change related risks such as food and water shortages through providing early warning systems and better monitoring of soil conditions and even water quality. At global, regional and at national level, extensive weather station networks are needed for monitoring key climate parameters such as wind speed, precipitation, barometric pressure, soil moisture, wind direction, air temperature and relative humidity. These parameters may be used both for forecasting and for decadal climate modelling hence helping in addressing climate variability due to climate change. The technologies needed include weather satellites and both local and Remote Automated Weather Stations (RAWS).

Satellite observations include visible spectrum cameras to detect storms and deforestation; infrared cameras to detect cloud and surface temperatures and sea level rise and others. According to International Telecommunication Union, the Geostationary Operational Environmental Satellites (GOES-11&12), and others, are capable of making these observations, which are essential in providing input to weather forecasting and climate change models. With an improved coverage of space and land based sensors, fine resolutions can be obtained with frequent updates to be able to generate the most accurate forecasts.

The European Meteosat-8 located over the Atlantic Ocean at 0^{o} longitude provides an operational European 'rapid scan' mode service, which commenced in the second quarter of 2008 (with images of Europe every 5 minutes. Meteosat-9 also at 0^{o} provides the main full earth imagery service over Europe and Africa (with images every 15-minutes). This clearly illustrate the possibilities of integrating such technologies through adoption of dedicated weather satellites, with improved resolution over their regions, to match the standards of weather and climate change forecasting in developed regions (Christina & David, 2012).

Information Communication Technologies (ICT) have helped increase the scale of available assets by combining the distant and the proximate; Mobile applications have improved the breadth of structural access by enabling integration of local producers like small entrepreneurs and farmers into regional and global supply chains, which also broadens the scale of asset availability, typically in terms of financial and physical capital (Ospina & Heeks, 2010; Chu Thi Hong Minh, 2011). Mobile-based telecommunications networks allow rapid communication of information, thus improving the speed of disaster warning, response and recovery.

According to Chu Thi Hong Minh, (2011), ICTs can fundamentally empower rural communities through access to relevant information and knowledge which can raise awareness and knowledge sharing to develop coping strategies to reduce risk and vulnerability. The voice of the poor can be strengthened and carried to the level of decision makers in order to demand action from the leaders and political accountability. ICTs also facilitate networking among communities, individuals and institutions to create multi-stakeholder partnerships to identify and share good practices and coping strategies.

2.9 Mobile phone technology facilitating access to information by the community

There has been a rapid growth of mobile phone networks in developing countries in recent years and mobile phone usage has expanded greatly leading to diminishing mobile divide between the developed world and many developing countries; mobile phones thus is regarded as a more accessible and less expensive means to close the digital divide. Besides, there is a trend that in the developing world, countries have skipped landline infrastructure and leaped directly into mobile technology. Therefore the average number of mobile phones has risen rapidly and has become the predominant mode of communication in the developing world (Chu Thi Hong Minh, 2011). Similarly, mobile phones are now being utilized in more advanced applications, including agriculture, capacity building and climate change adaptation information/applications through connection to mobile broadband technology. In the context of ICT and agriculture, environment related information ranks high in the needs of the rural populations in developing countries. At the farmer level mobile phones are likely to remain the key information medium. Mobile phones have been used to provide agricultural advice in the form of voice and text messages (Karanasios, 2011).

In Africa, where half the continent’s population uses a mobile phone, people now have unprecedented access to information via their handsets. There are multiple ways mobile phones have catalyzed innovation, including in the farming sector. Farmers from isolated areas can access weather information via text messages (SMS) or phone calls, to prepare for upcoming drought spells, heavy rain or floods (CGIAR, 2011). As more and more information becomes available via smartphones, the Microfinance Organization; Grameen Foundation in Uganda countryside for example has started to lease smart phones to local farmers to enable them to receive weather information, planting advice, disease diagnostics, markets prices and more. Information is received by farmers via text messages; also the organization has also started sending images to the farmers to help them identify and diagnose diseases on plants and crops via visual means (CGIAR, 2011). This and many others clearly indicate the integration of mobile phone technology in delivering climate and weather information to communities. There are a few initiatives that have attempted to bridge the gap in as far as access to climate information by farmers is concerned. The use of mobile phones is instrumental in the given examples herein.

2.9.1 Developing a climate-smart tool for agro-weather information in Kenya

The World Bank group through RSMI is developing Agro-weather decision Support System for Agriculture in Kenya. The project main objective is to increase the adaptive capacity of farming communities by improving access to information on weather and climate patterns hence improving farm management capabilities under conditions of climate risk. The pilot project which is scheduled to commence in Embu, will develop web and mobile-phone based agro-weather tools that incorporate climate-information and best-bet agronomic management recommendations for the farmers. The system will help farmers to plan and manage weather risks, maximize productivity, and minimize the environmental impacts of farming practices. It will entail the delivery of climate-smart agro-advisory information using ICTs such as SMS and smart phone applications, and more conventional media such as radio messages. It will be hosted on the National Farmers Information Services (NAFIS) as a dissemination platform (Macharia, 2013).

2.9.2 Mobile money transfer (M-Pesa) system in Kenya

Kenya's mobile phone network operator (Safaricom) operates a mobile phone based money transfer system (M-Pesa) that has been at the forefront of Kenya's agri-technological innovations. Not only can farmers make and receive payments for seeds and crops, but financial institutions, such as savings and credit co-operatives and microfinance schemes, can disburse loans and collect payments. Almost all financial institutions in Kenya now offer M-Pesa services. Similarly, using mobile phones, farmers are reached via Short Text Message (SMS) platform, through "411 Get It" news, entertainment, verses, quotes, stock exchange and others. There is also the SMS Sokoni where commodity prices, market transactions, and farm input advice is obtained by farmers and business people (Jost, 2013).

2.9.3 Kilimo Salama, Kenya

Another web and mobile-based technology programme is Kilimo Salama, run by the Syngenta Foundation for Sustainable Agriculture (SFSA), part of a Swiss agribusiness operating in 90 countries, in partnership with UAP Insurance of Kenya, and Safaricom, Kenya's biggest mobile network operator, it offers crop insurance against drought or excessive rains. Smallholders purchase cover through local agro-dealers while buying their seeds, fertiliser and insecticides. Using solar powered weather stations, Kilimo Salama collects information about extreme weather that may reduce yields and sends farmers these reports via SMS. If the company's climate station registers extreme weather, it sends insured farmers a mobile money payment that covers the costs of their seeds, fertiliser and other inputs such as insecticide that have been insured. Even if the entire crop is lost, the insurer provides the farmer with the funds to buy next season's seeds (Macharia, 2013).

2.10 Theoretical Framework of the study

Theories are constructed in order to explain, predict and master phenomena (e.g. relationships, events, or the behavior). In many instances we are constructing models of reality. A theory makes generalizations about observations and consists of an interrelated, coherent set of ideas and models. The theoretical framework of the study is a structure that can hold or support a theory of a research work. It presents the theory which explains why the problem under study exists. Thus, the theoretical framework is but a theory that serves as a basis for conducting research. This study has borrowed largely from three theories namely systems theory by Ludwig Von Bertalanffy, (1968), communications theory also referred to as transmission model by social scientists Shannon and Weaver, (1949) and vulnerability-adaptation framework advanced by Ospina & Heeks, (2010). The three theories and how they have guided this study are explained in the paragraphs that follow herein.

2.10.1 Systems Theory

This study is guided by the systems theory by Von Bertalanffy (1968) in its theoretical framework. Free Management Library defines a system as an organized collection of parts (or subsystems) that are highly integrated to accomplish an overall goal. The system has various inputs, which go through certain processes to produce certain outputs, which together, accomplish the overall desired goal for the system. So a system is usually made up of many smaller systems, or subsystems. For example, an organization is made up of many administrative and management functions, products, services, groups and individuals. If one part of the system is changed, the nature of the overall system is often changed, as well. By definition then, the system is systemic, meaning relating to, or affecting, the entire system.

A systems approach posits that the performance of the whole is greater than the sum of the performance of its parts. It seeks to identify all parts of an organized activity and how they interact. General systems theory is an area of study based on the assumptions that everything is part of a larger, interdependent arrangement. Identification of systems at various levels helps translate abstract systems theory into more concrete terms.

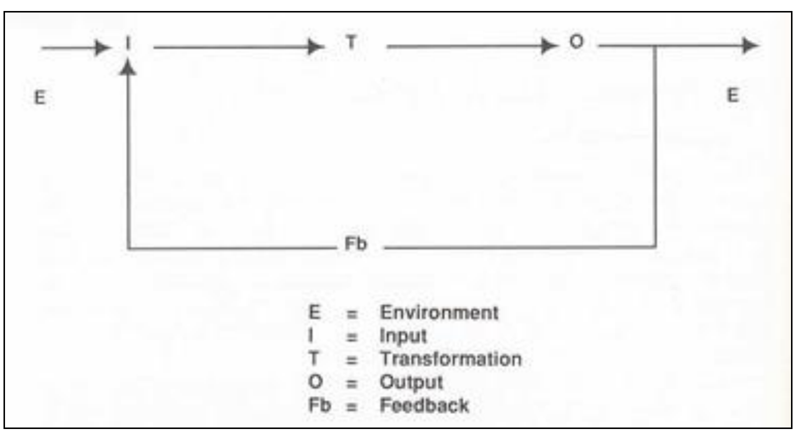


Fig 2.5: Simple Systems Model, **(Source: Littlejohn, 1999)**

The fundamental systems-interactive paradigm of organizational analysis features the continual stages of input, throughput (processing), and output, which demonstrate the concept of openness/closedness. A closed system does not interact with its environment. It does not take in information and therefore is likely to atrophy, that is to vanish. An open system receives information, which it uses to interact dynamically with its environment. Openness increases its likelihood to survive and prosper. Based on the systems theory this study has applied the model, and sees the farming enterprise as a system; climatic information is the input and wheat and maize production is the output. The farmers form a sub system or sub component and their willingness and ability to utilize climatic information is crucial for the system to be complete. Output is determined by how much input as is the case for an open system. The study has focused on farmer's access to climate and weather information because it is one of the inputs among many factors that influence production if all other variables were held constant in a variable climatic system.

2.10.2 Communication theory

The study is also build around communication model principles outlined in the simple model often referred to as the transmission model by Shannon and Weaver (1949). The social scientists Claude Shannon and Warren Weaver structured this model based on the elements of communication that must be present and include: an information source, which produces a message; a transmitter, which encodes the message into signals; a channel, to which signals are adapted for transmission; a receiver, which 'decodes' (reconstructs) the message from the signal and finally the destination, where the message arrives.

To communicate information effectively, one needs to understand the basic principles of communication where we must have the initiator; a recipient; a mode or vehicle; a message and an effect. Simply expressed, the communication process begins when a message is conceived by a sender. It is then encoded and transmitted via a particular medium or channel to a receiver who then decodes it and interprets the message, returning a signal in some way that the message has or has not been understood (Walker *et al*., 2001).

In this study, climate information that includes seasonal climate forecasts is important in agricultural production systems as many decisions are based on availability and access of such information. It is therefore important that those mandated to disseminate this information through the various available channels do so in a proper way if such information is to be useful to the intended recipient. A basic communication model should be able to facilitate the response to some questions such as "*are the meteorological services or meteorologists able to encode climate and weather information? Is medium or channel being used for the coded message the correct one? Are farmers able to decode seasonal climate forecasts encoded by meteorological services or meteorologists?*" This calls for understanding or having a shared meaning between the encoder and decoder for communication to be complete and to have meaning.

The senders of information in the study are the meteorological scientists and the receivers are the users of climate and weather information who include the farmers. A communicator however needs to be aware of factors which may inhibit the effectiveness of communication as stated by (Terblanche & Mulder, 2000). The message to be delivered through the preferred medium is a set of opinions and scientific facts related to climate and weather which the meteorologist wish to relay to the farmers in a simple understandable language with the hope that farmers will first of all receive, be able to understand it and act upon it in a timely manner. The uptake of such messages may vary depending on other factors related to the farmer's environment that may include farming experience over the years and their traditional knowledge base in relation to weather patterns, attitude towards use of climate and weather advisories and if at all they trust the originators of such messages.

2.10.3 Vulnerability adaptation framework

Another framework utilised in the study is the vulnerability-adaptation framework by Ospina & Heeks, (2010). In the framework, the vulnerability context refers to impacts related to climate change. In this study, crop production losses as a result of climatic variability brought about by climate change is the vulnerability context. Vulnerability to climate change can reduce the ability of households to cope with impacts and recover from shock. Households can be vulnerable to climate change in terms of their livelihoods. According to Pettengell, (2010), adaptation is often seen as a choice between reducing general vulnerability by way of improving people's incomes or by diversifying their livelihood strategies, and preparing to cope with specific hazards.

Adaptation in rural livelihood requires intervention in planning, policy and information that include access to climate and weather information showing changes in rainfall patterns and changing seasons with negative impacts in farming cycles. Variations in rainfall onset and cessation days which may include delayed onset or extreme events in some instances. Similarly, access to the necessary technology is key; to cope with impacts of climate change in areas experiencing flooding or droughts, farmers will need access to set of activities such as growing a number of different crops to reduce the risk of crop failure or using several varieties for crops that are more flood and drought-tolerant. Ensuring that such diverse crops are widely available to the farmers where they are needed most is crucial and that access is not hampered by a lack of information to the farmers (Ospina & Heeks, 2010).

2.11 Conceptual framework of the study

The conceptual framework in this study has relied on availability of improved Global observation infrastructure and meteorological services capacity by among others the WMO Global Telecommunication System and other global forecasting centers. The Kenya Meteorological Services relies on such centers together with information from Automatic Weather Stations (AWS) to provide their climate and weather information. The observations available in a quality controlled format, is distributed via the WMO Global Telecommunication System (GTS), the forum for sharing these data globally.

This allows the Kenya Meteorological Services department to monitor weather approaching.

The researcher expounds that in the study, the independent variables that include farmers experience in growing maize and wheat over time, their indigenous knowledge systems practice, their attitude towards use of climate information, level of education, information seeking behaviour are all dependent on climate information awareness levels, access to climate information, medium of communicating climate information to farmers. Addressing these factors will help improve a farmer's decision making on the farm. The researcher further argues that the farmer's indigenous knowledge systems in weather prediction, experience gained over time in maize and wheat cultivation, and their attitude towards use of climate information becomes beneficial when access to climate and weather information (SMS alerts) are embraced today due to the fact that the prevailing climatic variability brought about by climate change has distorted completely the timing of seasons familiar to farmers through experience cultivating maize and wheat crop in the County.

There has been a shift in seasons and rainfall patterns have changed from the normal occurrence making the farmers' knowledge and experience difficult to comply with as the case has always been. The intervening variable here is climate variability and the technologies that facilitate provision and access to climate and weather information. Therefore, if the two scenarios are combined by farmers, a better and beneficial adaptation strategy can be implemented by famers hence attaining improved livelihoods as crop losses are minimized or avoided early. The advisories or SMS alerts are transmitted to the farmers using their mobile phone handsets. Transmitting timely and accurate advisories and other weather information to farmers helps to improve decision making in the farming calendar at the farm level.

A feedback mechanism from farmers helps in addressing questions or farmers needs in addition to a dedicated website that enhances climate and weather information access by maize and wheat farmers. Documents of relevance to the farmer are uploaded in the website and can be accessed by farmers easily for more detailed information. The climate and weather products or services and advisories or alerts are generated by the forecaster in a format which is most applicable to the farmer. The information is downscaled by a team consisting of Directorate of meteorology and Agriculture at the county level and tailored information is sent to the farmer in a timely way. The information delivered thus through the system is climatic information that may include onset and cessation dates of rainfall, weather advisories and all forms of alerts intended to assist maize and wheat farmers minimize or avoid losses in their farming activities.

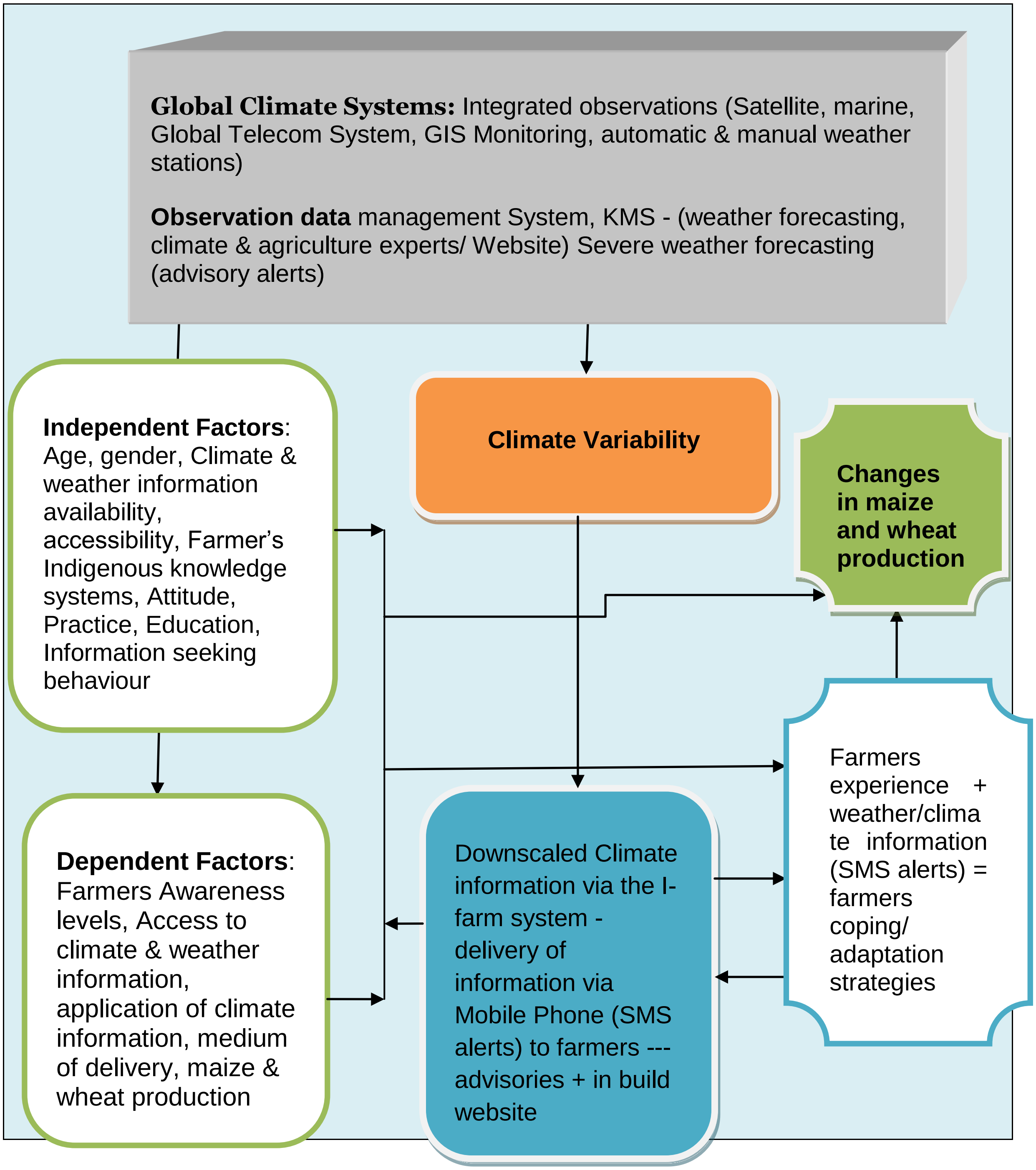


Fig. 2.6: Conceptual framework - Communicating climate information to farmers using Mobile phones (SMS Alerts). (Source: Author, 2013)

CHAPTER THREE

RESERCH METHODOLOGY

3.1 Introduction

This chapter provides the general materials and methods used in carrying out this study. It describes the study site location, topography and climate, soils, vegetation cover and land use; agricultural production and the population size of the study area. It also outlines the study design used, the target population, data collection procedure, instruments and methods used, ethical considerations and data analysis approaches. To capture the required data, a reconnaissance of the study area was carried out in June 2013, the period when the questionnaires were developed, interview schedule formulated and sampling procedure designed.

3.2 Study site location

Uasin Gishu County has six sub counties namely:-*Turbo, Soy, Moiben, Anapkoi, Kesses and Kapseret*. According to Uasin Gishu County profile report 2013, from the Office of the Governor, the total area of the County is 3327.8 Km^2 with arable land covering 2603.2 Km^2 and non-arable land covering 682.6 Km^2. The County extends between longitude 34° 50′ and 35 ° 37′ east and 0° 03′ and 0° 55′ north. It shares common borders with *Trans Nzoia* County to the North, the *Marakwet* and *Keiyo* County to the East, *Baringo* County to the southeast, *Kericho* County to the South, *Nandi* County to the West and *Lugari* Sub-County to the North West. The County, divided into six sub-counties has the following sizes in terms of land distribution:-Kapsaret 400 Km^2, Ainabkoi 383 Km^2, Kesses 611 Km^2, Soy 762 Km^2, Turbo 324 Km^2 and Moiben 738 Km^2 (GoK, 2008).

The headquarters of Uasin Gishu County is Eldoret town located on the main highway serving Uganda and other great lakes region areas that include Rwanda, Burundi, Congo, Zaire and Tanzania. The town is located at an altitude of 2085 m above sea level with a relatively cool climate experiencing daily mean maximum temperatures of 23.7°C and a mean minimum of 9.5°C. Eldoret town is traversed approximately latitude 00º 30’ North and Longitude 35º 15’ East of the Equator. It is approximately 320 kilometres North West of the Kenyan capital city of Nairobi (Nyakaana, 1996).

Uasin Gishu County was chosen as area of study because it has traditionally been considered the bread basket of Kenya but recent declines in crop production in the region calls for a better understanding of factors responsible hence enabling improvement in production of maize and wheat and ultimately ensuring a food secure nation and poverty alleviation at the community level.

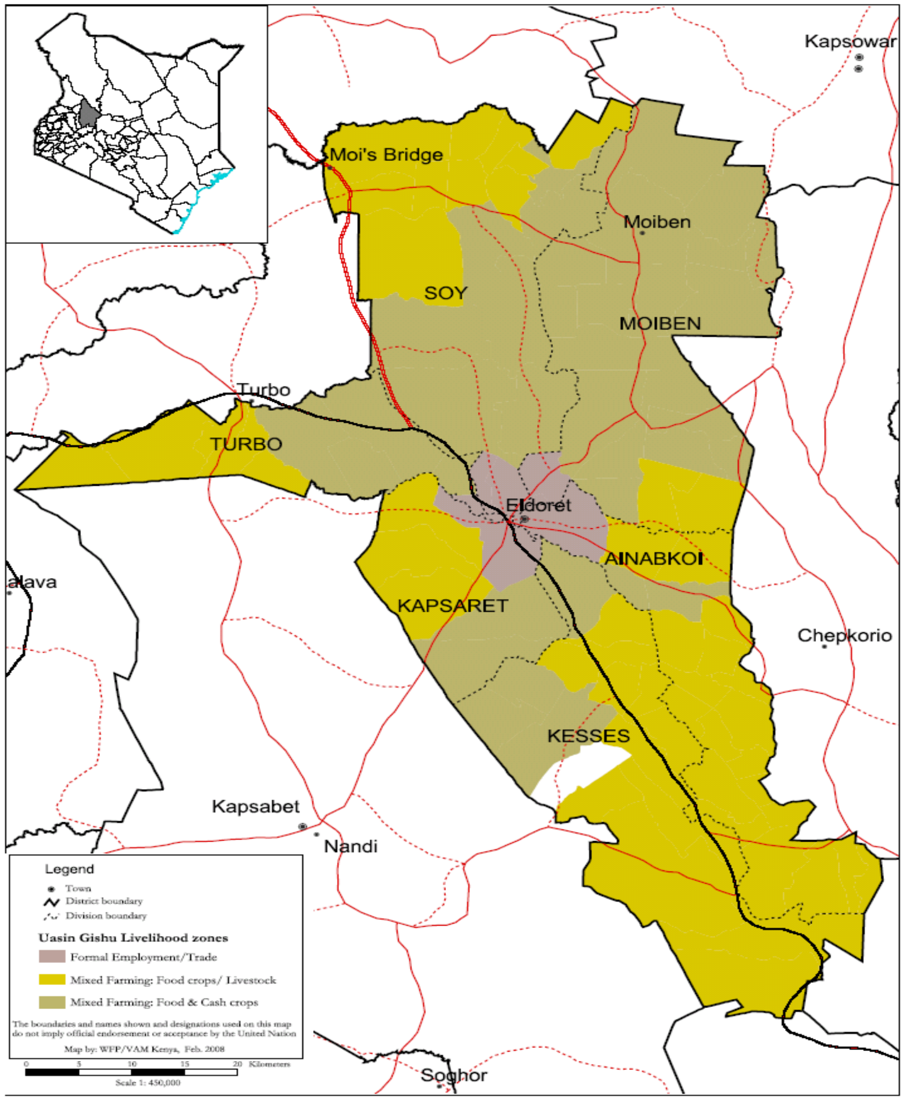


Fig 3.1: Map of Uasin Gishu County showing *Moiben Soy* and *Kesses* Sub-County study areas

(Source: GoK, 2013)

3.2.1 Topography and Climate of Uasin Gishu

The terrain of Uasin Gishu County is generally undulating highland plateau varying with altitude between 1,500 meters above sea level at *Kipkaren* in the west to 2,600 meters above sea level at *Timboroa* in the east. Eldoret town is at 2,085m marking the boundary between the highest and the lowest altitude of the county. The gentle undulating terrain allows the practice of mechanized farming. The rainfall amounts and regimes are influenced by altitude and wind direction usually high, reliable and evenly distributed with some annual average of around 900mm in the last few years. It is bimodal occurring between the months of March and September with two distinct peaks in May and August. The wettest areas are found in *Ainapkoi*, *Kapseret* and *Kesses* sub-counties. The other three sub-counties of Soy, Moiben and Turbo receive relatively lower amounts of rainfall (GoK, 2008).

Temperatures range from 25^0C as the highest and the lowest at 8.8^0C and humidity averaging 56%. February is the hottest month while July is the coldest. The variations in temperature across the county follow the same pattern as rainfall. Farmers generally prepare land for maize planting during the months of January and February and planting starts towards the end of March. Preparation for wheat farming starts in March to May and planting starts towards the end of June (GoK, 2008).

3.2.2 Agricultural production in Uasin Gishu County

Uasin Gishu County is basically an agricultural district producing more than a third of the total wheat production in the country. Similarly, maize ranks second both as food and cash crop. According to the (Kenya Food Security Steering Group (KFSSG), 2009) committee in the Office of the President, the 2009 long rain season maize production was about 1.84 million Metric Tonnes, which was 28 percent below normal. There was a growing apprehension that the production could further be revised downwards due to insufficient and erratic rains in some parts of the main maize producing areas in North Rift including Uasin Gishu County. In 2012, maize production in Uasin Gishu County realized 343,795 tonnes while that of wheat production was 88,116.7 tonnes. This is in comparison with production in 2013 where maize harvest increased to 406,728 tonnes while that of wheat dropped to72, 962 tonnes (GoK, 2013).

During the 2009 period, the Ministry of Agriculture report in Eldoret revealed that Kenya would have to rely on massive importation of wheat to meet a looming shortage in the country. As harvests continue to stagnate, more and more farmers were contemplating a shift to other crops. Formerly key wheat farming areas of Narok, Uasin Gishu and Nakuru were a sorry state of affairs. Ministry of Agriculture projections in 2009 stated that the North Rift would produce barely more than four million bags of wheat against the country's annual consumption of 11 million bags. Even the four million bags target was not achieved due to erratic rainfall, the escalating cost of farm inputs and the dreaded wheat stem rust, which damaged the wheat crop (GoK, 2013)

3.2.3 Population size

The 1999 population census showed that Uasin Gishu County had a population of 622, 705 with a growth rate of 3.35% p.a. According to the 2005 – 2010 Uasin Gishu District Strategic Plan, the district population was projected to increase from 622,705 recorded in 1999 to 682,342 people by the year 2002 to 729,079 people by the year 2004. This would increase further to 780,187 people by the year 2006. By 2010, the population was projected to increase to 829,046 people. The Kenya national population census report gives the population of Uasin Gishu County as 894,179 with a population density of 269 persons per Km^2. and 147, 939 households (GoK, 2009).

3.3 Study Design

The study utilized both qualitative and quantitative techniques. Both techniques were cross sectional in nature which enabled obtaining adequate information from the respondents. The use of both quantitative and qualitative research techniques are known to complement each other especially where exploration of indigenous knowledge among farmers is important. The qualitative aspect helped consolidate the themes emerging from the interview or survey.

The developed web based mobile phone SMS System (I-farm model), the methodology adopted was Agile development. In Agile development which is an incremental build model methodology, the product is designed, implemented and tested incrementally. The software is developed in incremental, rapid cycles with each release building on previous functionality of the model. Agile software development focuses on keeping the code simple, testing often, and delivering functional bits of the application as soon as they're ready. The incremental nature of I-farm system design involved developing the database, the model interface for both the client side (representation) and the server side (Business logic). The in-build Short Text Message (SMS) gateway was also developed together with the feeds and content management. I-farm system is currently operational and can send SMS alerts to farmers using their mobile phones.

3.4 Target Population

The target population was all farmers engaged in maize and wheat production resident in Uasin Gishu County at the time of study. According to Uasin Gishu County profile report of 2013, there are a total of 134, 490 farmers engaged in maize and wheat production.

3.5 Sample size determination

Because of its nature of utilizing both qualitative and quantitative techniques, a representative sample was picked considering the levels of stratifications. The basic unit of analysis for the study was the household. Households in the County engaged in farming are 134, 490 in number. The sampling frame for the study is 129, 384 farmers distributed as follows: - *Soy* Sub-County = 61, 138, *Moiben* Sub-County = 38, 950 and *Kesses* Sub-County=29, 296.

For finite populations Reid & Bore (1991) showed that a representative sample size could be calculated using the equation:

$$n = \frac{N}{[(1 + N(e)^2]} \quad (1)$$

Where n is the sample size, N is the total population (sampling frame) and e is the error of margin (at the desired confidence level)

By substitution in the formula (N=129, 384 and e=0.05), we have sample size as used being

$$n = \frac{129384}{\{1+129384\,(0.05)^2\}} \quad \mathbf{= 399} \quad (2)$$

Thus, a minimum of 399 farmers were included in the present study. In addition 12 key informants were interviewed; one from each ward totalling to 9 and also 2 from Directorate of Agriculture and Directorate of Meteorology in Uasin Gishu County respectively. One other key informant from the Kenya Meteorological Services in Nairobi was interviewed as well.

3.6 Sampling Procedure

The study adopted purposive, stratified and random sampling procedure to be able to capture a representative sample of farmers. Stratification was first done on the basis of

Sub-County level. Uasin Gishu County has 6 Sub-Counties namely: - *Turbo* Sub-County with 5 wards, *Soy* Sub-County with 7 wards, *Moiben* Sub-County with 5 wards, *Anabkoi* Sub-County with 3 wards, *Kesses* Sub-County with 5 wards and *Kapseret* Sub-County with 5 wards. The entire 6 Sub-County areas of Uasin Gishu County were analyzed to identify sub counties exhibiting both maize and wheat production. Based on this criterion, 3 sub-counties namely *Moiben*, *Soy* and *Kesses* were selected purposively. A further stratification was done at ward level. Wards that grow both maize and wheat were purposively selected again as follows: - In *Soy* Sub-County; *Soy, Kipsomba* and *Ziwa* wards were selected for the study. In *Moiben* Sub-County; *Moiben, Sergoit* and *Karuna/Meibeki* wards were selected. In *Kesses* Sub-County; *Kesses, Tarakwa* and *Megun* wards were picked for the study. The number of maize and wheat farmers in the respective sub counties is as follows: - *Soy* Sub-County = 61, 138, *Moiben* Sub-County = 38, 950 and *Kesses* Sub-County=29, 296 giving a total of 129, 384 farmers growing both maize and wheat.

In order to determine the number of farmers to be picked in the selected wards, the use of data from households mapping done by the Kenya National Bureau of Statistics (KNBS) through the Kenya National Census and Household Surveys (KNCHS) 2009 was utilised. Using the numbers derived for households and structures for example structure number fifteen and household number thirty denoted S0015/030 were all populated in the data analysis Statistical Package for Social Sciences (SPSS) computer software and a command issued to randomly pick the required number of households (farmers) in each ward. The randomly generated numbers were used to pick the households to interview the farmers. The household numbers selected randomly by the computer were identified on the ground through support of the village elders who are familiar with the mapping exercise of households during the 2009 census. The following sample was derived in the respective wards selected:-

The following are derived number of households in the three each Sub-County areas including the wards: ***Soy*** **Sub-County**= 189 households, ***Moiben*** **Sub-County**= 120 households and ***Kesses*** **Sub-County** = 90 households. In each of the selected 9 wards, the farmers were picked as follows in the respective households:

Soy **Sub-County;** *Soy* ward= 77 households, *Kipsomba* ward = 78 households and *Ziwa* ward = 34 households. ***Moiben*** **Sub-County;** *Moiben* ward= 44 households, *Sergoit* ward = 50 households and *Karuna/Meibek* ward= 26 households. ***Kesses*** **Sub-County;** *Kesses* ward= 20 households, *Tarakwa* ward =30 households and *Megun* ward =40 households

In each of the wards therefore, the randomly generated numbers was used to pick the household where a farmer whose main preoccupation was mainly handling maize and wheat farming was identified and interviewed. This led to picking of 399 farmers who were then administered the questionnaire.

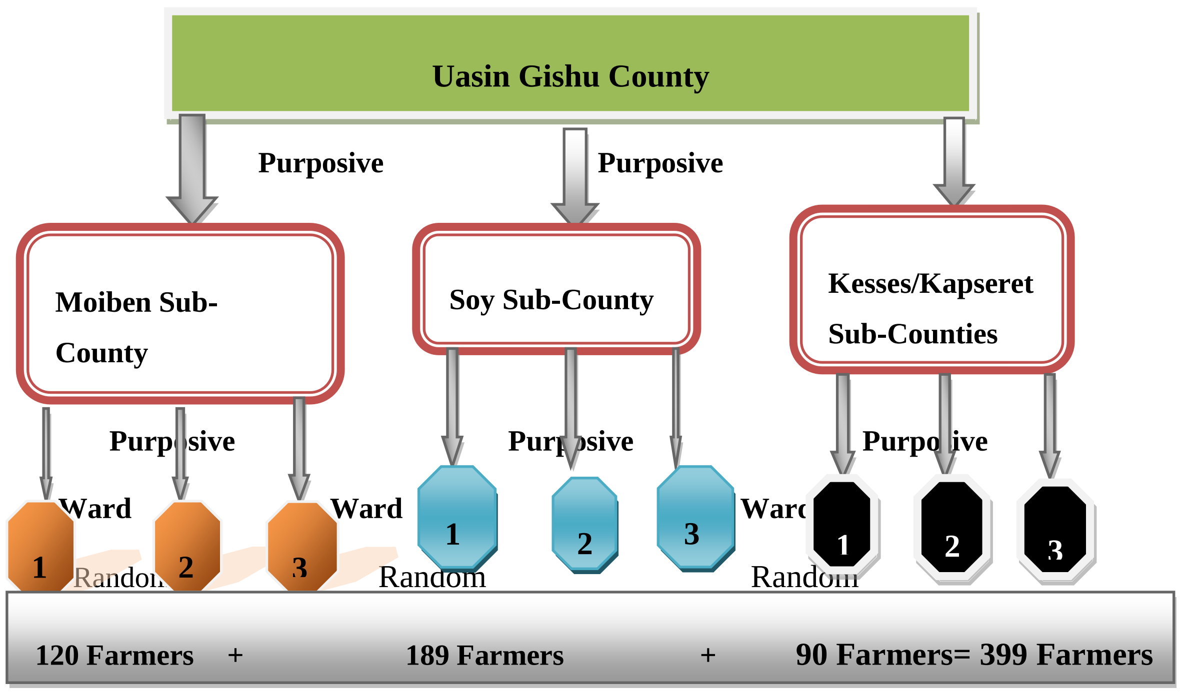


Fig.3.2: Schematic presentation for sampling procedure

(Source: Author, 2013)

3.7 Inclusion and exclusion Criteria

The following was used as inclusion and exclusion criteria in the sample selection for the study:-

3.7.1 Inclusion criteria

All farmers engaged in maize and wheat production resident in Uasin Gishu County at the time of the study were included in the survey. Farmers who were household heads whether male or female constituted the sample. Any farmer sampled whether engaged in large scale, medium and small scale farming constituted the sample in this study.

3.7.2 Exclusion Criteria

Farmers who grow other types of crops were not included in this study. Similarly farmers engaged in either wheat only or maize only did not constitute the sample as well. Similarly, children under 18 years were not included in this study.

3.8 Data Collection Methods

The study applied document review method to elicit data and information required during the formative period of the study and during literature review. The survey method was used where the questionnaire was interviewer administered. This is where the farmers were interviewed as they completed the questionnaires. Key informant interviews were also conducted to elicit more information on the variables of interest. This included interviews with village or community elders, farmers, Agricultural staff and Meteorological Services Staff. Observation and photography formed part of data collection methods as well.

3.9 Data Collection Instruments

The study employed both a questionnaire and an interview schedule attached in the Annex of this Thesis to collect the required data. The questionnaire was administered to the farmer who is the household head during the study period. The household head in this context is a person responsible with farming activities in the household. They include the man or woman who is usually the head of the household or an elder son who has been entrusted with farming activities on behalf of the other members in the family.

The questionnaire administered to the farmers was designed to capture data on the types and sources of climate and weather information accessible to maize and wheat farmers, the modes of information communication utilized to relay climate and weather information, the perception of farmers towards the use of climate and weather information and the influence of their traditional knowledge system in maize and wheat production, the role of climate and weather information in maize and wheat production and acceptability of use of mobile phone technology to relay climate and weather information to farmers in the community.

Based on the informational needs of farmers, a web based model application to relay SMS alerts to farmers (weather and climate related advisories) was developed. Mobile phones were used during model development and testing of SMS Alerts and capturing images, Safaricom modem and a laptop acting as server for model deployment were in place. Open source programming platforms (Webserver and servlet container (Tomcat5.5.). Nagios open source software was also installed to monitor uptime and down time of the server housing I-farm system. This will ensure that when the server goes down an alert is sent to the person responsible with I-farm system management.

3.9.1 Validity and reliability of the instruments

It was found necessary to test the validity of the data collection tools. After the reconnaissance of the study area, a pre – test was done on the questionnaires with the aim of correcting errors. Ten questionnaires were administered to ten farmers residing in the respective 10 wards of the County growing both maize and wheat to examine the questionnaires for content validity. This helped to test whether the questionnaires could, in fact, capture the required information from the farmers. The feedback in form of comments from the respondents were used to modify some questions to make them more understandable hence achieving a standard tool able to elicit required information in line with the set objectives of the study.

3.10 Techniques for data collection in the study

The main data collection techniques utilized in this study included document review, use of secondary data, questionnaires and interview schedules.

3.10.1 Document Review/Secondary Data

Document review was carried out during the first phase of the study especially during proposal development and subsequent literature review around the study area of interest.

The secondary data was important for identification gap in knowledge and verification of similar or related studies to the current research. This was done by reviewing literature in books, Journal articles including online publications, policy documents, reports and relevant articles. This method provided factual and authoritative information and data with regard to the study thematic area.

3.10.2 Questionnaire administration

This was the main method used to gather data for analysis. A semi-structured questionnaire was developed and interviews conducted based on the set objectives. The respondents were required to answer so as to provide the required information hence both quantitative and qualitative data was gathered. The questionnaire was administered to the household head (male or female spouse) concerned with farming at the household. This tool aided in attaining the objectives of research by eliminating subjectivity and biases from part of the researcher and also the respondents hence being able to attain more focused and relevant data. It was organized in sections as per the study objectives.

Plate 1: Data collection exercise, Moiben ward in Moiben Sub-County, December 2013 (Source: Author, 2013)

3.10.3 Interview schedule

An interview schedule was designed to obtain some direct, significant and isolated information from the respondents who were the key informants. The schedule was a set of open ended questions that guided the interview in sourcing the right information. The interview schedule had a summary of some few selected themes in the research study that needed a deeper examination and was administered among the purposefully selected respondents in the wards at Sub-County level and nationally at the Meteorological Department.

3.11 Data Management

Completed questionnaires were coded and entry done in access database. It was later exported into the Statistical Package for Social Sciences (SPSS V.16) for analysis. Both qualitative and quantitative data were analyzed using appropriate methods. Analysis was based on research objectives. For quantitative data, frequencies, mean and standard deviation were used to summarize the data. The Chi-square test was used to check for significant relationship between categorical variables. Significance level was set at $\alpha=0.05$. Qualitative data was analyzed by theme generation.

3.12 Ethical Considerations

Permission to conduct this study was obtained from the relevant authorities that included the County Directorate of Agriculture and the University of Eldoret, School of Environmental Studies who issued letters of support to undertake the research as attached in the Annex section of the Thesis. Written informed consent was sought from the farmers and participation was on voluntary basis. Confidentiality of the information obtained from the farmers was ensured by not including names of participants on the data collection tools. Completed data collection tools were kept in a secure place accessible only to the researcher. Electronic data in the computer was protected by use of password validation.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results of the study. Analysis of farmer's demographic data and their maize and wheat growing activities is presented in the first section. This is followed by examining types and sources of climate and weather information accessible to maize and wheat farmers in the county, modes of communicating such information to farmers, determining the perception of farmers towards the use of climate and weather information mainly focusing on their practice (indigenous knowledge systems) in relation to the prevailing climatic variability, role of climate and weather information in maize and wheat production and finally looking at the acceptability of use of mobile phone technology to relay climate and weather information to maize and wheat farmers in the community. A web based application model to relay climate and weather information to farmers in Uasin Gishu County has been developed and is ready for implementation and rollout.

4.2 Analysis of demographic data

A total of 399 maize and wheat farmers participated in the study, that is 331 (83%) were male and 68 (17%) were female. Majority of the farmers that is 229 (59.6%) were in the most productive age group of ages 26 and 46 years old. The education levels of farmers reveal a population that have largely attained primary level of education or 157 (39.6%) followed by those with no formal education at 113 (28.5%) and those who had attained secondary level of education at 89 (22.5%).

Most farmers that is 266 (69.3%) have a farm size of 1-20 hectares followed by 81 (21.1%) with 21- 40 hectares as indicated in Table 4.1

Table 4.1: Socio-demographic characteristics of the respondents in Uasin Gishu County

Characteristic	Frequency	%
Gender		
Male	331	83
Female	68	17
Age-group(years)		
≤25	20	5.2
26-46	229	59.6
47-59	105	27.3
≥60	30	7.8
Education level		
None	113	28.5
Primary	157	39.6
Secondary	89	22.5
Tertiary	25	6.3
University	12	3.0
Farm size (hectares)		
<1	18	4.7
1-20	266	69.3
21-40	81	21.1
>40	19	4.9

On average, the size of maize farms ploughed was 11 (minimum 1, maximum 90) hectares while that of wheat was 9 (minimum 1, maximum 96). Similarly, majority of the farmers 274 (69%) reported to harvest between 20-29 bags of 90kgs of maize per acre per year and 289 (75.9%) affirmed that they harvested between 10-19 bags of 90kgs of wheat per acre per years as indicated in Figure 4.1. This shows variations in yields between maize and wheat (20 – 29 bags of 90 kg for maize and 10-19 bags of 90 kg for wheat) per acre. Maize crop yield more than the wheat crop in Uasin Gishu County. The results compare well with statistics from Uasin Gishu County Agricultural Office where maize production in 2013 is compared with that of wheat (406,728 tonnes for maize compared to 72,962 tonnes for wheat). Similarly, in 2012, the yield for maize was (343,795 tonnes compared to 88, 116.7) tonnes for wheat (GoK, 2013Uasin Gishu County profile 2013).

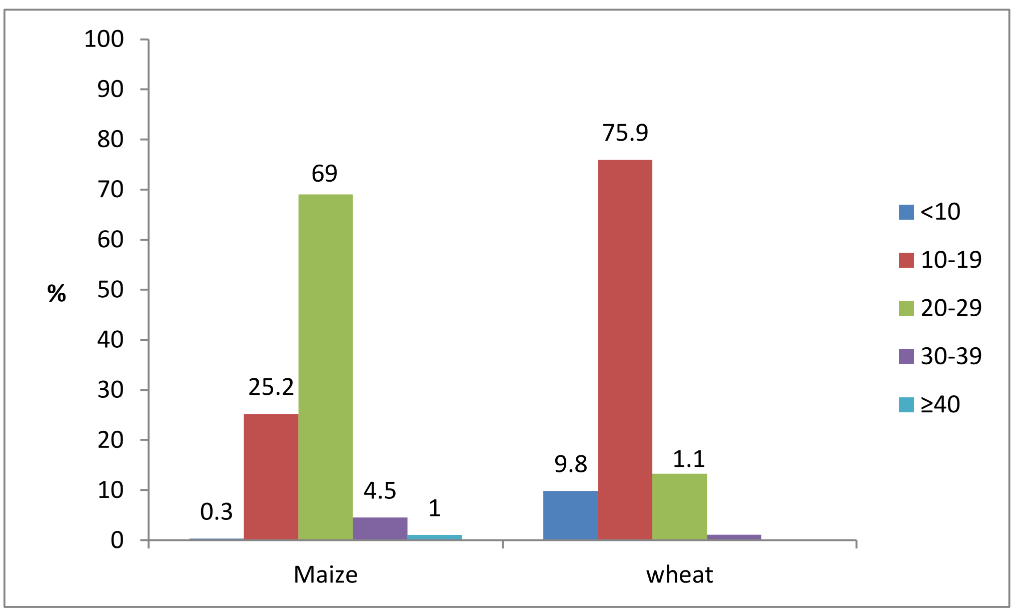


Fig 4.1: Yield (No. of 90 kg bags) per acre per year in Uasin Gishu County
(**Source: Field Data, 2013)**

The study also examined the farmer's education level and compared it with access to climate and weather information to determine if there was any significant relationship between the variables. The findings are presented in Table 4.2 herein.

Table 4.2: Relationship between access to climate and weather information and education level in the County

Farmers education level	Climate information Access		Chi	P
	Yes	No		
None	3 (2.5%)	9 (7.5%)		
Primary	27 (23.9%)	86 (76.1%)		
Secondary	70 (44.6%)	87 (53.4%)	17.957	0.001
Tertiary	43 (48.3%)	46 (51.7%)		
University	12 (48%)	13 (52%)		

The results presented in Table 4.2 reveal that there existed a significant relationship between the farmers level of education and access to climate and weather information (Chi = 17.957, P = 0.001). The proportion of those accessing information increases with increase in level of education up to secondary level as seen earlier in Table 4.1 where majority of the farmers had primary education level followed by those with no formal education then those with secondary education.

4.3 Types, sources and access to climate and weather information by farmers

The findings on access to climate and weather information by maize and wheat farmers, the types or categories and sources of the climate and weather information are discussed here under.

4.3.1 Access to climate and weather information by farmers

The results showed that only 155 (40%) reported to receive the information while 120 (31%) of them reported not to receive the information, 100 (26%) did not receive but were interested to access such information and 15 (3%) did not know anything about such information as illustrated in Figure 4.2.

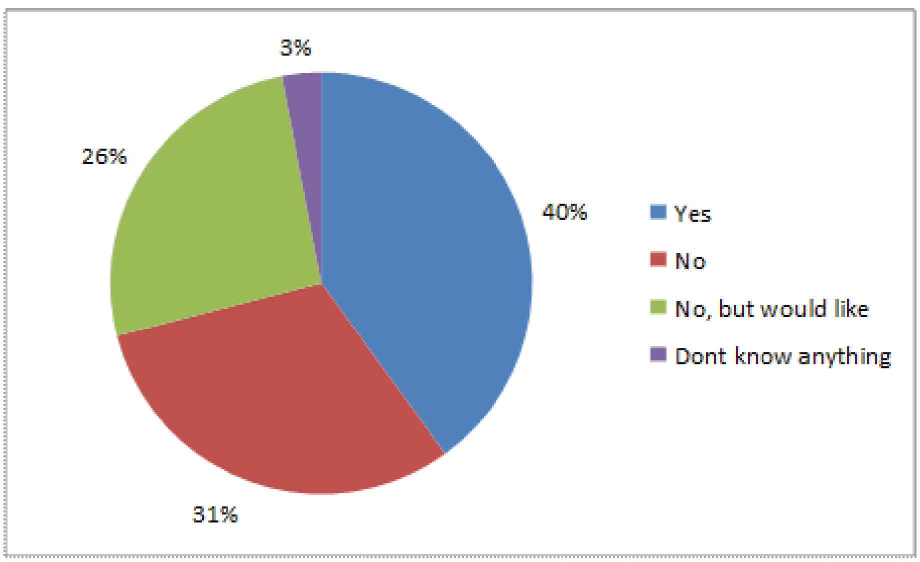


Fig 4.2: % of Respondents receiving information on climate and weather in Uasin Gishu County (Source: Field data, 2013)

The responses in fig 4.2 clearly show that access to climate and weather information was low at 155 (40%) compared to 236 (60%) who do not receive the information at all. The findings here agree with findings from other studies showing that despite the availability of relatively reliable weather and climate information and products by the late 1990s, farmers seldom used them for farm level decision-making (Hansen 2002; Hammer *et al*. 2001). This is mainly due to lack of adaptability of the information to the locality and difficulties in accessing the information on time and in a format that farmers can easily understand. The results in this study reveal a farming population that does not largely integrate climate and weather information in their farming decisions and practices. This has a potential to impact negatively on maize and wheat production especially in the prevailing climate variability globally, nationally and at the local county level.

4.3.2 Categories and types of climate and weather information and services

Close to half of the farmers 193 (49.2%) reported not to receive any product or service for use in their farming activities. However 78 (19.8%) received Farmer's Guide while 75 (19.1%) received targeted information for maize and wheat farmers showing what variety to plant where to plant and when to plant as reflected in Figure 4.3.

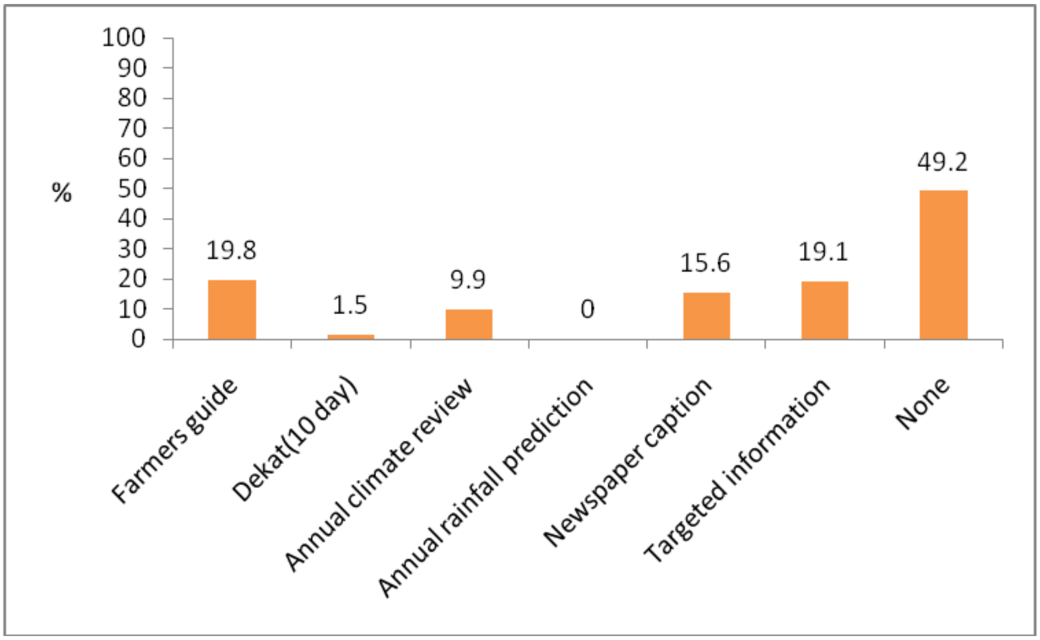


Fig 4.3: Climate and weather services/products from KMS received by farmers in Uasin Gishu County (Source: Field data, 2013)

Again, the results show that close to half of the farmers interviewed affirmed that there was no information product they received and used in their own experiences to make farming decisions. From the foregoing, it is evident that the farming population largely rely on their own judgment to carry out certain crop activities but with the prevailing climate variability, the accuracy of own judgment is at stake. It is important thus for the government through the directorate of Agriculture to carry out sensitization campaigns to educate farmers on the need to understand the importance of accessing and using climate and weather information in their farming decisions. This situation is explained further by studies by Vogel and O’Brien (2006) and Hansen *et al*. (2007) which states that even when climate information is available, incorporation of scientific climate information into local decision making may not often occur because of the way such information is communicated and disseminated. Despite such efforts, climate and weather information seem not to have reached the farmer in right format, time and method to enable them consider it in their farming decisions. This leaves the farmers indeed vulnerable to variability in weather patterns.

From the data gathered during key informant interviews, an Agro-meteorologist at the Kenya Meteorological Services stated that large scale farmers get tailored weather information from the business support services section of the Department of Meteorological Services. He further stated that consultants working for NGOs go to the same section for information on dry planting, rainfall onset and cessation dates and any other information for use by members under various organizational management frameworks.

4.3.3 Relationship between access and use of information

In order to understand whether there was any relationship in the access of climate and weather information by farmers and their utilization, cross tabulation of the two variables was executed and *P value* determined as shown in Table 4.3.

Table 4.3: Relationship between access and use of climate and weather information in the County.

Responses on Access of information	Use of Climate information		Chi	P
	Yes	No		
Yes	116 (74.8%)	39 (25.2%)	87.263	< 0.001
No	66 (27%)	178 (73%)		

The result shows that there is a significant relationship between access of climate and weather information and its usage by farmers (*Chi = 87.263, P < 0.001*). Majority of farmers accessing the climate and weather information are using the said information to plan their crop activities. It is important therefore that access to such information by farmers should be facilitated. As seen earlier, 49.2% affirmed that they did not access the information thus access is critical if farmers are to utilize the information hence improving their crop productivity.

4.3.4 Sources of climate and weather information accessible to farmers

On how they obtain any climate and whether that could assist them to make some informed decisions on maize and wheat growing, half of the farmers that is 197 (50%) said that they consulted with their fellow farmer for climate and weather information while 69 (17.6%) did not contact anybody because they believed they knew what and when to plant the crops. Those farmers who contacted Agricultural Extension Officer for support to explain more about climate and weather information utilization in maize and wheat farming were 182 (46.2%) as shown in Figure (4.4).

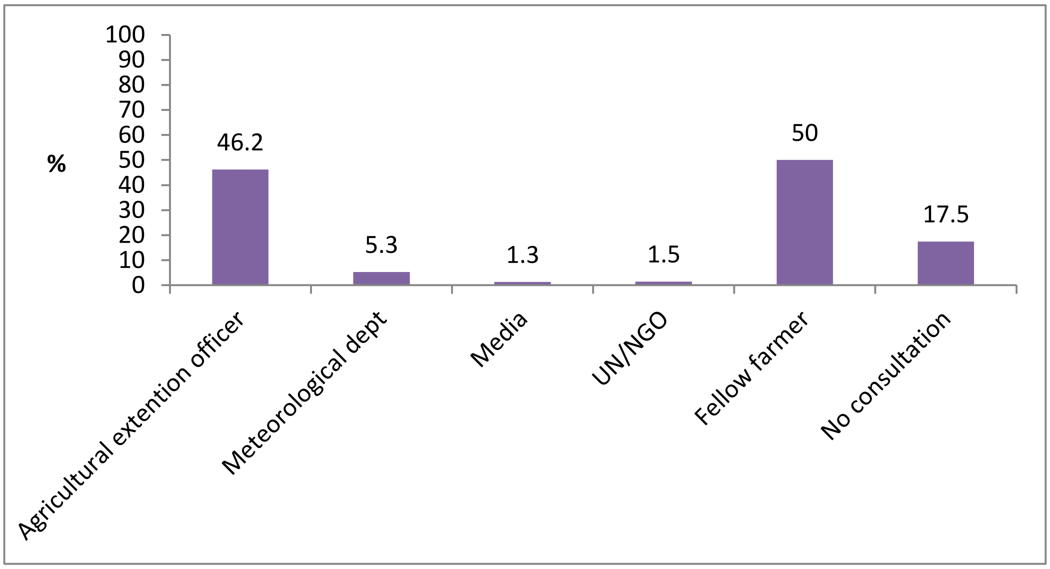


Fig 4.4: Sources of climate and weather information for farmers in the County

(Source: Field Data, 2013)

The results in this study corroborate that by Kadi, (2011) who found that farmers in Kenya mainly receive climate information from extension services, the media (radio, television, newspapers) and through community interactions or fellow farmers. Similarly, the findings agree with those by Konneh (2006) cited from Hansen, 2003; Jones *et al*., 2003; Walker *et al,* 2003) which showed that climate information is likely to have value, if communicated through extension agents or contacts who farmers already know and trust. Seasonal forecast communication, therefore, needs to go through existing trusted institutions or individuals. Such an arrangement albeit may pose other serious challenges if access to climate and weather information is not accessible and with climate variability, farmers who obtain information from fellow farmers or extension workers may end up getting information that may not be useful to them at all.

In an effort to address this challenge, one of the key objectives of this study was to develop climate and weather information model to relay climate information to the farmers in the community. The developed I-farm web-based model will help bridge the existing gap of lack of access to climate and weather information as demonstrated by farmers and expounded in the conceptual framework of this study. Extension officers and farmers need to be empowered with adequate training on climate and weather information utilization through campaigns at the farm level as they remain trusted channels.

The responses given on indirect access to climate and weather information by farmers is s as given in Table 4.4 maize and Table 4.5 wheat. This was on the assumption that such gatherings usually have information for the farmers on climate and weather.

Table 4.4: Activity attended in the year by a maize farmer in Uasin Gishu County

Activity attended	Frequency	Percent
District agricultural shows	221	55.4
Farmers field day	216	54.1
Agricultural demonstrations	169	42.4
None of the above	69	17.3

As indicated in Table 4.4, more than half of the farmers 221 or 55.4% reported to have attended District Agricultural Shows while 216 (54.1%) of the farmers attended field days. Less than half 169 (42.4%) attended agricultural demonstrations while a total of 69 (17.3%) did not attend any of the activities mentioned.

Table 4.5: Activity attended in the year by a wheat farmer in Uasin Gishu County

Activity attended	Frequency	Percent
District agricultural shows	197	49.4
Farmers field day	198	49.6
Agricultural demonstrations	162	40.6
None of the above	71	17.8

As wheat farmers, 197 (49.4%) reported to have attended District Agricultural Shows, 198 (49.6%) attended farmers field day while only 162 (40.6%) attended agricultural demonstrations as shown in Table 4.5. 71 (17.8%) did not attend any activity in relation to wheat growing.

From the foregoing, it is evident that maize and wheat farmers receive whatever information they may require be it climate and weather or related information through their own initiatives by way of attending agricultural shows, farmers field day and demonstrations. This is largely a farmer led exercise that may face challenges given the prevailing climatic variations in the agricultural sector. While it is commendable that farmers take their initiative to seek for information, facilitation of climate and weather information may not be readily available in such gatherings. Both County and the National government therefore, can target such avenues to reach the farmer with requisite climate and weather information that they may need during their farming decisions.

Other responses on how farmers have been exposed to access or knowledge of climate and weather information and other useful agricultural information show that majority of farmers 382 that is (97.9%) stated that they knew the maize and wheat seed varieties suitable for growing in their farming areas for maize growing and 369 or (97.4%) stated so among those growing wheat. Asked on how they became aware of the various seed varieties and their suitability, 175 or (44.9%) stated that they have used personal experience over time practising maize and wheat growing. This is followed by those who got the information from fellow farmers who know certain maize and wheat seed varieties do very well around the neighbourhood 164 (42.1%). Those who identify Agricultural Extension Officer accounted for 140 (35.8%).

Here, it is evident that the key sources of information for maize and wheat farmers with regard to seed varieties, their suitability and the best yielding variety in Uasin Gishu County are largely farmer led and also experience related as outlined in the findings. Farmers have clearly indicated that they have used their own experience over time cultivating maize and wheat and therefore know which seed variety is suitable for certain areas (indigenous knowledge systems). The role of Agricultural Extension Officer is also crucial if climate and weather information is to be relayed across to the farmer. The personnel especially the Locational Agricultural Extension Officer operates closely with the farmers at the farm level hence in a better position to discuss emerging issues contained in the advisories provided by the meteorological departments. The finding in this study tie well with finding by Konneh (2006) cited from Hansen (2003); Jones *et al*. (2003) and Walker *et al*. (2003) which states that climate information is likely to have value, if communicated through extension agents or contacts who farmers already know and trust.

With the prevailing climate variability, seasons have shifted and farm timings known to farmers are distorted leaving a farmer quite vulnerable to unpredictable weather patterns. It is critical that farmers get the right information on the best maize and wheat seed variety to plant to complement what they know based on their experience over time. It is also important that they access climate and weather information at the right time to help them make informed decisions. The National and County governments can support farmers by streamlining access to climate information at the farm level.

4.3.5 Production and distribution of climate and weather information products

Farmers were asked to state the organizations and individual responsible for the production and distribution of the needed climate information products. The following were the farmer's responses in relation to the information service or products outlined: - Majority of the farmers over 50% in all the outlined products in Table 4.6 reported that no organization produced and delivered such information to them.

More precisely, the responses were as follows based on each product outlined in Table 4.6. For the Farmers guide 157 (55.1%) affirmed that no such information was provided to them. The Dekad (10-day) agro-meteorological bulletin was not received by 190 (70.4%), Annual climate review was not accessed by 155 (55.6%), Annual or seasonal rainfall prediction was not accessible to 157 (55.5%), Newspaper caption on farmers activities was not accessible to 151 (53.1%) and Targeted info for maize and wheat farmers was never accessed by 149 (52.5%) as indicated in Table 4.6. Similarly, those who accessed climate information through Newspaper advertisement (Newspaper caption) on weather/climate information and crop production/food security around the country in general were 95(33.5%) farmers.

Table 4.6: Climate and weather Information products and organization producing it

	Provider of Information service				
Information Product	**1KMS**	**2 MoA**	**3KSC**	**4NGO**	**5None**
	(Multiple responses in percent (%)				
Farmer’s Guide	31 (10.9)	97 (34)	0 (0)	0 (0)	157 (55.1)
Dekad (10-day)Agro-meteorological Bulletin	62 (23)	11 (4.1)	1 (0.4)	6 (2.2)	190 (70.4)
Annual climate review	111 (39.8)	9 (3.2)	2 (0.7)	2 (0.7)	155 (55.6)
Annual or seasonal rainfall prediction	88 (31.1)	25 (8.8)	7 (2.5)	6 (2.1)	157 (55.5)
Newspaper caption on farmers	12 (4.2)	18 (6.3)	95 (33.5)	8 (2.8)	151 (53.1)
Targeted info for maize and wheat farmers	9 (3.2)	107 (37.7)	7 (2.5)	12 (4.2)	149 (52.5)

Key: 1. Kenya Meteorological Services, 2. Ministry of Agricultural, 3. Kenya Seed Company 4. Local NGO, 5. No Organization produces such information

In this study, farmers affirm that no organization produces climate and weather information products and services that can be made accessible to them. The findings in this study in relation to organization producing climate information differ with those by Kadi *et al*.(2011) and KMS, 2014) which reveal that the Kenya Meteorological Services produces climate products or services that include daily weather forecasts; dekadal agro-meteorological bulletins; monthly climate outlooks; seasonal climate outlooks; climate alerts; observed climate impacts; and tailored information for users (farmers) including various types of climate mean maps on different parameters. From the given results it becomes evident that farmers do not access the produced information by the Kenya Meteorological Services hence their assumption that "*No organization produces climate and weather information*". The developed model therefore is envisaged to facilitate access to climate and weather information by farmers once it is operationalized.

Another explanation that could explain why majority of farmers (over 50%) belief that there is no information product produced by any organization is due to the fact that when climate information is produced and distributed, information delivery modes do not facilitate direct access to climate information to the farmers and even if they receive the information from their television set and radio, they do not have a feedback mechanism in place to ask or clarify issues of concern to them.

The uptake of climate and weather information may vary from country to country therefore; the level of users of such information is of outmost importance. If there is a communication mismatch, between the generators of the climate information who are the meteorological scientists and the consumers of the same information who are the farmers, the situation remains the same as there is no shared meaning among two categories or groups. This is corroborated by some field studies conducted in the Southern part of Africa that revealed the existence of a considerable gap between information needed by farmers and that provided by meteorological services. According to a study by Walker (2000) and Blench (1999) there existed a communication barrier between the information providers and its intended users. The farmers know what they want and the Meteorological services know what they need to give to the farmers, but there is no “shared meaning” (without a shared meaning in communication, the value attached to particular information availed to the user is diminished and may not serve the intended purpose.

It is therefore critical to understand important variables among the farmers that have to be taken into consideration. This will include farmer’s indigenous knowledge systems in weather and climate prediction, their farming experience over time, delivery mode of climate information and others. A study by Rengalakshmi (2002) explains that understanding the local people’s perception on rainfall prediction is necessary to communicate the scientific forecast, since it is learned and identified by farmers within a cultural context and the knowledge base follows specific language, belief and process. Perceiving such a knowledge base facilitates social interaction and acceptance among the farmers hence effective utilization of scientific information (climate and weather information).

4.3.6 Organizations providing climate and weather information services

When farmers were asked to state the organizations that provide them with the required climate and weather information service, the following responses were gathered: - 254 (67.9%) farmers reported that KMS produces information on rainfall onset and cessation dates while 213 (57.9%) of the farmers reported that KMS also produces information on rainfall variability and distribution. Still majority reported that no information is provided on 10-day summaries of crop and weather advisories (Dekad data), Normalized Difference Vegetation Index (NDVI) data in some instances and plant density and soil moisture 203 (59%), 183 (60.2%) and 172 (49.4) respectively.

Farmers seem to be more interested on rainfall onset and cessation dates unlike the more scientific NDVI, Dekad data and plant density with the associated soil moisture. This makes them miss out on critical information related to farming decisions that can help them improve their crop output at the farm level. Such information that farmers seem to disregard can be downscaled and delivered via convenient medium like the farmers mobile phones in form of text messages. This will facilitate uptake of such information if it makes sense to the farmer.

The farmers reporting that they received information on temperature variability, potential evapotranspiration and solar radiation were 173 (48.2%) while those who affirmed that no information was provided on the same aspect stated were148 (41.2%) this was almost equally split. This also can be explained by the fact that farmers view rainfall amounts as most important in crop germination and most of them may not bother to understand the role of temperature variability, PET and solar radiation. More than half 208 (57.6%) reported to have received information on Crop disease/pests and adverse weather conditions from District Agricultural Officers as indicated in table 4.7.

Table 4.7: Climate and weather information service and the provider in Uasin Gishu County

	Provider of Information service				
Information Service Provided	**1KMS**	**2AEO**	**3KSC**	**4Farmers**	**5None**
	(Multiple responses in percent (%)				
Rainfall onset and cessation dates	254 (67.9)	26 (7)	5 (1.3)	41 (11)	48 (12.8)
Rainfall variability and distribution	213 (57.9)	28 (7.6)	3 (0.8)	11 (3)	113(30.7)
Temperature variability and potential evapotranspiration, solar radiation	173 (48.2)	12 (3.3)	5 (1.4)	21 (5.8)	148(41.2)
Crop disease/pests and adverse weather conditions	42 (11.6)	208(57.6)	7 (1.9)	23 (6.4)	81 (22.4)
10-day summaries of crop and weather advisories	90 (26.2)	28 (8.1)	11 (3.2)	12 (3.5)	203 (59)
Plant density and soil moisture	51 (14.7)	93 (26.7)	28 (8.0)	4 (1.1)	172(49.4)
Normalized difference vegetation index data in some instances	84 (27.6)	23 (7.6)	11 (3.6)	3 (1.0)	183(60.2)

Key: 1. Kenya Meteorology Department, 2 Agricultural Extension Officers, 3. Kenya Seed Company 4. Farmers who understand better climate and weather patterns prevailing in the year, 5. None of the information is provided

The results in the study show that most of the climate services especially on rainfall onset and cessation dates, rainfall variability and distribution is obtained from the Kenya Meteorological Services through the seasonal climate outlook bulletin and "*utabiri wa hali ya anga*" (daily weather forecasts) relayed on radio and television to the Kenyan public including farmers. The Agricultural Extension Officer is a critical component of delivery of climate services to the farmers as seen earlier and integrating them climate information provision is beneficial. This is because they are able to interact with the farmer at the farm level where consultation takes place on emerging issues as seen on the responses on crop disease/pests and adverse weather conditions climate service provision in Table 4.7.

According to information from key informant interviews carried out, the Kenya Meteorological Services under the Ministry of Environment, Water and Natural Resources has partnered with the Agricultural Sector Development Support Programme in the County to come up with Participatory Scenario Planning Process where they come up with a weather outlook for the prevailing season and advisories (*Weather Outlook for Uasin Gishu County for March – May 2015 Rainfall Season and Advisories*). Scientific forecast spearheaded by KMS is integrated with elders input on weather forecasting using traditional methodologies. The stake holders include scientists, the community, traditional forecasters and those other entities that rely on such information in managing their activities. The consultative meeting produces a harmonised weather forecast for the county, develop advisories and eventually go to the field to disseminate the information followed by monitoring to check on uptake levels of climate information (Ramtu & Kemei, personal interview May 15, 2015).

The study also reveal that to be able to ensure access and use of climate and weather information services effectively by farmers, it is paramount to understand the local people's knowledge systems as this influences a lot their ability to embrace scientific information. There is need also to establish clear communication channels for the delivery of such information. Such efforts need to be complemented with effective outreach programs coupled with educational initiatives to help users of relevant climate information to realise its full potential. Like this study, the findings of Sivakumar (2006) and Hill & Mjelde (2002) showed that giving greater priority to extension and communication activities (including the communication of forecast uncertainties and probabilistic climate information) and improving the relevant institutional and policy environment is of outmost importance.

4.3.7 Climate and weather information required by farmers in Uasin Gishu County

It was found necessary to understand what type of information farmers require so that this could be addressed by the concerned institutions when attempting to provide the needed agro-climate information. The study finding reveal that more than half of the farmers growing maize reported to require information on rainfall onset and cessation dates 238 (63.8%). This information was rated as high in priority. They also rated the importance of accessing information on rainfall variability and distribution at both high level 173

(46.5%) and moderate 133 (35.8%). Maize farmers also indicated the need for information on crop disease/pests and adverse weather conditions to a high extend 222 (59.4%) as shown on Table 4.8.

The 10-day summaries of crop and weather advisories and Normalized difference vegetation index (NDVI) data type of information service was rated low by maize farmers. This can be explained by the fact that farmers did not know much about NDVI data and 10 – day summary (Dekad data) as explained during the data gathering period by farmers themselves. They did not know anything about such a service.

Table 4.8: Extent of the need for information on seasonality in maize production in Uasin Gishu County

Information required	Extend of Need of climate & weather Information			
	Don't Know (%)	Low (%)	Moderate (%)	High (%)
Rainfall onset and cessation dates	25 (6.7)	13 (3.5)	97 (26_)	238 (63.8)
Rainfall variability and distribution	26 (7)	40 (10.8)	133 (35.8)	173 (46.5)
Temperature variability, potential-evapotranspiration, solar radiation	48 (12.9)	100 (26.8)	123 (33)	102 (27.3)
Crop disease/pests and adverse weather conditions	29 (7.8)	45 (12)	78 (20.9)	222 (59.4)
10-day summaries of crop and weather advisories	95 (26)	96 (26.3)	94 (25.8)	80 (21.9)
Plant density and soil moisture	60 (16.2)	93 (25.1)	114 (30.2)	104 (28)
Normalized difference vegetation index data in some instances	144 (41.6)	96 (27.7)	62 (17.9)	44 (12.7)

Table 4.9: Extend of need of information on seasonality in wheat production in Uasin Gishu County

Information required	Extend of need of climate and weather information				
	Don't Know (%)	**Low %**	**Moderate (%)**	**High (%)**	**Mean(SD)**
Rainfall onset and cessation dates	17 (4.7)	17 (4.7)	100 (27.4)	231 (63.3)	3.5 (0.8)
Rainfall variability and distribution	8 (2.2)	60 (16.6)	141 (39.1)	152 (42.1)	3.2 (0.8)
Temperature variability, potential eva-potranspiration and solar radiation	43 (11.9)	107 (29.6)	121 (33.4)	91 (25.1)	2.7 (1.0)
Crop disease/pests and adverse weather conditions	15 (4.1)	38 (10.4)	96 (26.4)	215 (59.1)	3.4 (0.8)
10-day summaries of crop and weather advisories	104 (29.1)	98 (27.4)	85 (23.7)	71 (19.8)	2.3 (1.1)
Plant density and soil moisture	52 (14.6)	96 (27)	114 (32)	94 (26.4)	2.7 (1.0)
Normalized difference vegetation index data in some instances	157 (46.9)	82 (24.5)	62 (18.5)	34 (10.1)	1.9 (1.0)

For wheat growing, more than half of the same farmers reported to require information on rainfall onset and cessation dates 231 (63.3%), and Crop disease/pests and adverse weather conditions 215 (59.1%) to a high extend as wheat farmers (Table 4.9). The 10-day summaries of crop and weather advisories and Normalized Difference Vegetation Index (NDVI) data type of information service was rated low in relation to wheat farming or they did not know anything about such service.

On average, farmers rated information on rainfall onset and cessation dates as high (a mean score of 3.5) though there was a significant variation in the responses as indicated by the standard deviation (0.8). Rainfall variability and distribution, temperature variability, potential eva-potranspiration and solar radiation, crop disease/pests and adverse weather conditions and plant density and soil moisture were rated as moderate (mean score 3) with significant variation in the responses as indicated by the standard deviation (≥0.8). 10-day summaries of crop and weather advisories and Normalized difference vegetation index data in some instances were rated as low.

The farmers growing both maize and wheat seem to consider in order of importance climate and weather information responsible for their crop success starting with rainfall onset and cessation dates; information seen as the most crucial followed by information on crop disease/pests and adverse weather conditions. Information on rainfall variability and distribution comes in as the third most important parameter as rated by farmers.

The results in this study are similar to findings in the study on "The state of climate information services for agriculture and food security in East African countries working paper no. 05 by Kadi *et al.* (2011) which argues that for better operational agricultural practices, information provided by climate and weather information providers on the daily and weekly weather forecast and the 10-day climate outlook were considered as important by farmers and other users. Similarly, seasonal rainfall onset and cessation dates, advisories/alerts (extreme climate events), early warnings (outbreaks of pests and diseases), monthly climate outlook, agro-met forecasts, seasonal climate forecast, were found to be very important. On the 10-day climate information provided by National Meteorological and Hydrological Services (NMHSs), the finding differed considerably as farmers in this study rated the said information as low in in their need list while the previous study rated the same information as very useful. This could be attributed to the fact that the two study populations were not homogeneous in any way and had various diverse needs altogether. The levels of understanding may differ significantly hence affecting responses.

4.4 Disseminating climate and weather information to farmers

An examination on modes of communicating climate and weather information to maize and wheat farmers in Uasin Gishu County reveal a group of farmers whose majority receive climate and weather information through radio 313 (79.8%) and television 266 (68.4%). Minority reported to receive through internet/E-mail 31 (7.9%) and fax or fixed telephone 5(1.3%) as indicated in Figure 4.5

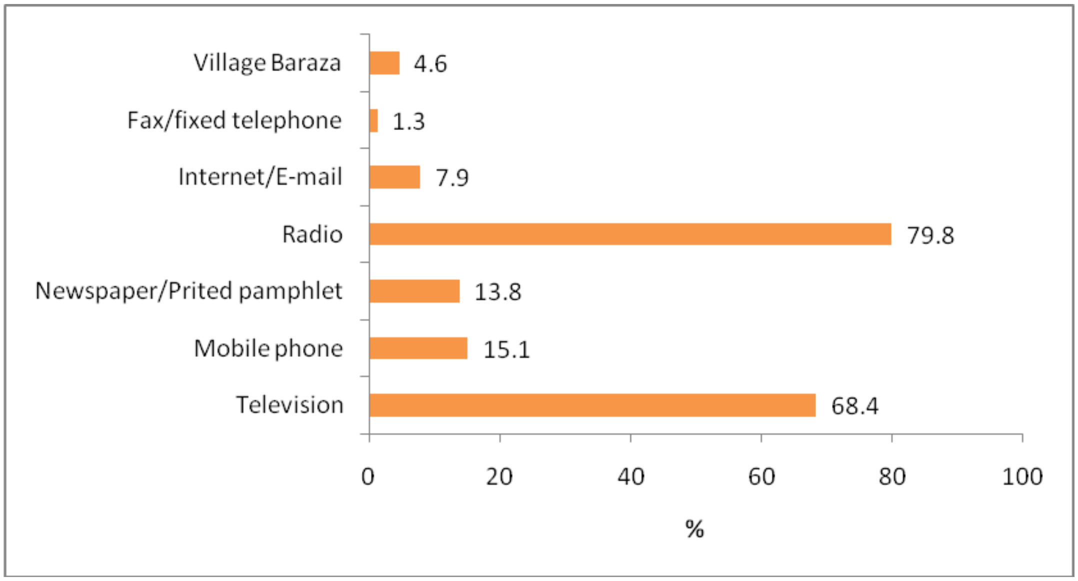


Fig 4.5: Media for communicating information on whether and climate in Uasin Gishu County (Source: Field Data, 2014)

The results on the media for communicating climate and weather information show that radio is the most commonly used channel to receive the climate information by farmers followed by use of television. The results are similar to findings of studies by Walker, (2001) and WMO (2000) showing that the media (newspapers, radio and television) are all very effective means of informing the public as they reach a maximum number of people. The most common means of reception of weather forecasts, warnings and other information is clearly by radio, (100% world-wide), followed by television (93% world-wide). This phenomenon is clarified further by Wanungwa of the Agromet section at KMS during key informant interview session in 2014. The agro meteorologist explained that seasonal forecasts are disseminated through the media and are downscaled by the County Meteorological Director to specific regions. There are specific visits to the Agromet division by organizations seeking climate and weather information. Also

Ministry of Information and Kenya Agricultural Research Institute (KARI) get opportunities to meet people to share the information during Chief's Baraza and farmer workshop.

According to the Uasin Gishu County Director of meteorology, climate and weather information in form of advisories emanate from the Deputy Director in charge of forecasting and County Meteorological services at KMS headquarters in Nairobi. The information is cascaded to all the County Directors of Meteorology via e-mail (Ramtu, 2015). The findings shown in Figure 4.6 are on the media preferred by farmers to receive climate and weather information. Majority of the farmers prefer to receive the information through radio 261 (66.4%), mobile phone 202 (51.4%) and television 170 (43.3%). Minority 7 (1.8%) preferred fax/fixed telephone as indicated in the results in Figure 4.6.

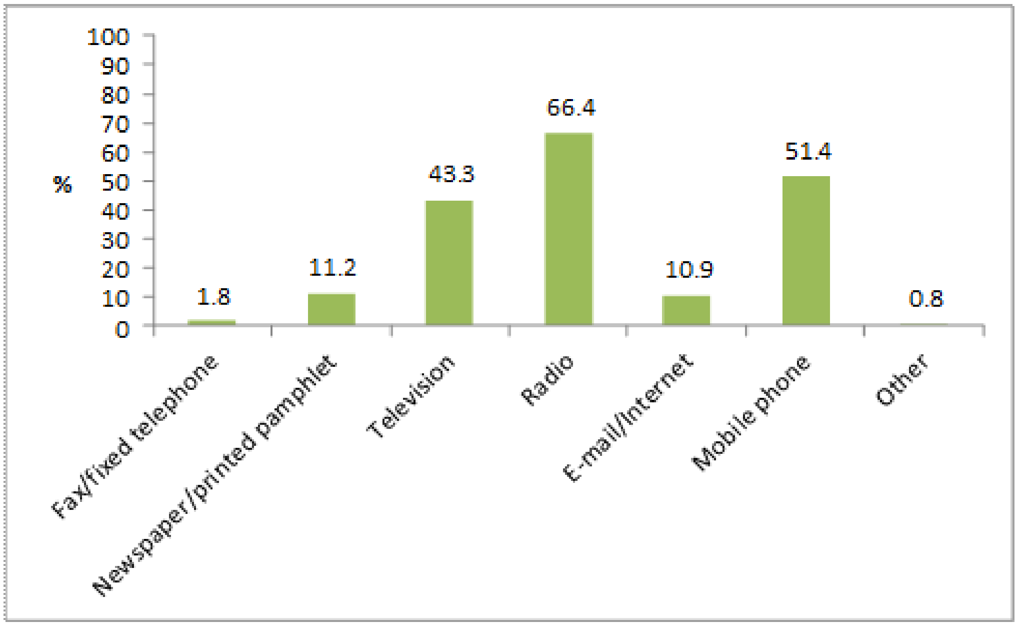


Fig 4.6: Preferred media to receive climate and weather information by farmers in Uasin Gishu County (Source: Field Data, 2013)

The results from the study show that majority of farmers still prefer the radio as the best method to receive climate and weather information. However, a rather more interesting phenomena is that still quite a large number 202 (51.4%) who are more than half of those participating in the study prefer the use of mobile phone technology (SMS alerts) to receive the same information. Farmers in this study were enthusiastic and eager about receiving direct SMS alerts in their mobile phones as explained during data collection exercise. The finding agrees with that by CGIAR (2011) that clearly showed that in Africa where half the continent's population uses a mobile phone, people now have unprecedented access to information via their handsets. Farmers from isolated areas can access weather information via text messages (SMS) or phone calls, to prepare for upcoming drought spells, heavy rains or floods.

It is now evident that the role of mobile phones in delivery of information will reign in most developing countries for quite some time. The developed web based application to relay climate information to the farmers will leverage the KMS efforts to deliver agro-climate information to farmers in the community in real time. According to Karanasios (2011), mobile phones are likely to remain the key information medium as they have been used to provide agricultural advice in the form of voice and text messages at the farmer level. This is true due to the fact that there has been a rapid growth of mobile phone networks in developing countries in recent years and mobile phone usage has expanded greatly; mobile phones thus is regarded as a more accessible and less expensive means to carry out communication activities.

4.5. Perception of farmers towards the use of climate and weather information and the influence of their traditional knowledge system in maize and wheat production

4.5.1 Farmers perception on climate variability in the recent years

In order to understand what farmers perceive or belief in relation to climate variability and its resultant effects to maize and wheat growing activities they were asked to use rainfall parameter to gauge the changes as this phenomena is relevant and familiar to them. They were asked to state whether *"in the recent years there were any changes in rainfall patterns experienced by them and that even the timing for maize and wheat* *growing had become uncertain"*, a total of 142 (36.7%) farmers strongly agreed with the statement and a further198 (51.2%) agreeing so and affirmed that the change in rainfall pattern had led to declines and losses in maize and wheat production. Only 47 (12.2%) disagreed with the statement as shown in Figure 4.7.

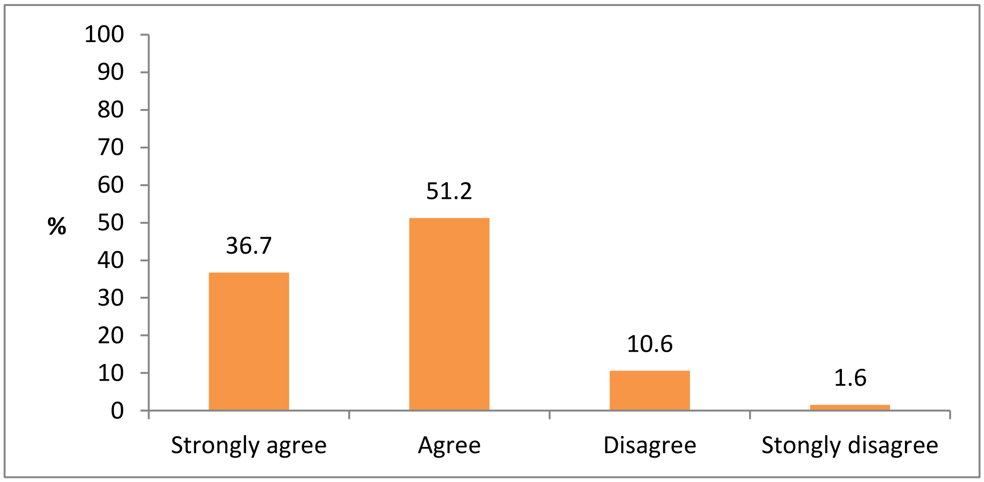


Fig 4.7: Changes in rainfall patterns affecting Maize and wheat production in Uasin Gishu County (Source: Field Data, 2013)

The study reveal that over 340 (87.8%) of the farmers agreed that in the recent years they had experienced changes in rainfall patterns and even the timing for maize and wheat growing had become uncertain and contrary to what they have known over time. This outcome seem to agree with Global Humanitarian Forum and World Meteorological Organization report stating that with the prevailing changes in weather patterns due to climate change, traditional knowledge relating to agriculture otherwise reliable for centuries could be rendered obsolete (WMO, 2012). The prevailing climatic variability has created a great need for climate and weather information to be delivered to those engaged in farming activities to supplement indigenous knowledge systems.

The prevailing climate variability makes farmers decisions on maize and wheat growing more difficult to make and in most cases farmers make their own uninformed decisions which has seen them incur losses in the farming activity. It is important to note that farmers were admitting that their knowledge and experience in maize and wheat growing was facing serious challenges and the need to supplement this knowledge with other technologies able to predict in a better way the rainfall patterns was inevitable.

On the state of yield of maize and wheat in the last 5 years in Uasin Gishu County, Majority of farmers responding 266 or (67.9%) reported that over the last 5 years, the yield of maize production in their respective farms has been increasing while 214 (58.3%) reported that the yield of wheat per acre has been declining as shown in Figure 4.8.

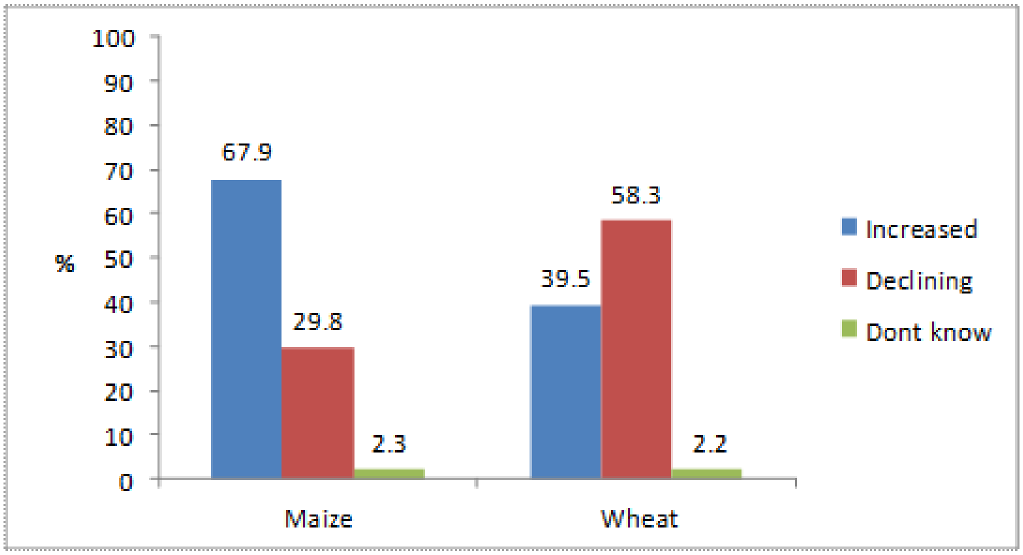


Fig 4.8: State of yield of maize and wheat per acre over the last 5 years in Uasin Gishu County (Source: Field Data, 2013)

This increase and degrease in maize and wheat production confirms that the changes farmers are experiencing are real and is affecting their production capacities. The increase in maize yields and the stated decline in wheat production could still be attributed to the changes in climatic parameters. The IPCC report of 2001 on projected changes in Africa for the coming decades corroborates the findings in this study. The report argues that although the magnitude of projected rainfall changes for 2050 is small in most African areas, it may be up to 20% of baseline values. These projected changes could lead to significant decreases in crop yields in some rain-fed African agricultural systems, with overall crop yields potentially falling 10–20% by 2050 because of warming and drying. However, this effect will not be uniform – yield losses may be much more severe in some places, while crop yields may increase in others (IPCC 2001).

It is equally important to note that other extraneous factors could have also come into play to create the increase in maize and the decline in wheat production. They may include improved seed variety in maize, proper use of fertilizer especially top dressing for maize, fungal infection and what farmers refer to as stem and leave rust infestation for wheat and others. Post-harvest losses could also account for the decline in "production per acre" as most commonly referred by farmers.

4.5.2 Factors influencing a farmer's decision in maize and wheat growing calendar

In an effort to understand what influences a farmers decision to commence an activity in the maize and wheat growing calendar (when to start land preparation, planting, type of crop to grow, weeding, top dressing, spraying of weeds, fungus or bacterial infection on crops and even harvesting) the following responses were gathered from the farmers:- Those who commence their activities just because those are the dates known to them through their experience over time in maize and wheat growing were 333 (84.9%). Farmers affirmed this by the fact that "*the farm is ploughed and prepared in December to February every year but planting for maize starts in March and Continues to April when long rains season commence in Uasin Gishu County. Wheat land is ploughed just like maize but harrowing continuously from May to June when planting starts and spills over to early July. Other crop activities follow as per the rain availability and crop growth (weeding, spraying, top dressing and others)"*.

Another group of farmers 141 (36%) rely on looking around for *"signs that rains are about to fall (wind direction from east to western side, cloud movement from eastern to western side of their farms and high sunshine intensity during the day and warm nights)".* Advice from the Ministry of Agriculture Livestock and Fisheries officials was mentioned by 29 (7.4%) of the farmers as having assisted them make decisions on the start of farming activities in their respective farms as shown in Figure 4.9.

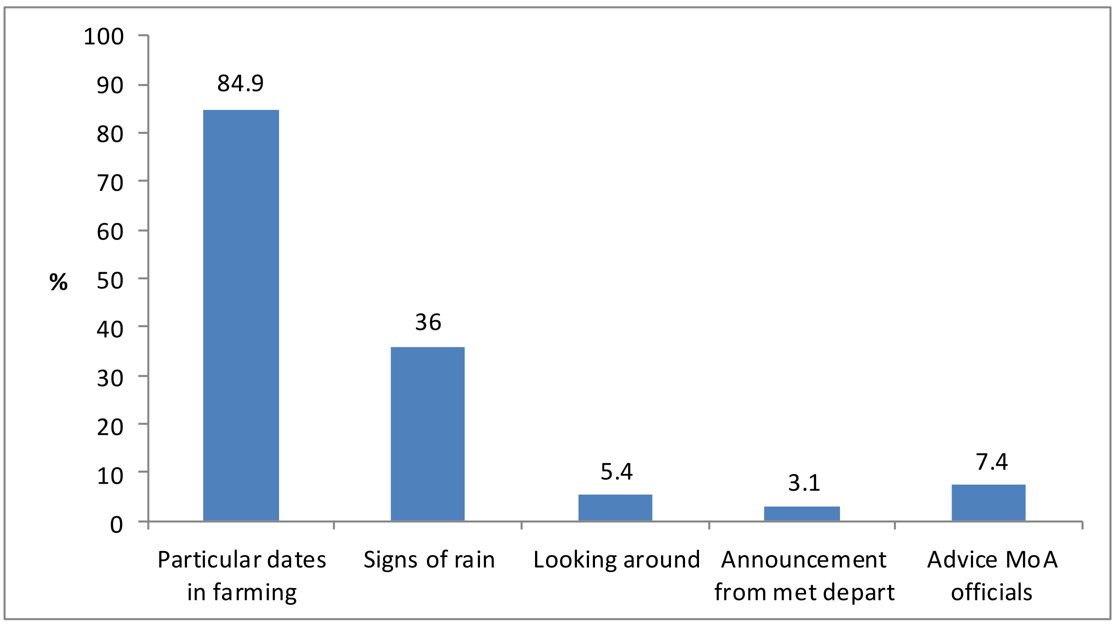


Fig 4.9: What determines a farmers decision to commence farming activities in Uasin Gishu County (Source: Field Data, 2013)

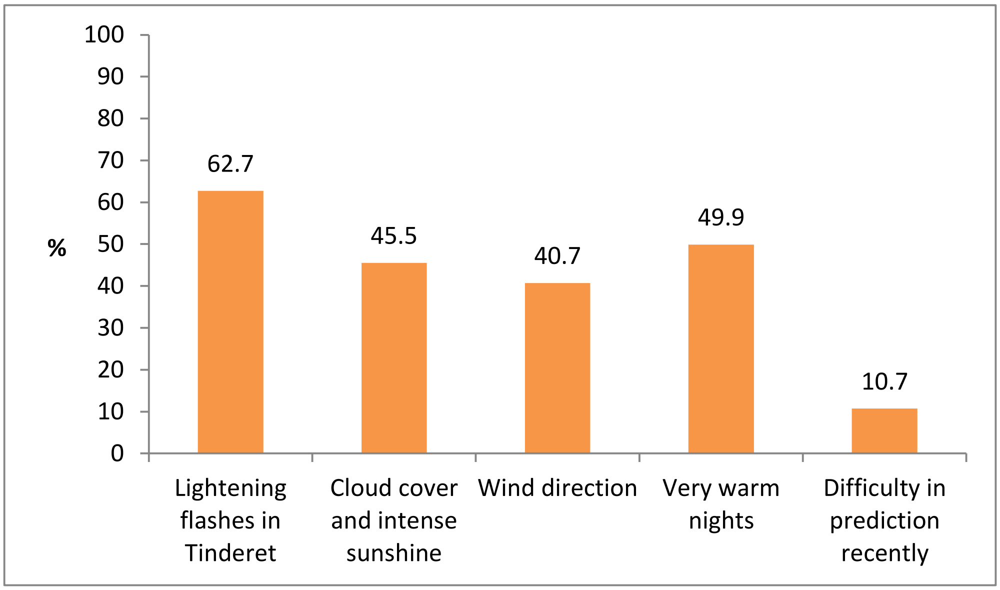
The results reveal a farming population solely dependent on their own indigenous knowledge system or experience gained over time in maize and wheat growing to make certain farming decisions. The fact that 333(84.9%) farmers commence their activities just because those are the dates known to them through their experience over time and another 141 (36%) looking around at some indigenous knowledge system indicators that rains are about to fall is a clear indication that framers do base their faming decisions on their own indigenous knowledge systems and experience gained over time.

Some of the traditional knowledge indicators that show that rains are about to fall as stated by farmers include "*wind direction blowing from east to western side, cloud movement from eastern to western side of their farms and high sunshine intensity during the day and warm nights. Also there are lightning flashes around the Lake Region or Tindiret area in Nandi South).* Depending solely on experience and knowledge over time practising maize and wheat creates a big challenge to the farmer especially with the prevailing climate variability that keeps on distorting seasons known to farmers. This makes farmers vulnerable and may incur losses during associated climatic variability. The findings in this study correspond with findings in Blench (1999), a World Bank funded workshop titled "Users responses to seasonal climate forecasts in Southern Africa" held in Tanzania which asserts that in different parts of the world, farmers depending on rainfed cultivation have developed complex cultural models of weather and may be able to cite local predictors of seasonal climate.

Also Bryan & Behrman (2013) cited from Vogel & O'Brien (2006) argue that even when climate information is available, incorporation of scientific climate information into local decision making may not often occur because of the way such information is communicated and disseminated. There is need to identify clear channels of information delivery and also downscale the information to make sense for the farmer for effective uptake of such information.

4.5.3 Farmers indigenous knowledge systems indicators in rainfall prediction

Farmers were asked to state what they thought were signs that rains were about to fall in their respective areas based on their experiences gained over time as maize and wheat farmers. The responses are as shown in Figure 4.10. Those who affirmed and believed that the real sign for rain commencement in their area is when there are consistent lightning flashes around the Lake Region or Tindiret area in Nandi South 245 (62.7%). Those farmers who belief that heavy cloud cover and intense sunshine during the day was a sign that rains were about to commence were 178 (45.5%). The farmers relying on wind direction (eastwards and sometimes westwards) to alert them that the rains were about to commence were 159 (40.7%). Farmers who belief that very warm nights was a sign that rains were about to fall in their area were 195 (49.9%). Those who affirmed that in the recent years, it has been quite difficult to predict when the rains are about to fall were few farmers 42 (10.7%).



(*multiple responses - farmers were allowed to note as many reasons as were applicable)

Fig. 4.10: Indigenous knowledge system indicators in rainfall prediction in Uasin Gishu County (Source: Field Data, 2013)

The findings in this study reflect a farming community that has developed its own indicators in the traditional knowledge system on rainfall prediction. The following set of indicators of rainfall used by farmers include consistent lightning flashes around the Lake Region or *Tindiret* area in *Nandi* South, heavy cloud cover and intense sunshine during the day, blowing of wind towards eastern side and sometimes westwards and very warm nights. During the key informant interview, the following were identified as key indicators used by farmers especially among the *Nandi* community and include examining the behavior of certain plants or trees to determine rainfall near onset. Among the plant species known include the tree *Erithrina Abyssinica (Kakarwet).* The tree starts flowering red with full leaves regained, *Vernonia Auriculifera (Tepengwet)* tree starts flowering, *Flacourtia Indica (Tungururwet)* start budding is an indicator for rainfall near onset and farmers prepare to do dry planting. The Fig tree (*Ficus Sycomorus*) known locally by farmers as *(Mogoiywet)* start shading leaves is an indicator for rainfall near onset. One other small plant (herb) growing in thickets or bushes *Scadoxus multiflorus* of the *Amaryllidaceae* family *(Ngotiotet)* starts flowering red around March period and found in thickets or bushes near river banks is a real indicator of rainfall near onset.

Meteorological indicators include wind direction blowing eastwards signifying rainfall near onset; clouds thicken at horizon and wind blowing from eastern to western side of their farms indicating near onset of rainfall. There is also high sunshine intensity during the day and warm nights or high temperatures at night and low temperature in the evening signify near onset of rains. Frequent lightning flashes around *Tindiret* area (Lake Region) with some dark cloud forming is an indicator of near rainfall onset. Animal indicators include migratory birds that include White Stock *(Kaptalaminik*) moving or flying towards the north signifying near rainfall onset and when flight changes towards the south, this signifies cessation. In addition to the indicators, the community had a unique way or prayer asking their God for rainfall or water for their domestic use during drought manifestation. The traditional prayer song *(ingoo)* was sang by mature women and those at child bearing age at night and many groups (3 to 4 groups of women) from various locations could join in the prayer song at night converging at one place in the open near a watering point away from homesteads as participants do it without cloths on them. They carried with them cooking items that include cooking sticks (*mukanget ak Kurbet*) and some finger millet flour (*Beek ab Kipsongik).*

This form of prayers was answered almost instantly there and then because before mid-night, heavy rains would fall on the singing women as they retreat back to their homesteads happy (key informant interview, 2015).

Indigenous knowledge rainfall indicators were also supported by season classification that would lend credence to the indicator being observed. January period was referred as *Ngatioto*; February is *Kiptamo*; March is *Iwotgut*; April is *Waki;* May is *Ngei*, June is *Roptui;* July referred to as *Buret*; August is *Epeso;* September is *Kipsunde ne Tai;* October is *Kipsunde nebo Aeng* November is *Mulgul Netai* and December referred to as *Mulgul nebo aeng.* All the seasons were named according to what happens during that particular period as explained in a key informant interview carried out then. However, this seasons have shifted for example rains used to fall in January and indicated by *Scadoxus multiflorus* of the *Amaryllidaceae* family *(Ngotiotet)* flowering but it is now being seen appearing and flowering around March still indicating rainfall near onset.

The study by Kadi et al. (2011) also supports the findings in this study and explain that majority of farmers prefer indigenous forecasting knowledge more than contemporary forecasting. The reasons being that indigenous information is more compatible with local culture and it has been tested, tried and trusted. In addition, it is more specific and is in a language that can be understood better by communities. There is a clear view here that it is important to document indigenous knowledge system used by maize and wheat farmers and ultimately integrate the knowledge with science based climate forecasting. Integrating both scientific and traditional knowledge will enable uptake and ownership of climate information by communities hence helping farmers avoid losses as a result of climate variability. This is because farmers consider the fact that their perspectives have been taken into consideration when their indicators for predicting rainfall near onset have been taken into account. This creates ownership and sustainability.

To effectively mainstream access to climate and weather information in key sectors, it is important to understand the local perspectives in relation to climate variability and coping strategies in place. Ignoring this fact might hinder uptake of climate and weather information by the farmers hence leaving them completely vulnerable to climatic variability.

Farmers were further tested on whether they relied on the use of climate and weather information or their indigenous knowledge/practice in their farming decisions and the responses were varied as outlined in Table 4.10

Table 4.10: Belief in use of climate and weather information or indigenous knowledge in Uasin Gishu County

Statement	All the time	Most of the time	Sometimes	Not at all
Often belief in seasonal climate and weather information	68 (17.3)	80 (20.4)	219 (55.7)	26 (6.6)
Often rely on experience/indigenous knowledge in maize production	89 (22.7)	148 (37.8)	141 (36)	14 (3.6)
Often rely on experience/indigenous knowledge in wheat production	85 (22.8)	163 (43.7)	111 (29.8)	14 (3.6)

More than half of the farmers 219 (55.7%) sometimes belief in seasonal climate and weather information, 163 (43.7%) rely on experience/indigenous knowledge in wheat production most of the time and 148 (37.8%) rely on experience/indigenous knowledge in maize production most of the time as outlined in Table 4.10. The results show a group of farmers who tend to belief in the use of climate and weather information to conduct their business of maize and wheat crop growing however, they remain influenced by their traditional knowledge system which they have relied upon over the years. This arrangement becomes very challenging at present with the prevailing climatic variability.

There is need to balance access to the two sets of information by farmers as stated by farmers in this study. The findings in the study agree with those in a paper on community based adaptation in climate change by Bryan and Behrman (2013) cited from Roncoli, Ingram, & Kirshen (2002) which reveal that farmers in Burkina Faso traditionally rely on observation of environmental indicators to predict climate patterns, but they lost confidence in their ability to predict rainfall given the increased climate variability and increasingly seek to incorporate scientific information.

To understand further the usage of climate and weather information and the influence of farmer’s indigenous knowledge systems in maize and wheat production over time, indicators used in rainfall prediction were examined together with usage of climate and weather information as shown in Table 4.11. The results portray existence of a significant relationship between indigenous knowledge system indicators for rainfall prediction and the use of climate and weather information in maize and wheat production activity as shown in Table 4.11

Table 4.11: Relationship between climate information and indigenous knowledge indicators in Uasin Gishu County

Indigenous Knowledge indicators	Climate & Weather Information Use		Chi	P
	Yes	No		
Lightning flashes around lake region/Tindiret area in Nandi	110 (44.7%)	136 (55.3%)	*0.476*	*0.490*
Cloud cover and intense sunshine	70 (39.1%)	109 (60.9%)	*6.391*	*0.011*
Wind direction	83 (52.2%)	76 (47.8%)	*4.059*	*0.046*
Very warm nights	70 (35.7%)	126 (64.3%)	*16.832*	*<0.001*
Difficulty in prediction recently	23 (53.5%)	20 (46.5%)	*1.074*	*0.300*

A higher proportion of the farmers relying on their indigenous knowledge system indicators to predict rainfall hence making decision on farming activities do not use climate and weather information as indicated in table 4.11. A greater negative influence is created on utilization of climate information by farmers if they are left alone to decide whether to embrace climate information or stick to their indigenous knowledge systems in their farming decisions. Farmers indigenous knowledge indicators and experience gained over time practising maize and wheat growing influence a lot their ability to use climate information therefore there is need for the County Directorate of Agriculture in

Uasin Gishu to undertake greater sensitization meetings during village Barazas and use of agricultural shows and farmer's field day outlets to educate farmers on the need to consider using climate information in addition to their experience learned over time in farming decisions as this will cushion them against extreme weather variations that may lead to crop losses.

Plate 2: Explanation of weather phenomena by a traditional weather forecaster in Moiben Sub County of Uasin Gishu (Source: Author, 2013)

Plate3: Laban Kipkon predicts weather phenomena in December 2013 at Moiben Sub-County of Uasin Gishu County (Source: Author, 2013)

The traditional weather forecasters form part of the decision making process sometimes when farmers experience delayed onset of rainfall when they look at their farming calendar. Farmers listen to what known traditional weather forecasters like Mzee *Laban Kipkon* of *Moiben* Sub-County can deduce from reading the arrangement of stars in the solar system and the "positioning of male and female star". *Kipkon* predicted that "*there was going to be plenty of rain in December 2013 and that rains would continue to March 2014. He advised the farmers to grow short duration crops like beans that take 3 months to mature*".

From the diverse responses by the farmers, it is evident that indigenous knowledge system plays a crucial role in farmer's decision making process; ultimately, it has a significant impact on their activities. With climate change being real in the region, farmers relying on "known signs" or meteorological indicators derived in their traditional knowledge systems are at a greater risk of losing out on benefiting from prevailing good conditions or avoiding bad weather leading to crop loss. Thus important to incorporate climate and weather information in their decision making process. Indigenous knowledge weather prediction methodologies are now facing serious challenges related to environmental degradation and interference of the natural ecosystem balance by man.

According to the Director of Meteorology in Uasin Gishu County and some traditional weather forecasters interviewed, most indigenous trees have disappeared completely and are being replaced by exotic trees which are alien to indigenous weather predictors. They have thin leaves thus their ability to sequestrate carbon in the atmosphere is reduced hence does not help much in arresting greenhouse gasses. Burning of farms has not only destroyed micronutrients and shrubs but also destroy insects and their migratory paths which traditional weather forecasters use to predict near onset of rains.

Some bird species have migrated elsewhere where they can still find a natural habitat hence rendering traditional weather forecasters using birds to predict onset of rains helpless. The slaughtering of a goat and dissecting the stomach to read what type of vegetative growth consumed by the goat is no longer viable because inside the slaughtered goats stomach, you will find other food stuff including polythene bags that cannot be used to carry out any tradition weather forecast unlike the earlier days when there was no much interference to the vegetation cover. Weather prediction then was almost reliable.

It is however important to integrate both scientific and traditional knowledge system as the scientific forecast diverges from traditional farmer's prediction in scale and to some extent on predictors (Ziervogel, 2011). In any case, some of the principles of the predictors like wind flow, temperature changes converge with the scientific forecast. Farmers have been using combination of various biological, meteorological and astronomical indicators to predict the rainfall. While the scientific forecast are developed using the predictors such as wind, sea surface temperatures and others which are primarily meteorological indicators.

4.5.4 Value attached to utilization of climate and weather information by farmers

To understand what value farmers attached to climate and weather information in relation to their maize and wheat growing, they were asked to rank their responses either as very important, important, unsure, and not important. As indicated in Figure 4.11, more than half of the farmers view climate and weather information as very important in both maize and wheat growing 215 (54.8%) and 206 (54.4%) respectively. Similarly, a large number of farmers still considered the same information as important 143 (36.7%) for maize growing and 136 (36.1%) for wheat growing.

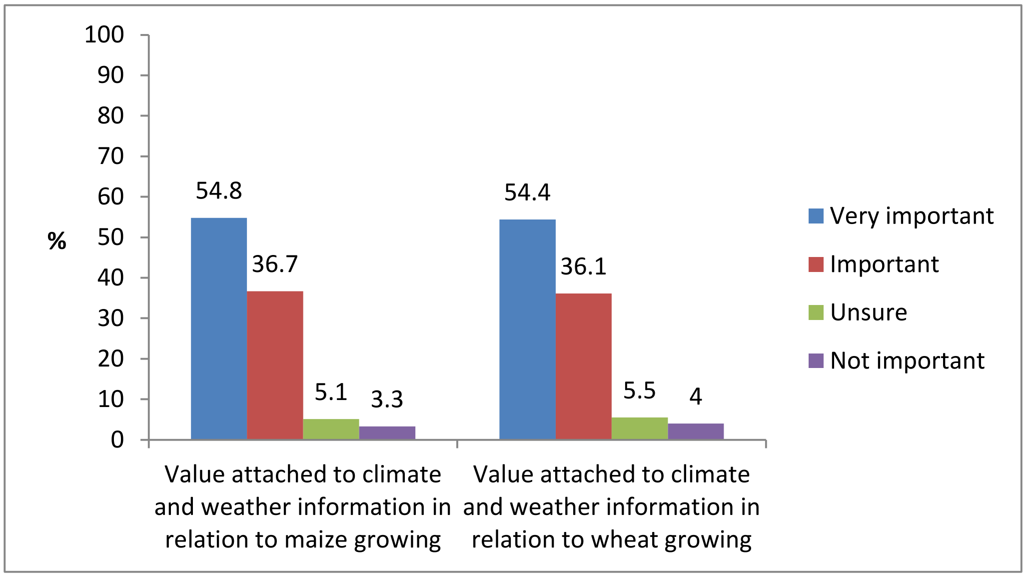


Fig. 4.11: Value attached to climate and weather information by farmers in Uasin Gishu County

(Source: Field Data, 2013)

As seen earlier farmers in this study have agreed that climate and weather information is important but whether this translates into action remains to be tested. A mere belief in some variable (climate and weather information) does not necessarily translate into adoption of the same especially where traditional knowledge systems influence decisions as seen elsewhere in the results of this study. This calls for greater efforts to educate farmers to be able to use climate information in farming decisions as mere belief in it would not alter losses they will incur especially with the prevailing climate variability which has distorted order of activities known to farmers in maize and wheat growing.

To understand further whether farmers perceive the climate and weather information as valuable and its subsequent usage, cross tabulations were done on the two variables of interest and the results are highlighted in Table 4.12

The results show a significant relationship between value attached to climate and weather information and its usage (*chi = 10.325, p = 0.016).* This means that the proportion of use of climate and weather information among those who perceive the information as important is higher compared to those who perceive it as not important.

Table 4.12: Relationship between value attached & use of climate and weather information by farmers

Value Attached to information	**Climate & Weather information use**		**Chi**	**P**
	Yes	**No**		
Very Important	109 (50.7%)	106 (49.3%)		
Important	66 (45.8%)	78 (54.2%)	10.325	0.016
Unsure	5 (25%)	15 (75%)		
Not Important	2 (15.4%)	11 (84.6%)		

From the responses stated in relation to value attached to climate and weather information, it is apparent that great value is attached to such information by farmers. However, this has not been reflected in practice as seen earlier when 333 (84.9%) farmers stated that they commence their farming activities at "*particular known dates in the farming calendar learned through experience over time as maize and wheat grower*". With climate variability being real, most of the farmers have incurred losses as they may not be flexible enough to accommodate changes in their "known farming calendar dates". Access challenges to climate and weather information related to the mode of communicating this information, the format and timing challenges of the information can partly explain this phenomenon. Since farmers who access this information use it for farm decisions, it is crucial that any hindrance in accessing climate and weather information should be addressed urgently by way of policy intervention by the respective County governments.

When farmers were asked to state reasons why they sometimes believed or not in climate and weather information provided by the Meteorological Department, 170 (42.5%) affirmed that they believed in the information as it supported what they already know as maize and wheat farmers as shown in Figure 4.12

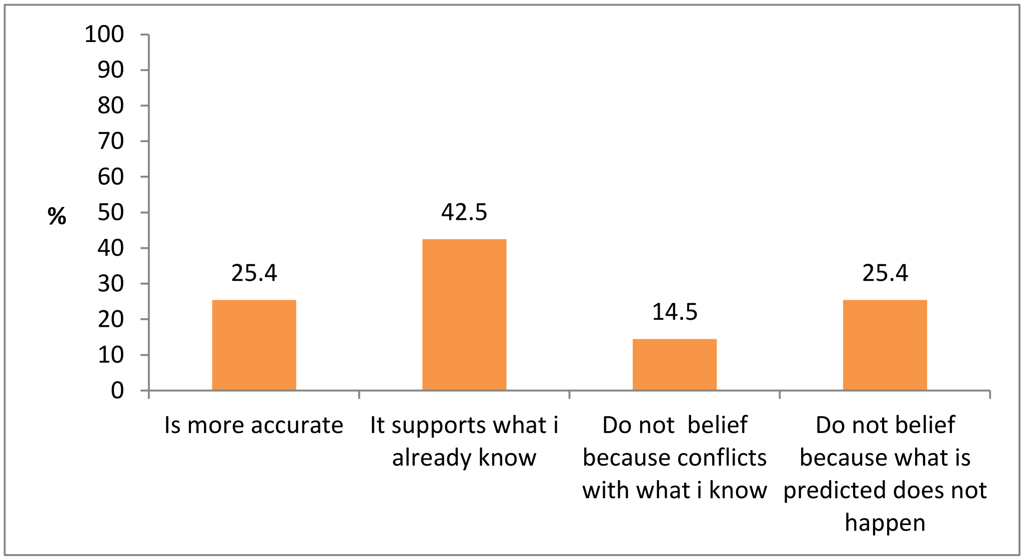


Fig 4.12: Reason why farmers believe in climate and weather information in Uasin Gishu County. **(Source: Field Data, 2013)**

From the observations of the responses, it is clear that farmers agree that climate information is supporting their indigenous knowledge systems. The reasons for belief and non-belief of climate information use are varied. Farmers who know and belief that the climate and weather information is more accurate are equally divided with those who do not belief in the information. Further, another group of farmer seem not to belief in climate and weather information as it usually conflict with what they already know (indigenous knowledge systems) about rainfall onset dates and distribution. This view by farmers has been supported by Bryan and Behrman (2013) on community based adaptation and observes that despite significant scientific gains in predicting the climate, often there is a lack of climate information available at the local level due to uncertainty in climate projections and seasonal forecasts.

Also Ziervogel (2001) asserts that seasonal climate forecasts are still a prediction, but they provide probabilities of rainfall totals and temperatures variations for the rainy season. This means that some predictions may not happen as predicted hence affecting a farmers activities. The views expressed in the two studies seem to agree with divergent responses by farmers in this study. In this study, the issue of probability nature of scientific predictions however is being explained to the farmers now during the participatory scenario planning process and during the dissemination period and they are having a clearer view on the issue. Farmers are also able to identify with KMS staff during such consultative meetings and are beginning to attach more value to climate information usage in the planning of their farm activities.

To further examine the value attached to climate and weather information use, farmers were asked to state how they rated their efforts in soliciting for climate and weather information for use in their maize and wheat production activities proactively. Hundred and eight farmers (28%) do not make any effort at all to obtain climate and weather information to assist in their maize or wheat farming, similarly, 180 (46.4%) of the farmers sometimes do make efforts (Figure 4.13).

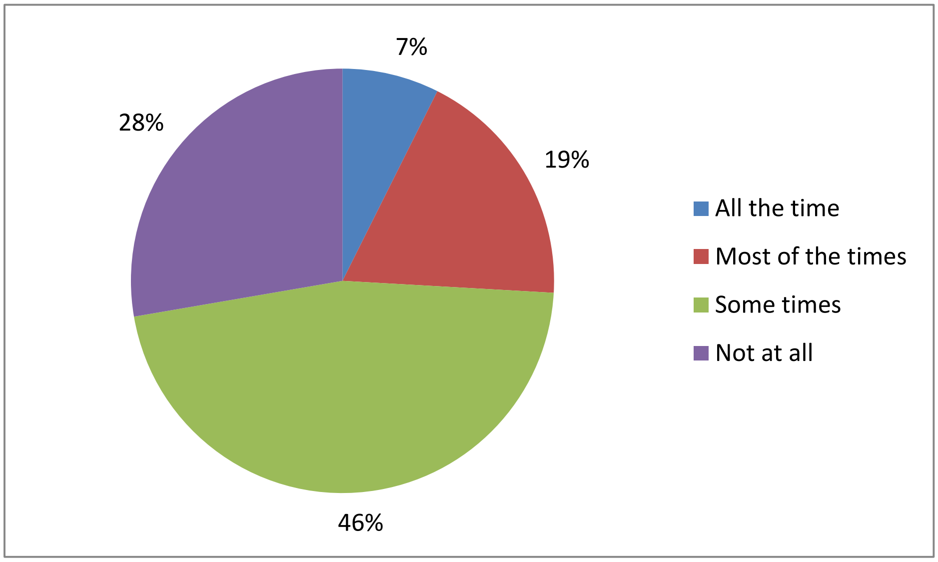


Fig 4.13: Effort to obtaining climate and weather information by farmers in Uasin Gishu County (Source: Field Data, 2013)

A high proportion of farmers who sometimes look for climate and weather information in addition to those who claim that they do not make any attempt at all to solicit for information reveal a group of farmers that may need support in terms of information access and the infrastructural facilitation so that the information is delivered to them closer to a point where they can use it. Downscaled climate information will be useful to maize and wheat farmers in Uasin Gishu County. An effective delivery mode through SMS alerts will also enhance timely access to the much needed information.

The findings herein is corroborated by Walker *et al*. (2001) cited from Klopper (1999) that there are constrains in the optimal use of seasonal climate forecast information (climate and weather information) by farmers generally. Some of these constraining factors include provision of information that is general such that such information may not be specific to any area or particular application or may be received too late for use or often too difficult for the user to decode and apply.

4.6 Influence of climate and weather information in maize and wheat production

This section of the study examines the influence of climate and weather information in maize and wheat production. Farmers were asked to respond to the question related to the decision they make with regard to maize and wheat growing activities in their respective farming areas. The activities were considered with respect to the prevailing climatic variations brought about by climate change.

4.6.1 Climate and weather information informing crop substitution by farmers

Farmers were asked to respond to a question where the Meteorological Department during its routine weather forecasting reveal a situation where drought will prevail during the season when farmers expect to commence the planting of maize and wheat. In their responses, more than half of the farmers 203 (52.7%) agreed that they would substitute the growing of maize or wheat with other crops to avoid any risks involved while 141 (35.5%) could not change their activities at all regardless of the advisory. Still 41 (10.6%) affirmed that they do not follow what the Meteorological Department say because they are never right in their predictions. The responses here reveal a group of farmers who are willing to substitute the growing of maize or wheat with other drought resistant cereal crops to mitigate climate variability.

To understand further what mitigation measures against climatic variability they have practiced during their farming practice farmers were asked to state if at one point in time or severally during their routine maize and wheat growing season they had substituted the growing of maize with either potatoes, beans finger millet or sorghum after weather forecast report reveal drought manifestation during the cropping period. More than half 126 (60%) reported that they had substituted maize growing with that of beans (Figure 4.14).

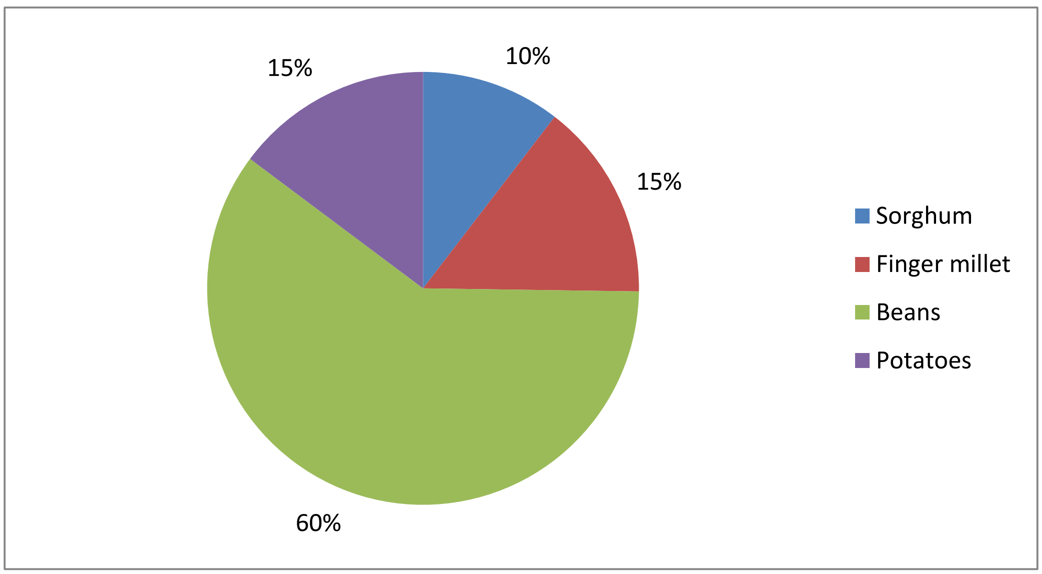


Fig 4.14: Maize substitution with other drought resilient crops in Uasin Gishu County (Source: Field Data, 2013)

Asked further about wheat growing and substitution of the s ame in the prevailing drought manifestation predicted by Meteorological Services and communicated to farmers as climate and weather information alerts, a big number 114 (57.6%) agreed that they had substituted wheat crop growing with the growing of beans (Figure 4.15). The rest of the farmers agreed that they had at some point substituted the growing of either maize or wheat with sorghum, finger millet cassava or potatoes though in small quantities.

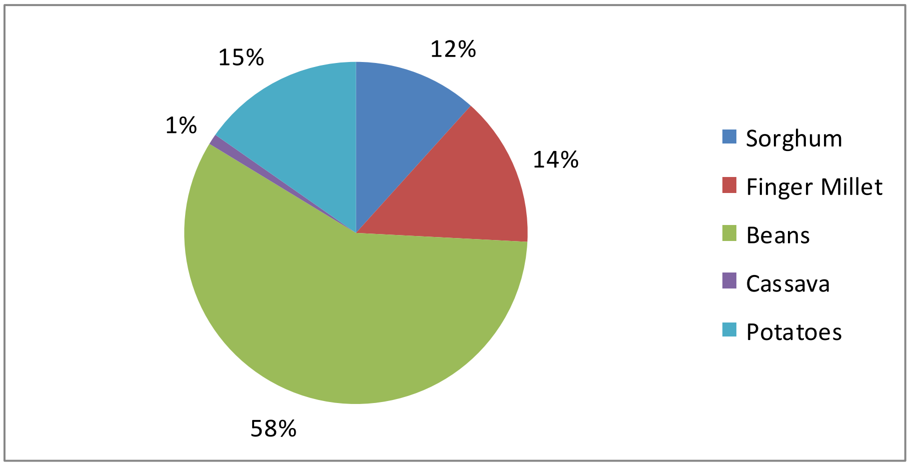


Fig 4.15: Wheat substitution with other drought resilient crops in Uasin Gishu County (Source: Field Data, 2013)

When substituting for both maize and wheat growing as shown in Figure 4.14 and Figure 4.15, farmers agreed and informed the research that the growing of beans is the most preferred substitute for both maize and wheat growing followed by potato crop. This was after receiving an advisory from the Kenya Meteorological Services warning of an impending drought in most parts of the Rift valley including Uasin Gishu County; the area where this study was conducted.

The findings herein are in agreement with those in by Chu Thi Hong Minh (2011) and Pettengell (2010) stating that ssuccessful adaptation means people becoming increasingly able to make informed decisions about their lives and livelihoods in a changing climate. Access to climate information is crucial in helping farmers to be well aware about the climate change and the external inputs to be able to make decisions about their future activities (adaptation strategies) otherwise, farmers have based their crop and other production decisions on local knowledge systems, developed from years of observations, experiences, and experiments and now facing challenges with the advent of climate change.

4.6.2 Crop losses incurred by farmers due to non-use of climate information

Farmers were asked to state whether they had ever incurred any crop loss during their farming experience. The following were their responses: - Maize and wheat crop damage due to lack of adequate rain during growing period was reported by 308 (78.6%) farmers. Maize yield loss due to too much rain during growing season, near harvest and harvest period was reported by 259 (66.1%) farmers. The same farmers reported that the same phenomena applied to wheat growing and 296 (74.2%) affirmed this as in Table 4.13.

Table 4.13: Crop loss and damage due to the prevailing rainfall variability in Uasin Gishu County

Statement	Frequency	Percent (%)
Maize crop damage due to lack of rain	308	78.6
Maize yield loss due to too much rain	259	66.1
Wheat crop damage due to lack of rain	308	78.6
Wheat yield loss due to too much rain	296	74.2

The responses from farmers confirm that framers have indeed incurred great losses during maize and wheat growing activities. Although 203 (52.7%) agreed that they would substitute the growing of maize or wheat with other crops to avoid any risks involved if an advisory is relayed to them, the responses in Table 4.13 tell a different story as farmers confirm the fact that they have incurred losses both during the growing season due to lack of rain and during growing season, near harvest and harvest period including post-harvest losses brought about by too much rainfall.

This occurrence reveals a vulnerable group of farmers who have fallen victim to unpredictable weather patterns brought about by changing climate. Farmers may not have responded to proper utilization of climate and weather information to assist them in their farming decision making. The finding in this study is supported by a paper presented in Nigeria on achieving food security in times of crisis by Anuforo (2009) which demonstrate that adequate use of climate and weather information conditions by farmers' results in at least 30% increase in crop yields. The utilization of this information reduces farmers' vulnerability to weather related risks, ensures that informed decisions are made on time, and reduces the risk of agricultural losses as well as indicating to farmers the most marketable crop in respective times.

When farmers were asked further about the climatic parameter responsible for major maize crop loss or damage, inadequate rain during planting/germination period was reported by majority of farmers 255 (67.6%). Too much rain during harvest/storage period was reported by 186 (49.3%) farmers and only 42 (11.1%) reported drought manifestation throughout the growing period as the parameter that led to the loss as in Figure 4.16

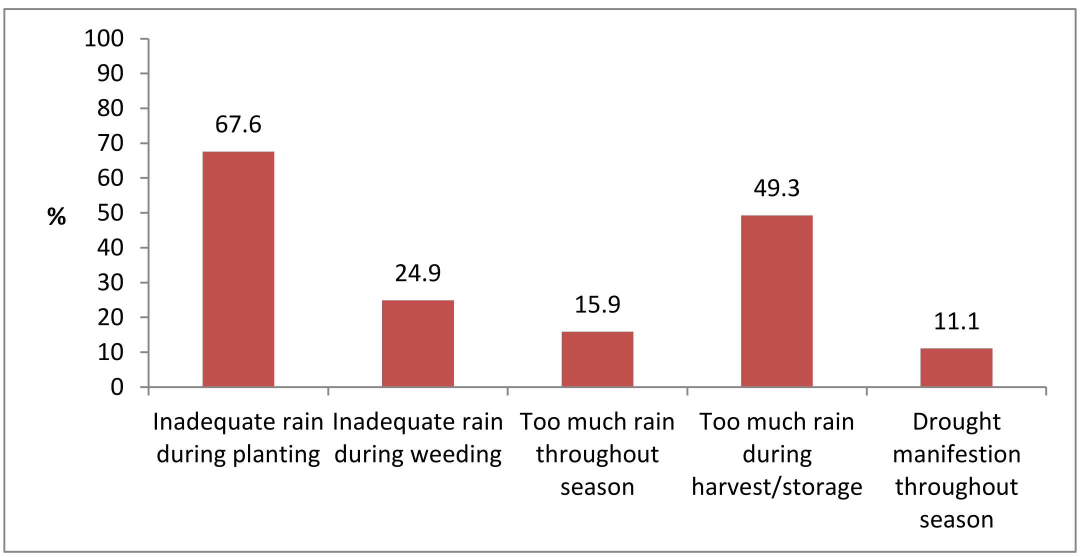


Fig 4.16: maize crop loss due to the prevailing rainfall phenomena in Uasin Gishu County (Source: Field Data, 2013)

Maize growing has largely been affected during the growing period from March to April in Uasin Gishu County. Farmers experience dictate that land should be prepared in November to January and part of February in readiness for planting at the end of March and going on to end of April. Farmers indicate here that there was inadequate rain during planting season meaning that farmers stick to their known farming dates without any input from the meteorological services which could have warned them about any anomaly that may affect the onset of rains during the long rains period. Post-harvest losses also can be attributed to the shift in seasons as a result of climate variability. Farmers are experiencing wet seasons during harvest time hence their crop get damaged during harvest and storage. Most of them do not have adequate storage facilities if rains become prevalent during such periods. Drying also is a challenge as most of them rely on solar energy to dry their maize. This has led to losses or damage hence farmers have incurred losses.

For wheat crop losses, too much rain during harvest/storage period was cited by majority of farmers 219(59%) as the major cause of loss or damage to the wheat crop. Inadequate rain during planting was reported by 207(55.8%) farmers as a cause for losses experienced in the wheat crop farming activity as shown in Figure 4.17.

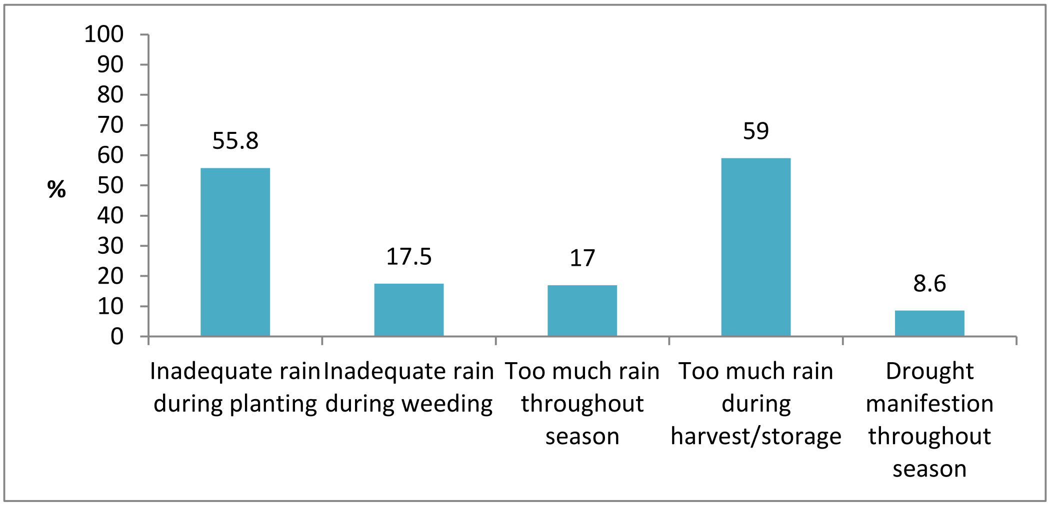


Fig 4.17: wheat crop loss due to the prevailing rainfall phenomena in Uasin Gishu County (Source: Field Data, 2013)

Wheat crop is sensitive to too much rain during drying and harvest period as any slight wetness during such times may cause crop germination hence damaging the yield or reducing the quality in case the damage is not great. There have been very unpredictable weather patterns that always find farmers facing uncertain weather conditions in their rain-fed agricultural practice. The results related to losses in maize and wheat reveal that farmers have not been timely in activities due to the unpredictable nature of the weather during the seasons. Losses have been incurred by farmers during germination and harvesting of crop and their indigenous knowledge system alone has not proved effective in predicting rainfall onset and cessation dates. Climate and weather information timely access is crucial in supporting farmer’s decision making process in crop growing.

Plate 4: Heavy rain during wheat drying period, Kipsangui Ward, Uasin Gishu County (Source: Author, 2013)

Plate 5: Solar drying of wheat at Kipchoge Keino Stadium, Eldoret, 2013

(Source: Author, 2013)

In Plate 4 and 5 taken during the research period, the danger posed by unpredictable nature of rainfall in the wheat growing areas of the county is evident. Plate 4 reveal a rainy period with heavy cloud cover during the month of September to October; a time when wheat crop dry's naturally from solar energy at *Kipsangui* Ward of Soy Sub-County. If rains persist for a while, the wheat crop gets damaged at the farm. Plate 5 show wheat being dried using solar energy on the open space at *Kipchoge Keino* stadium in Eldoret to reduce the moisture content to recommended levels of 13.5% required by grain millers and the National Cereals and Produce Board (NCPB) for storage purposes.

The drying method is basically unhygienic as the grains may get contaminated during the process. This is usually done by some farmers and middle men who want cash in the early market demand. They buy wheat from farmers at a lower rate deliver the same product to Millers who have colluded with them to hand them orders for supply of wheat. Farmers incur loses here and the national together with county governments should provide policy guidelines in the handling of maize and wheat with the aim of protecting farmers against unfair competitors and maintain hygiene in human food handling.

The findings in this study are supported by others studies contained in a World Bank report of 2010. The report by World Bank on mainstreaming adaptation to climate change in agriculture and natural resources management projects guidance notes 6 states that seasonal climate forecasts and early warning systems include some of the most useful climate-related information for farmers and rural communities in general (World Bank, 2010). That the farmers usually do not know what climatic conditions to expect in the following growing season but have evolved conservative cropping strategies based on their experience. These strategies may fail to capitalize fully on beneficial conditions and also frequently buffer poorly against negative effects of climatic changes. The report further states that seasonal forecasting can greatly assist in managing climate risks in agriculture, particularly in risk-prone rain-fed environments, by providing planners and farmers with timely information, which allows them to decide upon and shift to the most suitable coping strategies over short time scales hence avoiding losses related to weather variability.

4.6.3 Impact of changing weather pattern on crop yield and the benefit of climate information use by farmers in Uasin Gishu County

To understand how maize and wheat farmers have been impacted by variations in climate and weather conditions that included drought manifestation during crop growing period and occurrence of excessive rainfall during the same growing period, farmers were asked to state their crop yield per acre in the last 5 years. The results were as follows:- More than half of the farmers yielded between 6 and 15 bags of maize and wheat as a result of drought, 176 (52.1%) and 164 (50.2%) respectively as indicated in Figure 4.18. Similarly, more than half of the farmers yielded between 6 and 15 bags of maize and wheat as a result of excess rain, 179 (57.6%) and 174 (58%) respectively as indicated in Figure 4.19.

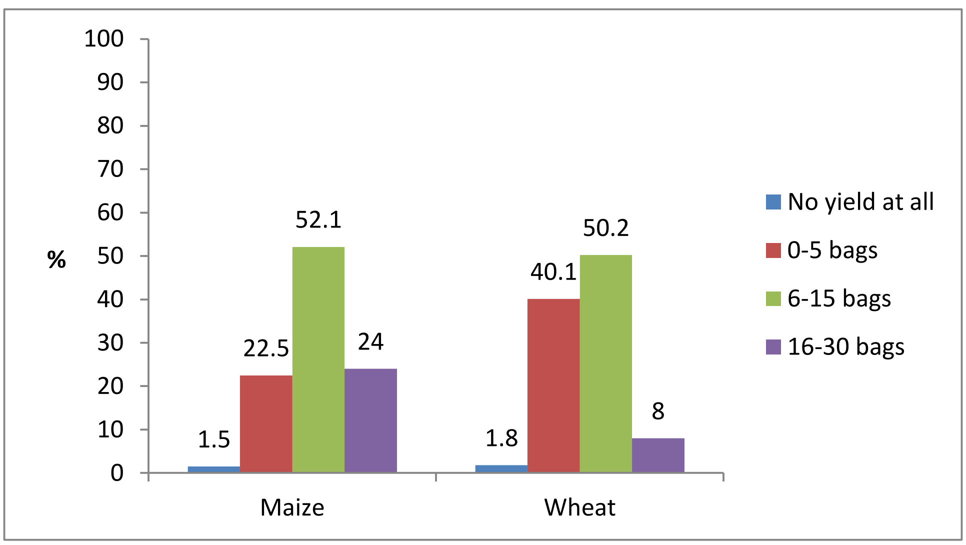


Fig 4.18: Production per acre after drought manifestation during season (2009 – 2013) (Source: Field Data, 2013)

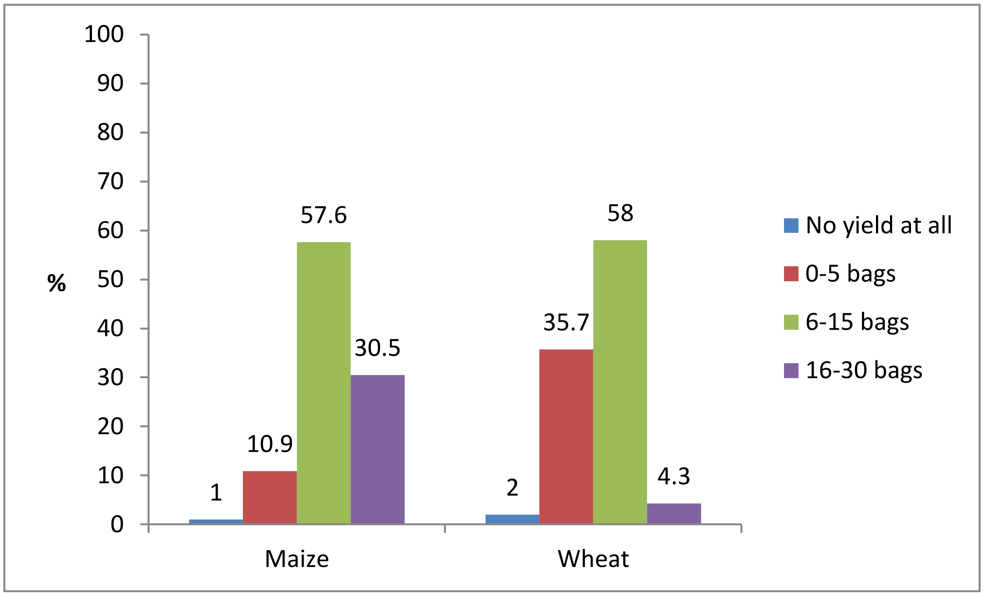


Fig 4.19: Production per acre after excessive rainfall during season (2009 – 2013)

(Source: Field Data, 2013)

According to the responses by farmers, the yield of maize and wheat remained the same (6-15 bags) of 90kg weight each whether there was drought manifestation during growing period or whether there was too much rain during the same period.

> *"For some time now the yield per acre has been degreasing rapidly. In the previous years, maize production per acre averaged 30-40 bags of 90 Kgs bag and that of wheat averaged 20 - 30 bags of 90 Kgs per acre. A few farmers however still attain this level of production".* This is according to the farmers in a key informant interview and informal discussions during data collection activity.

These phenomena can be attributed to the prevailing climate variability as farmers lose their crops when there is drought manifestation or during occurrence of excessive rains during the cropping season. Similarly the non-change in yield output per acre could be attributed to other factors at play that may include soil acidity and application of correct fertilize that does not increase the level of acidity in the farm bearing in mind that the farmers have been practising maize and wheat crop for many year in the same farm land. Farmers need to ensure that their soils are tested to determine their pH levels hence can be advised accordingly on the type of fertilize to apply on their farms. The seed variety could also play a role in production because the use of non-certified seeds may not change much the production per acre in both maize and wheat crops. These extraneous factors however were not the principal focus of this study.

The findings herein mirror what The Consultative Group on International Agriculture (CGIAR) research programme in Climate Change and Food Security (CCAFS) report of (CGIAR, 2014) and of Lobell & Field, (2007) reveal. The report explains that through historical studies, climate change has already had negative impacts on crop yields. Maize, wheat and other major crops have experienced significant climate-associated yield reductions of 40 mega tonnes per year between 1981 and 2002 at the global level.

To understand further the role of climate and weather information in crop production farmers were asked to state the benefit accrued after utilization of climate and weather information as indicated in Table 4.14. One hundred and seventy four farmers (44.7%) reported that after utilization of information on weather and climate, they were able to successfully apply fertilizers/top dressing, weeding and apply agro-chemicals. In addition, 135 (34.7%) were able to avoid lack of adequate rain during planting season by waiting a little longer till the onset of rains before commencement of planting of either wheat or maize.

Table 4.14: Benefit of utilization of climate and weather information by farmers in Uasin Gishu County

Benefit realised after use of climate information	Frequency	Percent %)
Ability to avoid lack of adequate rain during planting period	135	34.7
Successful application of fertilizers/top dressing	174	44.7
Avoided harvest loss due to heavy rains	67	17.2
Ability to substitute maize and wheat as per the situation	29	7.5
Information did not help	16	4.1
No information was received	74	19

Farmers acknowledge the fact that if one embraces the use of climate and weather information, it greatly enhances farming decisions at the farm level and one is able to benefit from its application. A test to determine if there was any significant relationship in the yield attained per acre and access to climate and weather information reveal the following results shown on Table 4.15.

Table 4.15: Relationship between climate information access and yield per acre

Climate information access	Yield per acre (1 bag = 90 kg)		Chi	P
	≤ 20 bags	**> 20 bags**		
Yes	146 (94.2%)	9 (5.8%)	0.042	0.838
No	231 (94.7%)	13 (5.3%)		

The result show that there is no significant relationship between access to climate and weather information and crop yield per acre (crop production) *P = 0.838 (p>0.05)* as indicated in Table 4.15. Whether a farmer accessed information on climate and whether or not, the yield seems to have remained the same. Although farmers seem to agree that utilization of climate and weather information helped them avoid losses that would have resulted had they not accessed the necessary information to support them in their farming decisions the relationship though is not significant. The situation in this study of non-significant relationship could be attributed to other confounding variables for example use of good or bad quality seeds by farmers, right/wrong fertilizer application, good/ineffective pesticides use, top dressing at the most appropriate time and others; this study however was not set to address this phenomena in its scope.

The study by Anuforo (2009) agrees with the findings in this study however. That facilitation of access to climate and weather information reduces farmers' vulnerability to weather related risks, ensures that informed decisions are made on time, and reduces the risk of agricultural losses. Also the same view is supported by Gunasekera (2009), arguing that there has been a positive effect associated with the use of climate and weather information in agricultural production as seen in some empirical studies carried out. Some of the examples where the use of climate information can have a positive impact include the following studies According to (Gunasekera, 2009), there has been a positive effect associated with the use of climate and weather information in agricultural production as seen in some empirical studies carried out.

Some of the examples where the use of climate information can have a positive impact as demonstrated by various studies Solow *et al.* (1999) analyzed the effect of improved ENSO predictions on US agriculture. The study estimated that the value of “modest” and “high” skill ENSO forecasts is $240m and $266m respectively per year (1995 US dollars), Lemos *et al.*, (2002) analysed the use of seasonal climate forecasts in drought mitigation strategies (including seed distribution, emergency drought relief and water reservoir management) in Northeast Brazil. This study highlighted the potential to offer considerable opportunity for state/local government level planners to undertake proactive drought relief planning using climate information. Thornton, (2004) analyzed the economic value of climate forecasts for livestock production in the Northwest Province of South Africa and the study demonstrated that, for the commercial farmers, long term average annual income could potentially be increased through using ENSO predictions (Gunasekera, 2009).

Plate 6: Poor maize crop due to erratic rains in Megun Ward, Kesses Sub-County of Uasin Gishu County, (Source: Author, 2013)

Plate 7: Wheat harvesting with unexpected heavy rains in Mumetet Ward, Moiben Sub-County of Uasin Gishu County, (Source: Author, 2013)

The maize crop in Plate 6 at *Megun* Ward, *Kesses* Sub-County is poor in development and the resultant yield was low during harvest in December 2013. In Plate 5, wheat harvesting with unexpected heavy rains in *Mumetet* Ward, *Moiben* Sub-County during the month of November 2013 was facing an eminent threat of heavy rains as seen from the cloud cover. Luckily, the heavy rains subsided but after having affected slightly the crop yield. The poor drying method led to post harvest losses however.

4.7 Mobile Phones to deliver climate and weather information to farmers

In order to understand how farmers viewed the use of mobile phone technology to receive climate and weather information for use in their planning activities in maize and wheat growing, it was important to ascertain the usage and ownership of mobile phones in the study area. The network coverage of most mobile phone service providers who have managed to access farmers in their respective location through installation of telecommunication boosters (mast) to step up their communication signal is also a factor to be examined. The following were farmers responses with respect to the information requested.

When farmers were asked whether they owned a mobile phone, 376 (94.2%) confirmed that they indeed owned a mobile phone. Asked further which service provider they were connected to, 346 (92.8%) said they were hooked to Safaricom, 24 (6.4%) were connected to Airtel while 3 (0.8%) were using Orange network. When farmers were asked if they use their mobile phone to receive any text messages, 353 (93.9%) reported to use the mobile phone to receive and read short text messages. Of those that use mobile to receive and read short text messages, 340 (96.3%) preferred to receive or get updates on climate and weather information through the mobile phone. For those who did not want to receive the information through mobile phone, 7 (33.3%) did not know how to read.

The findings reveal a situation where the mobile phone is now very accessible to almost everyone in the community and that even farmers are now turning to the mobile phone to obtain information to support their farming activities. The fact that farmers are willing to receive SMS updates on weather advisories clearly demonstrated how farmers are eager to obtain targeted information. The dissemination channel is important to the farmers and a mobile phone will enable them receive timely information and does not depend on availability of the Internet, Television and Radio sets that may confine a farmer in some particular location.

The finding related to mobile phone coverage and usage agree with findings in Chu Thi Hong Minh (2011) stating that there has been a rapid growth of mobile phone networks in developing countries in the recent years and mobile phone usage has expanded greatly leading to diminishing mobile divide between the developed world and many developing countries; mobile phones thus is regarded as a more accessible and less expensive means to close the digital divide. At the farmer level, mobile phones are likely to remain the key information medium. Mobile phones have been used to provide agricultural advice in the form of voice and text messages elsewhere successfully according to Karanasios (2011).

Farmers were further asked to state the most convenient method of presenting climate and weather information to them and their responses were as follows: - More than half of the farmers 231 (58.6%) suggested vernacular FM radio and Mobile phone SMS alerts 213 (54.1%) as the most convenient methods of presenting climate and weather information for maize and wheat farmers in the county as shown in Figure 4.20

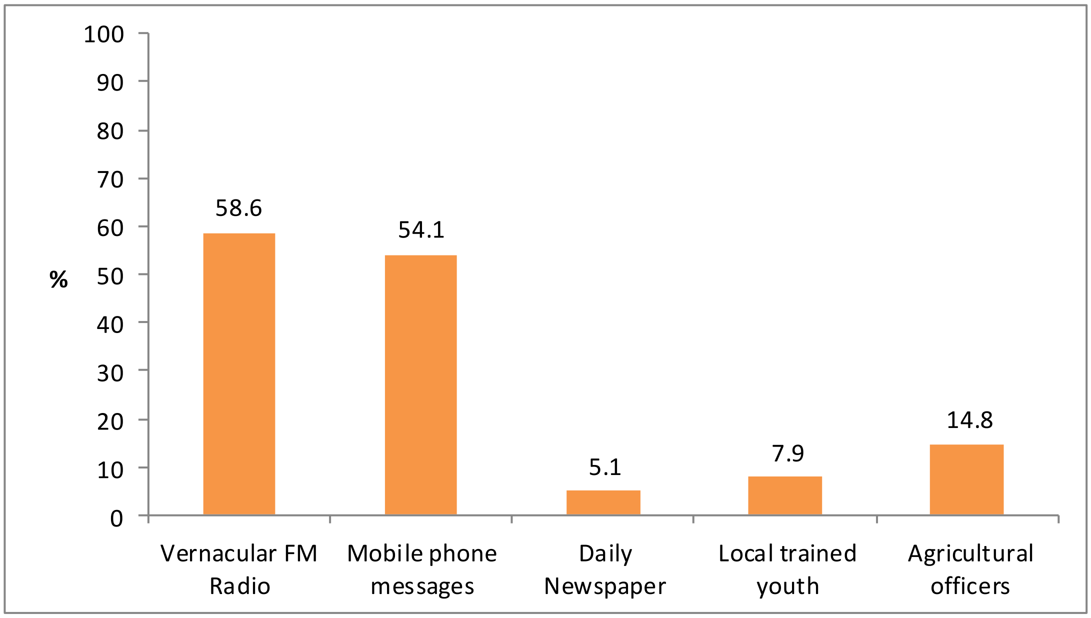


Fig 4.20: Most convenient method of presenting climate and weather information to farmers in Uasin Gishu County (Source: Field Data, 2013)

The findings in this study show that besides the traditional radio broadcast, a sizeable number of farmer's prefer to receive their weather updates through their mobile phones. Mobile phones are very convenient to the farmers and most farmer transaction today in Uasin Gishu and Kenya in general is mobile phone based. Vernacular radio stations also are quite popular among the rural communities as more often interesting topics are aired and most would make calls to the local radio station to explain an issue of concern especially in politics. This is a good avenue also that can be targeted to deliver climate and weather information in addition to the mobile phone short text messages that farmers prefer. This finding agree with research by the Consultative Group on International Agriculture (CGIAR) stating that in Africa, where half the continent's population uses a mobile phone, people now have unprecedented access to information via their handsets. There are multiple ways mobile phones have catalyzed innovation, including in the farming sector. Farmers from isolated areas can access weather information via short text messages (SMS) or phone calls, to prepare for upcoming drought spells, heavy rain or floods (CGIAR, 2011).

Beside basic connectivity, mobile phones offer benefits of mobility and security to owners. In addition to voice communication, some technical advantages of mobile phones allow for the transfer of data, which can be used in the context of applications for the wide range of purposes such as weather forecast. A good example of how mobile phones have been used in delivering advisories related to some disasters is The Noula Platform in Haiti. An innovative SMS-based flooding early warning system was developed in Haiti to provide information based on weather forecasts, in the local Creole language as well as in French (Hansen *et al*., 2011).

CHAPTER FIVE

I-FARM APPLICATION MODEL: AN AGRO-WEATHER TOOL FOR CLIMATE-SMART AGRICULTURE

5.1 Introduction

One of the key objectives of this study was to design a communication model (Short Message Service) alerting protocol to relay climate and weather information to Maize and Wheat growing farmers in Uasin Gishu County of Kenya. Due to climate and weather variations brought about by climate change, farmers have constantly faced greater risks throughout the growing season in the maize and wheat calendar. The unpredictable onset, frequency and intensity, cessation of rainfall can lead to drastic variations in yield or, worse still, the widespread loss of crop. To navigate such risks, maize and wheat farmers need better and more complete and timely information on both climate (long-term patterns over months or years) and weather (short-term changes in conditions) throughout the growing and harvest period.

More information means farmers can plan more effectively, optimizing their management in light of forecasted weather, and so reducing crop losses or increasing potential gains. The dissemination of climate and weather information – known as climate services – can be a crucial tool in addressing the challenge of managing yields in a changing climate (Grainger-Jones, 2013). The mobile phone web based application for SMS alerts to farmers has been developed to really meet the needs of farmers. I-farm application is clearly described in the preceding chapters on its functionality, requirements and type of information that can be delivered to the farmers in need.

5.2 Functional description of I-farm model; a web based application for mobile phone SMS alerts to farmers

The purpose of this document is to describe the functionality, requirements and general interface of the I-farm application; a web based application to deliver climate and weather information to farmers using mobile phone (SMS alerts).

I-farm is a web based interactive application aimed at increasing adaptive capacity of farming communities by improving access to information on weather and climate patterns through use of mobile phone to deliver SMS alerts to farmers. The application system will basically improve farmer's farm management capabilities under conditions of climate risk. The system will help farmers to plan and manage weather risks, maximize productivity, and minimize the environmental impacts of farming practices. It will entail the delivery of climate-smart agro-advisory information using SMS alerts to farmer's mobile phones.

The system is designed to inform farmers through messages notifications on prevailing weather patterns, advisory alerts, best practices all geared towards supporting a farmer's decision at the farm level. An informed decision made by the farmer will positively impact on productivity hence attaining profit in the farming enterprise. The system will also provide general and more specific agricultural topics or information on crop management at the farm level, post-harvest management and preservation and marketing of farm produce. It is a tool that links farmers to new information. I-farm is a timely, comprehensive agro-climate information service, intended to serve farmers' needs throughout the county including the rural areas where Internet access is limited. Farmers on the other hand can raise issues of concern by writing an SMS back to the help desk at the County Directorate of Agriculture where a staff mainly Locational Agricultural Extension Officer or designate can attend to queries raised by farmers. The feedback mechanism ensures that farmers play a role in the success of the system application. The system has capability for scale up to cover more counties engaged in agricultural production.

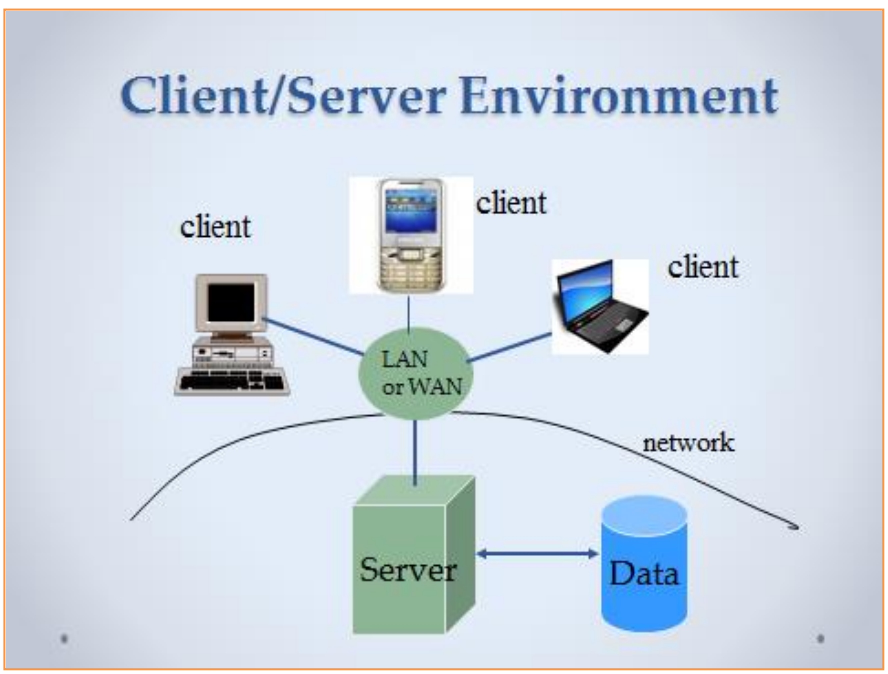


Fig.5.21: Client/Server Model for I-farm system

(Source: Author, 2013)

Client/server model is a concept for describing communications between computing processes that are classified as service consumers (clients) and service providers (servers). Web-based systems today are entirely two-tier and three-tier client/server architectures. At the client side, the user's computer or phone executes scripts in Web pages. At the Internet side, Web servers and application servers process data before returning results to the user. The Wide Area Network (WAN) and the Local Area Network (LAN) is the connectivity infrastructure for the client/server model.

I-farm is a system whose client application is mainly developed using Java Server Pages. Java Server Pages (JSP) is a technology utilized to dynamically generate web pages based on HTML, XML, or other document types. Java Server Pages are normal HTML pages with embedded Java code. The Java Script was used to carry out client side validation. The business logics reside at the middle layer developed in Java Programming Language. These layers interact with Mysql database at the third layer. I-farm utilizing client/server model is run on a web server (Servlet container like Tomcat 5.5). The web server processes client requests via Hypertext Transfer Protocol (HTTP); the basic network protocol used to distribute information on the web based systems. The primary function of a web server is to store, process and deliver web pages to clients. The communication between client and server takes place using the Hypertext Transfer Protocol (HTTP).

The application requires a messaging gateway to relay and receive messages. Short Message Service (SMS) gateway is a mechanism by which SMS messages are sent and received. The SMS gateway facilitates and streamlines text messaging processes. The system has an inbuilt SMS gateway. I-farm allows utilization of proprietary gateways for scalability purposes.

5.3 Data type and flow mechanism in I-farm model

Specific climate and weather information tailored towards benefiting the farmer shall be sent to the farmer in form of short text message (SMS) alerts. Requisite climate and weather information for appropriate planning of agricultural activities by maize and wheat farmers include: seasonal rainfall onset and cessation dates, rainfall variability and distribution, temperature variability, advisories/alerts (extreme climate events like drought & floods), early warnings (outbreaks of pests and diseases), daily and weekly weather forecast, 10-day summaries of crop and weather advisories (Dekad) data, Plant density and soil moisture, potential evapotranspiration (PET), solar radiation and Normalized Difference Vegetation Index data (NDVI) in some instances. NDVI provides a crude estimate of vegetation health and a means of monitoring changes in vegetation over time which is very important to the farmer’s decision.

This information shall be summarized and sent to farmers’ mobile phones on a weekly or monthly basis; detailed information shall be accessible at the website hosted within the server in Eldoret (top level domain hosting) and such information shall be accessible to the farmers in form of pdf and word documents. Also messages on climate resistant crop varieties and new marketing standards shall be part of the information sent to the farmers.

This information shall emanate from the Kenya Meteorological Services and Ministry of Agriculture (data source) who are custodians and experts in climate and weather information. Links have been provided also from the I-farm Application website to useful organizations that may provide important information to meet farmer’s needs. The County Directorate of Agriculture and their counterpart County Directorate of Meteorology shall work hand in hand to access climate and weather information from listed sources, downscale such information and relay tailored information to the farmers directly through their mobile phones (SMS alerts). Farmers can also make inquiries on issues of interest and the Locational Agricultural Extension Officer and team shall respond to such queries. Farmers will have a dedicated helpdesk to respond to their requests at all the time. Climate data and information flow is illustrated in figure 5.22 depicting I-farm outbound messages to farmers and Figure 5.23 I-farm inquiry messages from farmers.

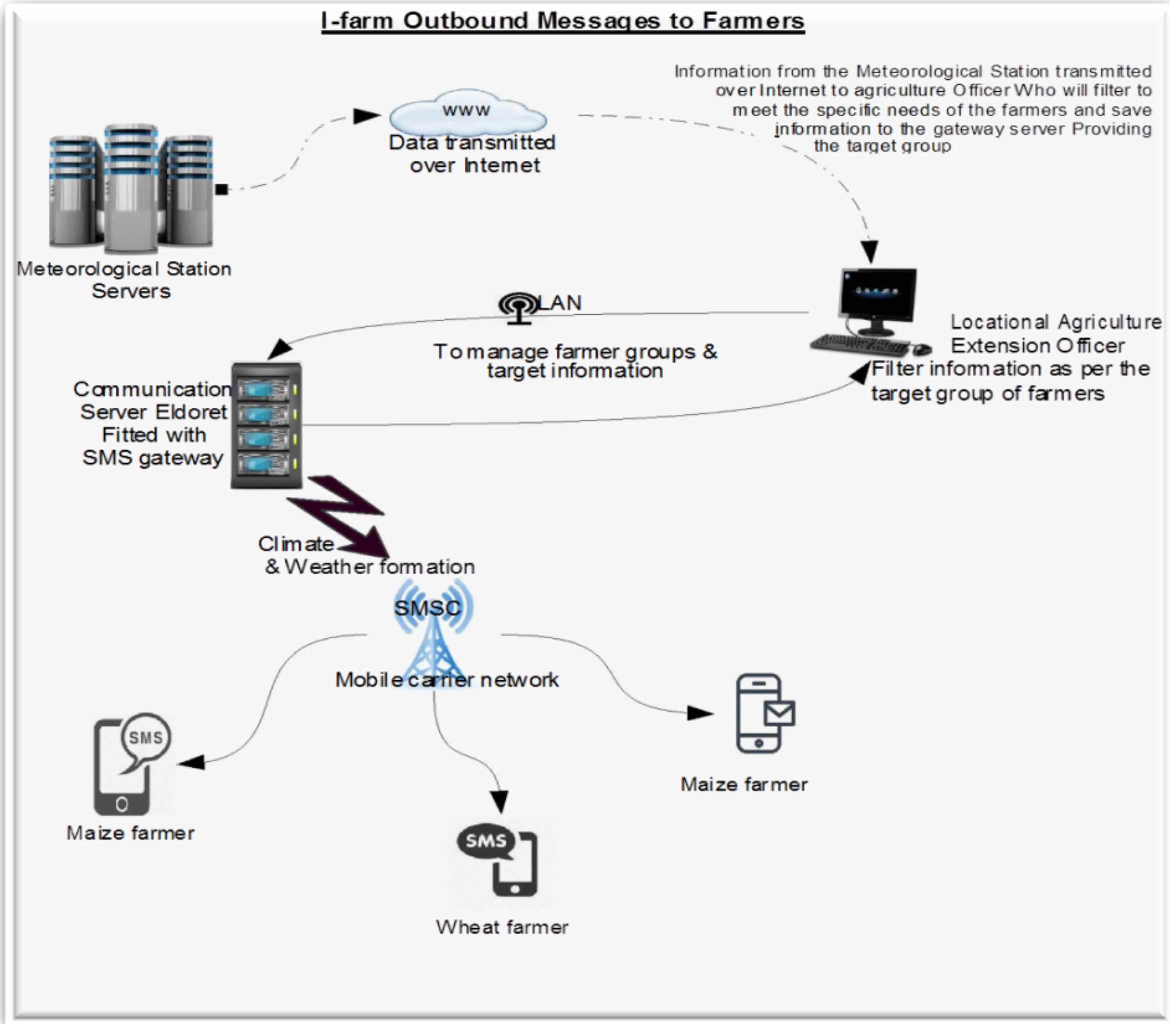


Fig. 5.22: Data flow system configuration (I-farm outbound messages to farmers)

(Source: Author, 2013)

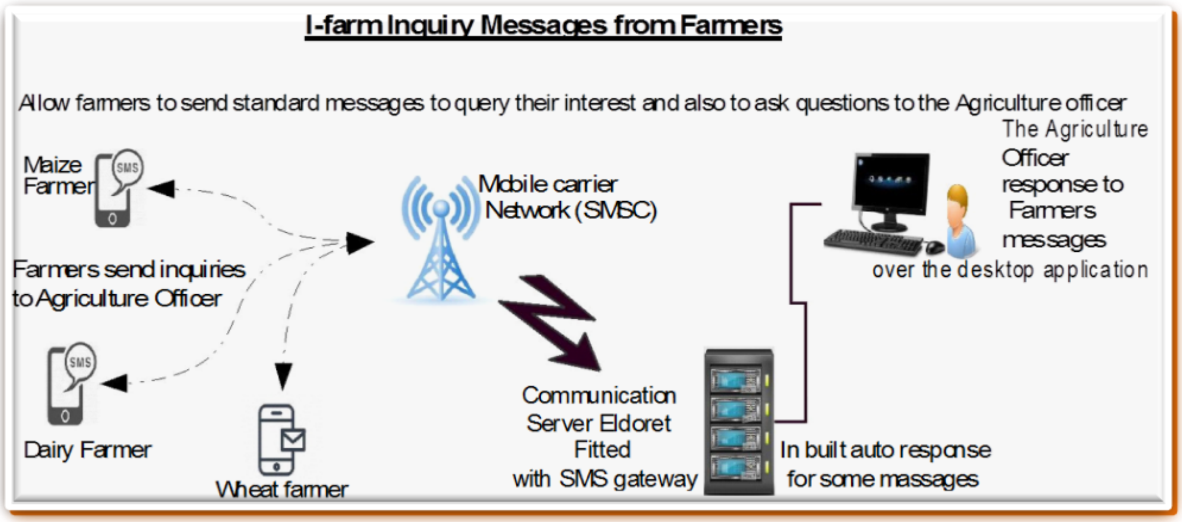


Fig. 5.23: Data flow system configuration (I-farm inquiry messages from farmers)

(Source: Author, 2013)

5.4 Systems Requirements for I-farm web based application model

The following infrastructure, hardware and software shall constitute the model thus making communication through mobile phones (SMS alerts) effective.

5.4.1 The Client side: Minimum requirements - Hardware & Software platform

- Pentium (IV) Personal computer
- RAM of 2 Giga Bytes (GB)
- 80 Giga Bytes (GB) of Hard Disk.
- Modem (Safaricom, Orange, Airtel)/Internet Connectivity.

- UPS power backup
- Power outlets/extension cables
- External hard disks to store data
- Java Enabled Browser

5.4.2 The Server side: Minimum Requirements - Hardware & Software platform

- Pentium (IV) Personal compute
- RAM of 2 Giga Bytes (GB)
- 80 Giga Bytes (GB) of Hard Disk
- .Internet Connectivity
- UPS power backup
- Power outlets/extension cables
- Backup server.

The redundant server (backup server) has to be updated so that if the main serve goes down, it can be powered on immediately to continue the process. The two servers must have equal data at any given time.

- HTML, Java, JavaScript, web server and servlet container like Tomcat5.5.
- Nagios open source software to monitor the uptime of the I-farm server.

Nagios software specifically does the following range of activities: - Check to see if a server is up and running, notify the person responsible with climate information dissemination if a server is down (by email/pager/SMS), allow specific alerts to only go to particular groups/individuals and get reports of downtime on the server.

During the setting up of I-farm application, user credentials are created to be able to login to the system hence allowing aces to the required platforms. A listserve for personnel responsible with the management of I-farm application systems administrator, the person feeding the information at the data source level (Agricultural Officer/the person supporting downscaling of climate information usually the Meteorological Scientist and other staff who may be important in ensuring that the system is up and running. A listserve for members (maize and wheat farmers) with their mobile phone numbers is created and uploaded to the system in readiness for delivery of climate information SMS alerts or advisories.

5.5 Data control and Security for I-farm model

Data security is important if a continued delivery of service to the clients is to be maintained. The system is password protected with fields that need validation. Scheduled backups is done and stored in external drives. Data backup for the last three days is done. Similarly, data is pulled and stored in the cloud (cloud computing). This technology allows for data storage in a different location for example Uganda, Nigeria, USA, Belgium and others if your location is Eldoret or Nairobi. If the server in Uganda is down, you can switch to the servers in other regions like Belgium. The server is not tied to a specific location.

5.6 User interface for I-farm web based mobile phone application

5.6.1 Login Page

Login page is an interface provided where a user can sign in to I-farm application. It also provides useful sites or links which can be essential to farmers. The page has a good user friendly interface where clients/users can easily navigate through various links that are essential to users/farmers in getting relevant information.

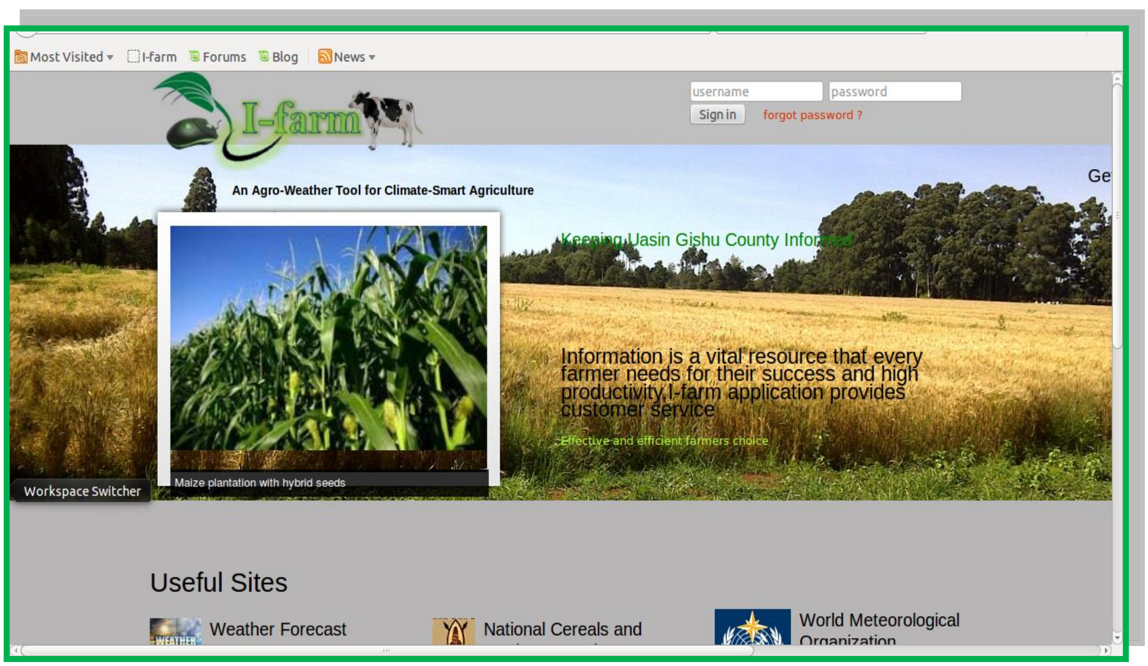


Fig. 5. 24: I-farm model user interface (Source: Author, 2014)

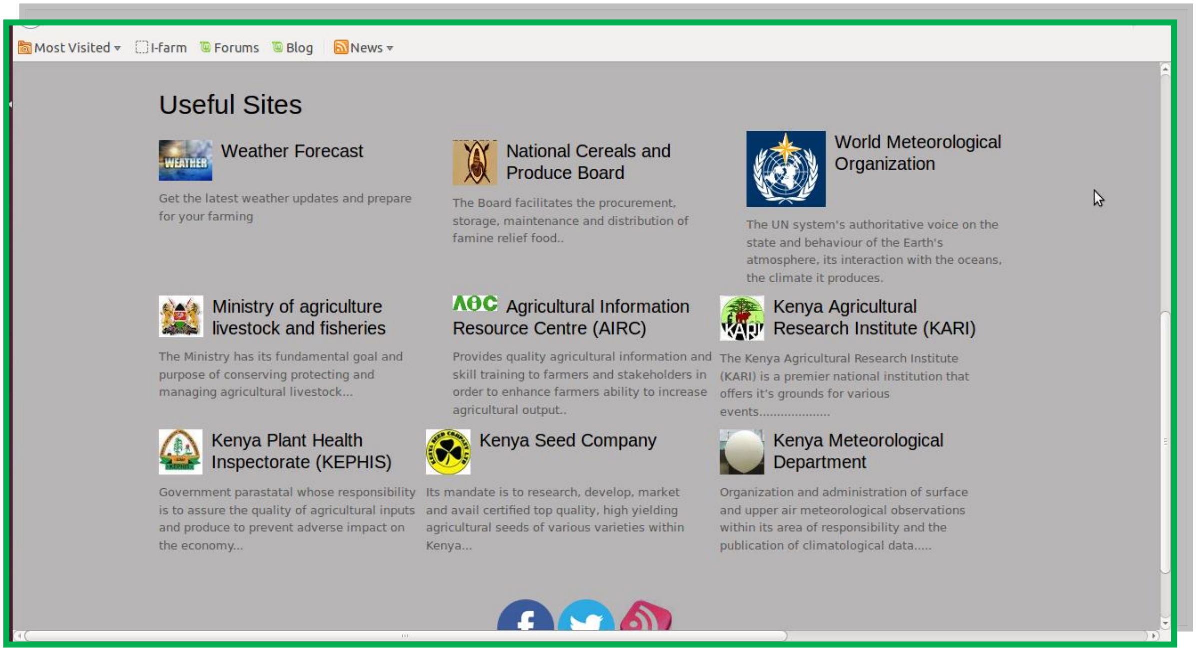


Fig. 5. 25: Useful links related to I-farm model (Source: Author, 2014)

Within the main I-farm user interface, one can access useful links that can of great help to the farmer. The links to Kenya Meteorological Services, World Meteorological Organization, weather forecast website, Kenya Seed Company, National Cereals and Produce board, KARI and other links to be created are additional sources of information that a farmer may require.

5.6.2 Main Menu – Members, Farmer groups, Password and Logout

When a user signs in to the system with the right login credentials, I-farm application opens up as show in the Figure 5.26:

Fig. 5. 26: Login level 1 main menu page (Source: Author, 2014)

5.6.3 Login level 1 main menu page contains four main menus

- Members
- Farmer Groups and Password
- Password
- Logout

The page facilitates provision for a user/client to add and search members. Members (farmers) can also be grouped into small groups with common interests or geographical location. They may be group growing maize only, wheat only, maize and wheat, beans and others. Similarly, farmers can be grouped as per Sub-County or ward levels. Here a user can send tailored messages to members of a group as per the need as shown in

Figure 5.27. The password and logout are administrative functions of the system that ensure security is maintained.

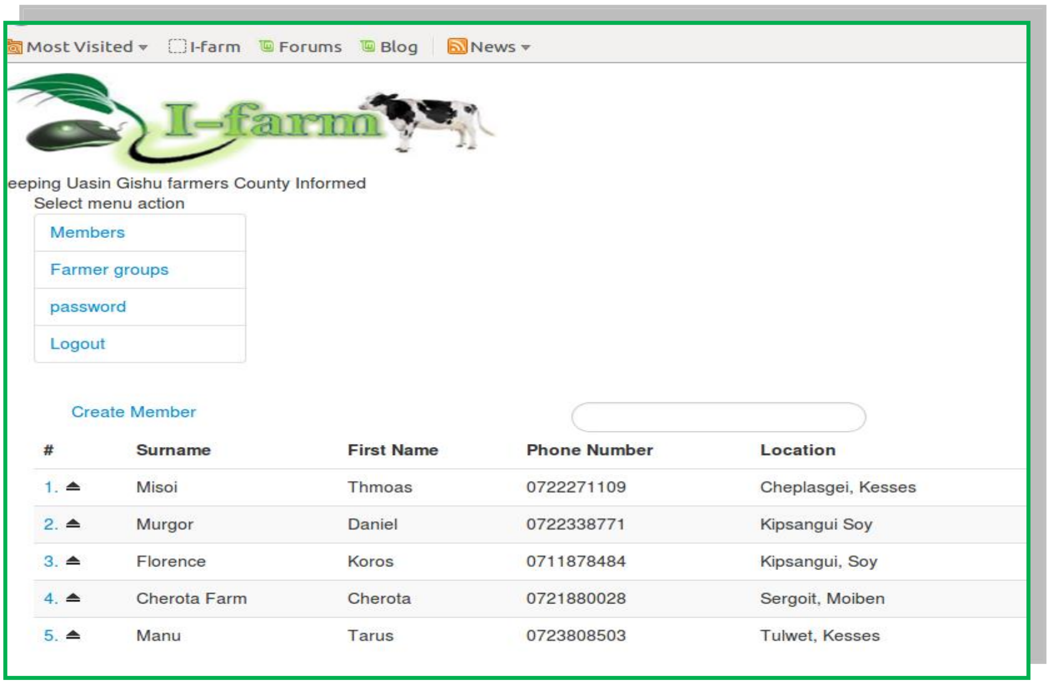


Fig. 5. 27: Menu for members display in I-farm system (Source: Researcher, 2014)

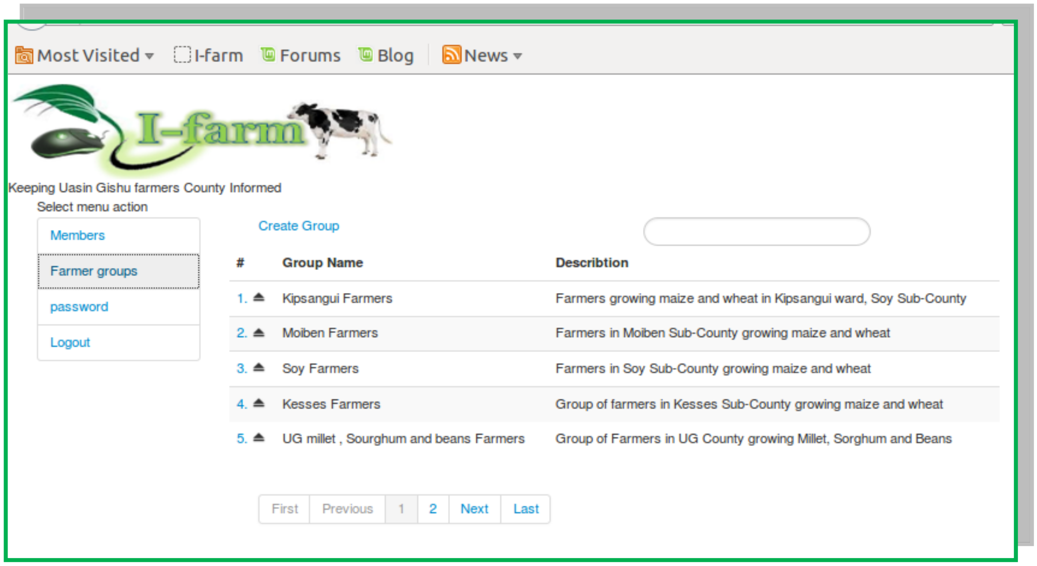


Fig. 5.28: Menu for farmer group display (Source: Author, 2014)

5.6.5 Login Level 2 messages Inbox, Archive and Logout for I-farm model

Fig.5.29: Main menu level 2 access (Source: Author, 2014)

5.6.6 Messages and reports

A user who wants to generate messages report and view all message logs in the system has to login to the messages section. I-farm application has both Inbox for incoming messages and Archive for read messages. A new message can be viewed by clicking the inbox button as seen in Figure 5.31. A user is also able to view messages, can generate received messages report, and send messages report from databases. These are requests send by clients/farmers querying for particular information of interest to them. Farmers from time to time would like to verify some information related to crop or weather situation. This feedback mechanism allows farmers to greatly interact with the personnel supporting the system hence being able to address farmers actual or perceived needs in their farming enterprise.

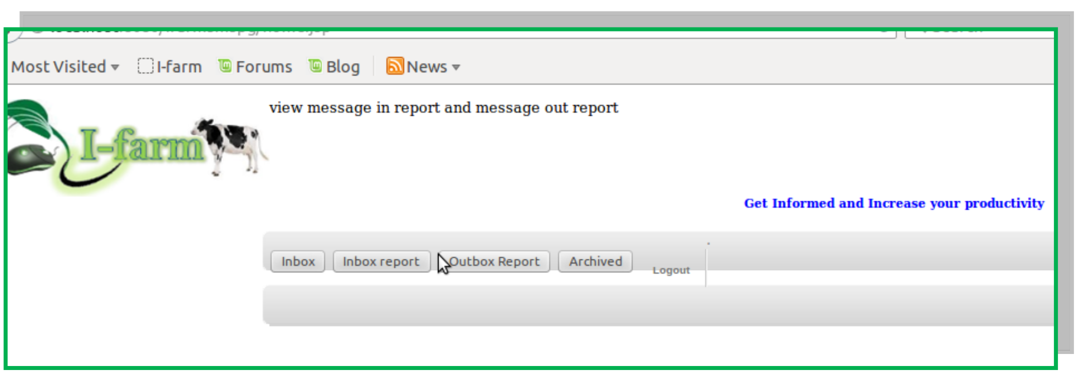


Fig. 5.30: Menu for inbox, outbox and archived report (Source: Researcher, 2014)

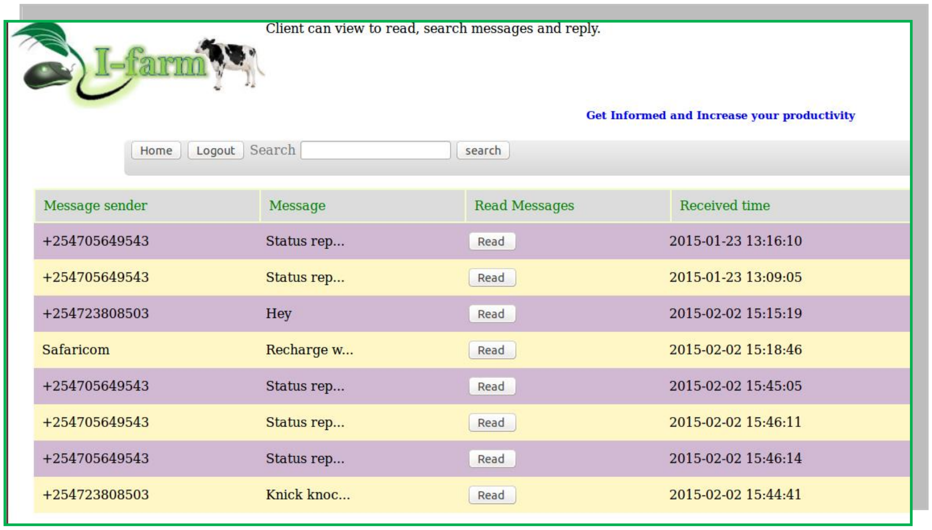


Fig.5.31: Inbox menu for incoming messages (Source: Author, 2014)

When you click read button on message page shown in Figure 5.31, a text box opens up where one can read the entire message and a reply text box where to type reply message to the sender as shown on Figure 5.32.

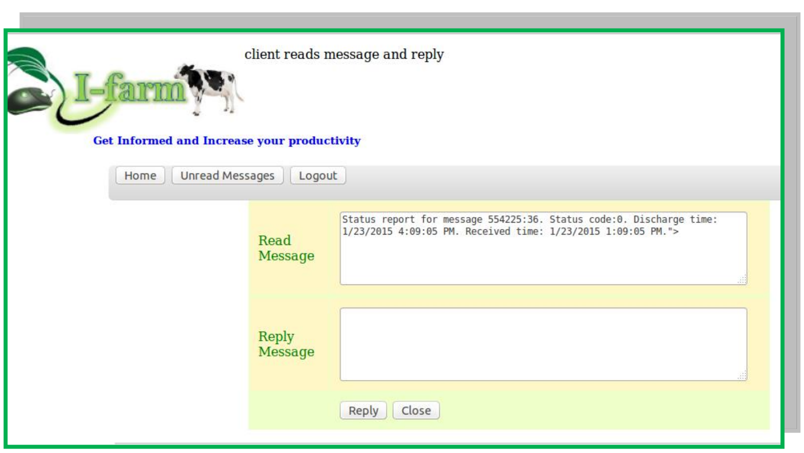


Fig.5.32: Reading and replying messages (Source: Author, 2014)

5.6.7 Search functionality in the system

This search feature allows the user/client to search messages based on date send and type of message in a like form. If you search numbers containing the digits 543 for example, all data containing the specified digits are displayed as seen in Figure 5.33. Searching allows the user to search just all messages with the desired value. If the value 69 is searched at the command box for search, all messages with value 69 shall be retrieved. Check on the screen shot below search by the value 543 at the command prompt.

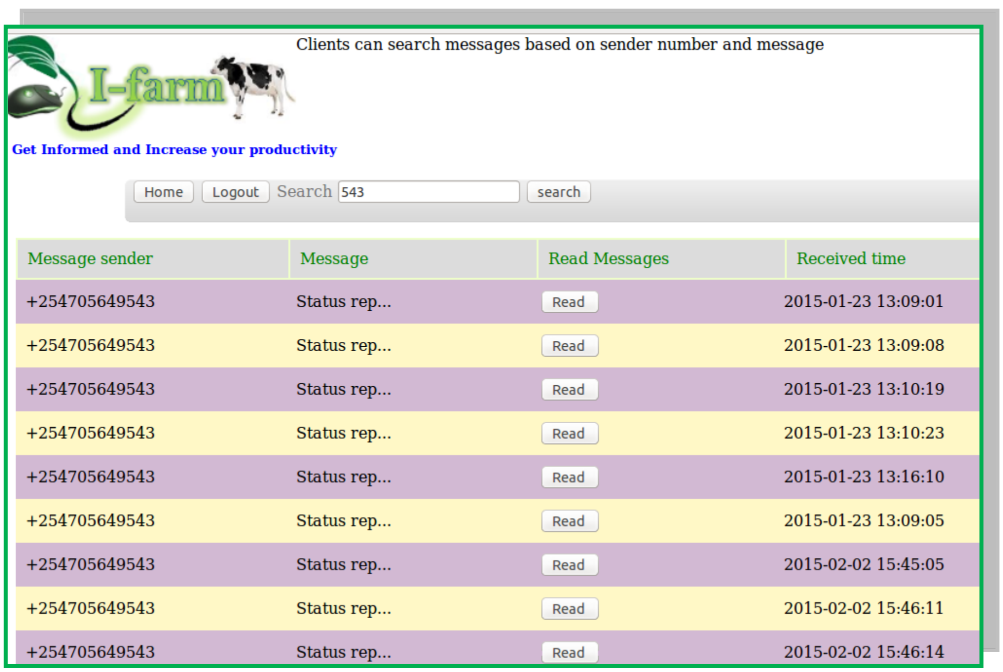
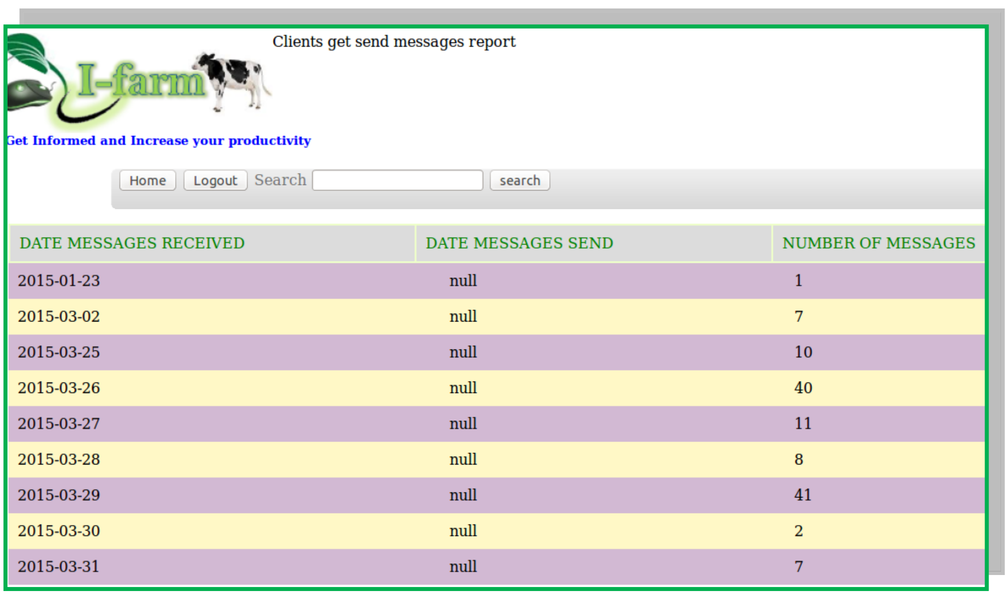


Fig.5.33. Searching messages **(Source: Author, 2014)**

5.6.8 Received and send messages report

This menu allows the user/client to view received messages in a report form by date send, date received and number of messages grouped by day. This menu also allows the user/client to view send messages in a report form by date send, date received and number of messages grouped by day as shown in Figure 5.34.



DATE MESSAGES RECEIVED	DATE MESSAGES SEND	NUMBER OF MESSAGES
2015-01-23	null	1
2015-03-02	null	7
2015-03-25	null	10
2015-03-26	null	40
2015-03-27	null	11
2015-03-28	null	8
2015-03-29	null	41
2015-03-30	null	2
2015-03-31	null	7

Fig. 5.34: Send and received messages report (Source: Author, 2014)

5.6.10 Web hosting and access to other documents required by farmers

I-farm application being a web based application will run on a top level domain to be subscribed annually. Detailed climate and weather information to the farmers shall be uploaded for additional access by farmers who may require detailed information. An SMS will be sent to the farmers indicating to them the URL or links that would facilitate them to download pdf or word documents containing detailed information required by farmers. To facilitate awareness to the farmers about the existence of I-farm mobile phone application, FM Radio stations broadcasting in Kiswahili and vernacular languages and village Baraza's shall be used to sensitize farmers on the existence of such climate and weather service in their respective farming areas. A visit to the farmers by a team of officers to ensure that farmers get to know about the service is important. This will ensure that farmers will appreciate and ultimately own the noble innovation geared towards supporting them hence ensuring sustainability of the service.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary findings and Conclusions

From this study, the following are summary of findings and conclusions made based on the stated objectives.

6.1.1 Types and sources of climate information accessible to maize and wheat farmers in Uasin Gishu County

The study revealed that there were various types or categories of agro-meteorological information produced by Kenya Meteorological Services as services or products for use by farmers and other interested groups.

Some of the types of information produced include daily weather forecasts, seasonal forecast, annual climate predictions, farmers guide, dekad (10-day) agro-meteorological bulletin, annual climate review, annual or seasonal rainfall prediction and socio-economic implications bulletin, newspaper caption on weather/climate information related to food security. The seasonal forecasts (weather outlook for the season), in Uasin Gishu County is produced in a participatory scenario planning process led by Kenya Meteorological Services and Agricultural Sector Development Support Programme (ASDSP).

Kenya Meteorological Services is also attributed to the production of services that show rainfall onset and cessation dates, rainfall variability and distribution as agreed by more than half (>50%) of the farmers. The 10 - day summary of crop and weather advisories (Dekad data), Normalized Difference Vegetation Index (NDVI) and plant density and soil moisture are also included.

Although Kenya Meteorological Services produces the listed climate informational products and services, there is still a major challenge in access to this type of information as revealed by majority of the farmers; 49.2% reporting not to receive any information service or product for use in their farming activities. Only a small percentage of 19.8% of the farmers noted that they received some service in form of farmers guide. From the stated findings a general conclusion can be arrived at stating that farmers in Uasin Gishu County do not largely integrate climate and weather information in their farming decisions and practices. This creates a challenge to the farmers when making farming decisions especially with the prevailing climate variability.

Agricultural extension officers and fellow farmers are sources of climate and weather information utilised by maize and wheat farmers in Uasin Gishu as stated by 46.2% and 50% of the farmers respectively. This clearly shows that seasonal forecast communications need to be channeled through existing trusted persons; in this case agricultural extension officers and the farmers themselves directly. The fact that farmers consult fellow farmers and agricultural extension officers has its own glaring dangers especially if the trusted channels do not access credible climate and weather information; farmers may end up getting information that may not be useful at all to their activities.

Indigenous knowledge systems and experience gained over time are other sources of information that informs a farmer's decision in the farming calendar. When farmers were asked if they knew the best maize and wheat seed varieties suitable for growing in their farms, an average of 96.7% of the farmers stated that they knew the maize and wheat seed varieties suitable for growing in their farming areas due to their experience over time stated by 44.9% and another 42.1% stating that they got the information from fellow farmers. From the foregoing, it is clear that farmers are greatly influenced by their traditional knowledge systems and experience in their farming decisions which make it difficult for them to cope or are left vulnerable to the prevailing climate variability brought about by climate change which has distorted seasons known to farmers over time.

There is low access to climate and weather information in the county as attested by 60% of farmers who do not access the information at all although KMS produces agro-meteorological information. Similarly, more than 50% are not aware of any organization producing such information. This is a true reflection of a situation where farmers do not largely integrate climate and weather information in their farming decisions.

Access to available climate information is generally farmer led and agricultural shows, farmer's field day /demonstrations are other information outlets that farmers use to access agro-meteorological information. The results reveal a farming population that does not largely integrate climate and weather information in their farming decisions. Some of the reasons advanced include adaptability, format and timing challenges of climate information produced nationally. This is where the developed I-farm model will meet the needs of the farmers in real-time.

There exists a significant relationship between access and usage of climate and weather information by farmers *(Chi = 87.263, P < 0.001)*. Majority of farmers accessing the climate and weather information are using the said information to plan their crop activities. Similarly, education level is significantly related to access to climate and weather information *(Chi = 17.957, P = 0.001).* The more educated a farmer is the more likely he/she will access climate and weather information. It is important therefore to understand the level of education of farmers before attempting to provide such information. If farmers are educated, they are able to access and ultimately use the available climate and weather information. Clear channels of information delivery need to be understood clearly as well as this will facilitate timely access.

Farmers in the study were not able to attribute the production of climate and weather information products to a particular organization as more than half (>50%) of the farmers responding to the question on availability of each product stated that no organization produced such information. The fact that many farmers were not able to attribute the production of climate and weather information means that they hardly come across the information (access challenges). If they come across it, the same information is not simplified enough (downscaled) to meet the needs of farmers. Deliberate efforts have to be worked on that will sensitize farmers on proper use of climate information and facilitate timely access of climate information

6.1.2 Modes of communicating climate and weather information to farmers

The second objective of this study was to examine the modes of communicating climate and weather information to farmers. Farmers interviewed revealed that the most common means of reception of weather forecasts, warnings and other information is the radio (79.8%) followed by television (68.4%). This shows that the media (Newspapers, radio and television) are all means of informing the public as they reach a maximum number of people.

Community *Barazas*, farmer's field day/workshops and agricultural value chains have been used by Kenya Meteorological Services and Agricultural Sector Development Support Programme (ASDSP) during their dissemination meetings of the seasonal weather outlook for example the "*Weather outlook in Uasin Gishu County for March – May 2015 Rainfall Season and Advisories*".

While the Radio and Television was cited as the most common means of receiving climate and weather information as agreed by (79.8%) and (66.4%) farmers respectively, farmers also preferred use of mobile phone (51.4%) to receive climate updates because mobile phones were owned by nearly all the farmers interviewed, in fact 94.2%

confirmed that they indeed owned a mobile phone. This is a window of opportunity to use to enable farmers access climate and weather information at their door step.

Delivery of climate and weather information to maize and wheat farmers is poorly coordinated and one of the challenges is the format and media used in disseminating this information. As seen earlier, climate information, is made available by Kenya Meteorological Services to the general public through the seasonal climate outlook bulletin and "*utabiri wa hali ya anga*" (daily weather forecasts) relayed on radio and television. This arrangement has not been considered effective by farmers. However, access to all the agro-meteorological services by farmers using proper communication channels will empower them to address challenges posed by unpredictable weather patterns in the farming enterprise.

6.1.3 Perception of farmers on use of climate and weather information and the influence of their traditional knowledge systems and practice in farming decisions

The third objective of the study was to determine the perception of farmers towards the use of climate and weather information and the influence of farmer's traditional knowledge systems in maize and wheat production. In order to bring farmers closer to the issue of concern in this objective, they were asked to give their opinion on what they understood about climate change and how they have been affected by the same phenomena. Majority of farmers (87.8%) agreed that in the recent years they have experienced changes in rainfall patterns and that even the timing for maize and wheat growing had become uncertain; an indication that climate change was real and present amidst farmers.

Farmers were also given an opportunity to rate and state what information they required in order of preference for their farming decisions. The rating of the information required would also help in gauging how farmers perceive use of climate information in their agricultural activities. In their responses, farmers on average rated information on rainfall onset and cessation dates as high with mean score of 3.5 and *SD of (0.8)* - significant variation in the responses shown. Rainfall variability and distribution; temperature variability, potential evapotranspiration and solar radiation; crop disease/pests and adverse weather conditions; plant density and soil moisture was rated as moderate (mean score 3) and *SD (≥0.8).* 10-day summaries of crop and weather advisories and Normalized Difference Vegetation Index data was rated as low (NDVI provides a crude estimate of vegetation health and a means of monitoring changes in vegetation over time). This clearly show that farmers value access to climate services and products if made accessible to them in a timely manner.

There is high value attached to climate and weather information as indicated by 54.6% of maize and wheat farmers. Similarly, the results show a significant relationship between value attached to climate and weather information and its usage *(chi = 10.325, p = 0.016).* This means that the proportion of use of climate and weather information among those who perceive the information as important is higher compared to those who perceive it as not important. However, this phenomenon has not been reflected in practice as seen earlier when 84.9% of the farmers stated that they commence their farming activities at “particular known dates in the farming calendar learned through experience over time as maize and wheat grower”. A mere belief in some variable (climate and weather information) does not necessarily translate into adoption of the same especially where traditional knowledge systems influence decisions as seen elsewhere in the results of this study. With climate variability being real then, most of the farmers may experience problems in their farming enterprise as they may not be flexible enough to change their “known calendar dates” as they fall back to their indigenous knowledge systems.

To further examine the value attached to climate and weather information use, farmers were asked to state how they rated their efforts in soliciting for climate and weather information for use in their maize and wheat production activities proactively. Hundred and eight farmers (28%) do not make any effort at all to obtain climate and weather information to assist in their maize or wheat farming, similarly, (46.4%) of the farmers sometimes do make efforts.

A high proportion of farmers who sometimes look for climate and weather information in addition to those who claim that they do not make any attempt at all to solicit for information reveal a group of farmers that may need support in terms of information access and the infrastructural facilitation so that the information is delivered to them closer to a point where they can use it. Downscaled climate information will be useful to the farmers in Uasin Gishu County in addition to implementation of an effective information delivery mode through which SMS alerts will reach the farmers hence facilitating timely access to the much needed climate information.

Farmers in Uasin Gishu County can identify with some traditional knowledge system indicators for rainfall prediction developed over the years. Meteorological indicators include wind direction blowing eastwards signifying rainfall near onset; clouds thicken at horizon and wind blowing from eastern to western side of their farms indicating near onset of rainfall. There is also high sunshine intensity during the day and warm nights or high temperatures at night and low temperature in the evening signify near onset of rains. Frequent lightning flashes around *Tindiret* area (Lake Region) with some dark cloud forming is an indicator of near rainfall onset.

Other indicators are related to behavior of certain plants and trees. The *Erythrina Abyssinica (Kakarwet*) tree start flowering red with full leaves regained, *Vernonia Auriculifera (Tepeng'wet*) tree starts flowering, *Flacourtia Indica* (*Tungururwet*) starts budding all are an indication of rainfall near onset. One other small plant growing in the bushes *Scadoxus Multiflorus* of the *Amaryllidaceae* family (*Ngotiotet)* starts flowering red around March period and found in thickets or bushes near river banks is a real indicator of rainfall near onset. The fig tree of species *Ficus Sycomorus* (*Mogoiywet*) starts shading leaves off is an indicator of near rainfall onset.

Among the animal indicators are the migratory birds that include White stork *(kaptalaminik*) moving or flying towards the north signifying near rainfall onset and when flight changes towards the south, this signifies cessation. In addition to the indicators, the community had a unique way or prayer asking their God for rainfall or water for use in their homesteads and their general hygiene at home during difficult times when drought manifest. The traditional song "*ingo*" was sang by mature women at night and many groups (3 to 4 groups of women) from various locations could join in the song at night converging at one place in the open away from homesteads as participants do it without cloths on them.

Just like all other farmers in different parts of the world, farmers who depend on rain-fed cultivation have developed complex cultural models of weather and are able to cite local predictors of seasonal climate. From this study majority of farmers prefer indigenous forecasting knowledge because they have a belief that indigenous information is more practical as it has been tested, tried and trusted over time. The dependency on traditional indicators alone without integrating with climate and weather information use can and has predisposed farmers to losses of crop as no adaptation measures have been implemented to help them navigate the risks of climate variability.

There are challenges now being faced by traditional weather forecasters due to environmental degradation, ecosystem disturbance and climate variability. Most indigenous trees have disappeared completely and are being replaced by exotic trees which are alien to indigenous weather predictors. Burning of farms has not only destroyed micronutrients and shrubs but also destroy insects and their migratory paths which traditional weather forecasters use to predict near onset of rains. Some bird species have migrated elsewhere where they can still find a natural habitat hence rendering traditional weather forecasters using birds to predict onset of rains helpless. The slaughtering of a goat and dissecting the stomach to read what type of vegetative growth was consumed by the goat is no longer viable because inside the slaughtered goat stomach, you will find other food stuff including polythene bags that cannot be used to carry out any tradition weather forecast. Weather prediction then was almost reliable. It is therefore important to integrate both scientific and traditional knowledge system as the scientific forecast diverges from traditional farmer's prediction in scale and to some extent on predictors

When Farmers were tested on whether they relied on the use of climate and weather information or their indigenous knowledge systems/practice in their farming decisions, varied responses were gathered. Although they belief sometimes in the use of climate and weather information to conduct their business of maize and wheat crop growing was high at 55.7%, most farmers remain influenced by their traditional knowledge systems in weather prediction which they have relied upon over the years. There is therefore a significant relationship between indigenous knowledge system indicators for rainfall prediction and the use of climate and weather information in maize and wheat production activity. A higher proportion of the farmers relying on their indigenous knowledge system indicators to predict rainfall hence making decision on farming activities do not use climate and weather information.

Farmer's experience over time cultivating maize and wheat greatly influences their decision in their farming calendar; farmers commence their farming activities just because those are the dates known to them through their experience over time in maize and wheat growing as agreed by 84.9% of the farmers and a further (36%) looking at signs of rain that is about to fall. This was confirmed by participants of key informant interview carried out during the period of data collection in the study. The use of farmer experience alone to plan farm activities have made famers incur loses as they fail to capitalize fully on beneficial weather conditions prevailing then but have frequently buffered poorly against negative effects of climatic variability in their farming enterprise.

6.1.4 The influence of climate and weather information on maize and wheat production

The fourth objective was to examine the influence of climate and weather information on maize and wheat production in Uasin Gishu County. To understand further the influence of climate and weather information in crop production, farmers were asked to state the benefit accrued after utilization of climate and weather information as indicated in table 4.14. About 45% of farmers reported that after utilization of information on weather and climate, they were able to successfully apply fertilizers/top dressing, weeding and apply agro-chemicals. In addition, 34.7% were able to avoid lack of adequate rain phenomena during planting season by waiting a little longer till the onset of rains before commencement of planting of either wheat or maize. There was really a positive influence of the stated information as farmers were able to avoid losses and realise the beneficial influence of climate information.

Asked if they would substitute their crops (maize and wheat) with other crops to avoid risks if the Kenya Meteorological Services predicted the occurrence of drought during the season when farmers expect to commence the planting of maize and wheat, more than half of the farmers (52.7%) agreed that they would substitute the growing of maize or wheat with other crops to avoid any risks that might occur. Maize growing was substituted with beans by 60% of the farmers while 58% agreed that they had substituted wheat crop growing with the growing of beans as a mitigation measure against drought manifestation. Access to timely climate information thus is crucial in helping farmers to be well aware about the climatic changes hence being able to plant crops that could tolerate the extreme weather conditions prevailing then.

Despite the fact that farmers were able to substitute their crops with other weather tolerant crops, many of the farmers reported experiencing crop damage due to lack of adequate rain during growing period reported by 78.6% of the farmers while 70% on average reported that they experienced loss due to too much rain during growing season, drying period and during harvest time. As seen earlier, although 52.7% of the farmers agreed that they would substitute the growing of maize or wheat with other crops to avoid any risks involved if an advisory is relayed to them, the responses above clearly show that that did not happen. Therefore, farmers remain vulnerable to vagaries of climate variability if they do not embrace climate and weather information in addition to their traditional knowledge systems to assist them in their farming decisions.

Despite the ability to mitigate, farmers remain vulnerable to climate variability due to lack of timely climate and weather information. The prevalence of drought and too much rain in the seasons has seen the output of both maize and wheat drop to average at (6-15 bags) of 90kg per acre in comparison to (25-30) bags of 90 Kg bag of maize or wheat per acre during pamper harvest time. The stated average for maize and wheat has reduced compared to the previous period. According to data from key informant interview "*average yield for maize per acre was 35-40 bags of 90kg while that of wheat was averaging at 25 – 35 bags during the 1980s and early 1990s. This was possible with serious farmers who apply the correct fertilizer and the right ratios with a good top dressing and application of pesticides and fungicides to protect the crop".* This clearly shows that the yield per acre has been degreasing rapidly and farmers are incurring losses related to climate variability.

In order to understand if there was any relationship in the yield attained per acre and access to climate and weather information a significance level test was done. The result shows that there was no significant relationship between access to climate and weather information and crop yield per acre (crop production) ($p>0.05$) as indicated in Table 4.15. Whether a farmer accessed information on climate and whether or not, the yield seems to have remained the same. This is slightly different from other studies where access to climate and weather information has been attributed to increase in crop yield as losses were avoided. In this situation, the non-significant relationship could be attributed to other confounding variables for example use of correct certified seeds by farmers, use of the right fertilizer in relation to soil requirements, correct pesticides and fungicides, timely top dressing and others and also accessing climate information without acting on it leaves a farmer with the same results.

For effective usage of climate and weather information, farmers need support in terms of information access and the infrastructural facilitation. This will ensure that the information is delivered to the farmers to a point where they can use it. Farmers are making decisions in their farms without regard to the value of climate and weather information especially now with the prevailing climatic variability which has resulted in crop losses. There exist constrains however in the optimal use of seasonal climate forecast information by farmers generally and some of these constraining factors include provision of information that is general for application (not specific to any area or particular application) or may be received late by farmers.

6.1.5 Acceptability of use of mobile phone technology to relay climate and weather information to farmers

The fifth objective was to determine acceptability of use of mobile phone technology to relay climate and weather information to farmers in the community.

Mobile phones were accessible to almost all the farmers interviewed as reflected by 92.2% confirmations of owning mobile phones with 92.8% hooked to Safaricom mobile service provider network. Farmers also further stated that they use their mobile phones to receive text messages (SMS) as affirmed by 93.9% of the farmers. Almost all the farmers (96.3%) preferred to receive or get updates (SMS Alerts) on climate and weather information through their mobile phone. This is the trend now in Africa and other developing countries where the larger population has now unprecedented access to information via their mobile handsets. Farmers from isolated areas can access weather information via text messages (SMS) or phone calls, to prepare for upcoming drought spells, heavy rains or floods. The developed model in this study would not have come at a better time. I-farm Application; a tool for use to attain climate smart agriculture will help bridge the knowledge gap in the delivery of climate and weather information to the farmers in Uasin Gishu County.

Due to the fact that the delivery of climate and weather information is poorly coordinated due to challenges of format and media used in disseminating this information to the farmers, Mobile phones have come in at the time such information requirements can be shared through SMS alerts directly to the farmer. Mobile phones have a clear advantage compared to the other media because in addition to voice communication, some technical advantages of mobile phones allow for the transfer of data, which can be used in the context of applications for the wide range of purposes such as weather forecast. It facilitates feedback mechanism in the communication process making it more effective.

6.1.6 Developing a model to relay climate and weather information to maize and wheat farmers in Uasin Gishu County.

The sixth objective of this study was to design a communication model (SMS Alert) service to relay climate and weather information to the Maize and Wheat growing farmers in Uasin Gishu County of Kenya. This has been developed and a detailed explanation given in chapter 5 of the study.

6.1.7 I-farm application model: an agro-weather tool for climate-smart agriculture

I-farm is a web based interactive application aimed at increasing adaptive capacity of farmers by improving access to information on weather and climate patterns through use of mobile phone to deliver SMS alerts to farmers. It will support improvement of farm management capabilities under conditions of climate risk. The system will help farmers to plan and manage weather risks and maximize productivity. It will entail the delivery of climate-smart agro-advisory information (SMS alerts) to farmer's mobile phones. The system is designed to inform farmers through messages notifications on prevailing weather patterns, advisory alerts, best practices all geared towards supporting a farmer's decision at the farm level. An informed decision made by the farmer will positively impact on productivity hence attaining profit in the farming enterprise.

I-farm application is a mobile phone web based application for relaying SMS alerts to farmers developed to meet the needs of farmers. I-farm Application explained in details in Chapter 5 of this study is an agro-weather tool, aimed at helping farmers attain the practice of climate smart agriculture. I-farm application has been designed as a model to be rolled out in Uasin Gishu County. The system is scalable and can be set up in other counties as well. The application has capability to meet all farmers' needs beyond climate and weather information as it connects farmers to a communication hub. Reaching farmers with new agro-weather information will greatly benefit the farmers. The County government of Uasin Gishu can adopt and use the system effectively before being replicated in other counties in Kenya.

6.2 RECOMMENDATIONS

Based on the findings and conclusions made related to the study objectives, the following recommendations can be made:

The type of climate and weather information available to farmers needs to be addressed in terms of its adaptability, format and timing challenges to enable its effective delivery and use. The information should be downscaled and repackaged in formats that farmers access, understand and use for ownership and sustainability. Climate and weather information content should be made simple to understand by ordinary farmers in the community.

Participatory scenario planning process used by Kenya Meteorological Services and Agricultural Sector Development Support Programme (ASDSP) including the stake holders to generate seasonal weather outlook in Uasin Gishu County is very important thus there is urgent need to identify sustainable finances to support activities. Similarly, effective dissemination channels for climate information delivery need to be put in place to supplement the use of community Barazas currently in use.

Farmers trust agricultural extension officers and their fellow farmer as sources for climate and weather information for their use. It is paramount thus that a policy to support agricultural extension officers and farmers with access to good quality climate and weather information need to be in place at the county government level.

Agricultural extension officers and meteorological staff need to be better equipped to advise farmers on issues related to weather, climate and climate change thus calling for specialised training in agro-meteorology. Both county and national governments need to mobilise resources for capacity building for the categories of staff.

Agricultural shows, farmer's field day/demonstrations, billboards, community barazas and agricultural value chains are important and strategic sources of agro – meteorological information that farmers easily access and targeting such point with climate and weather information tailored for farmers should a priority. Continued sensitisation of farmers and stakeholders in the rural areas on importance of weather and climate information use in farming and the interpretation of relevant weather and climate products to support farming decisions is of outmost importance and should be championed by County governments in their policies and frameworks.

Repackaged information that suit the farmers need to be disseminated using appropriate channels recommended by the farmers. The channels preferred are use of vernacular FM radio stations and mobile phones in form of SMS alerts. The designed model fits well to the farmer's demands.

Since access to climate and weather information is significantly related to farmers level of education, it becomes crucial therefore to understand the level of education of farmers before attempting to provide such information. Effective outreach programs coupled with educational initiatives to help farmers understand the use of climate information to realise its full potential is important. This will involve giving greater priority to extension and communication activities and mainstreaming climate information access in all relevant agricultural sectors.

It is crucial to understand the local people's (farmers) indigenous knowledge systems and practice if delivery and uptake of climate and weather information is to be embraced and owned by farmers. In any case, some of the principles of the predictors like wind flow, temperature changes converge with the scientific forecast. The farmers will truly benefit more if they accessed climate and weather information as they shall be able to take advantage of the prevailing favourable weather conditions and avoid losses due to weather variability and environmental degradation.

There is need to integrate both traditional knowledge systems and scientific information for synergy forecasting that generate reliable climate information. Incorporating farmers perspectives by slightly modifying and using them to meet current needs and situations will help address the needs of farmers and may be a motivator in embracing the use of climate and weather information as their traditional knowledge system perspectives have been incorporated. This will create ownership by communities as farmers have a belief that indigenous information is more practical as it has been tested, tried and trusted over time. This will help minimizing loses in crops related to extreme weather conditions.

Relying only on traditional weather forecasting by farmers is catastrophic now due to changes on the environment associated to environmental degradation; ecosystem disturbance and climate variability which have seen important traditional predictor indicators disappear or lost completely from the environment. It is therefore important to integrate both scientific and traditional knowledge system to supplement the loss on traditional indicators of rainfall prediction that used to support farmer decisions. In any case, the scientific forecast share a lot in common with traditional weather forecast and may only differ in terms of scale and to some extent on predictors.

A strong link, including feedback loops between scientists, advisory agents and farmers is crucial for communicating climate information and facilitating access by local communities. It is important for the meteorologists to understand farmers (real and perceived) needs as the farmers know what they need at what point in time and not what the meteorological scientists think is needed by farmers. A policy guideline on a closer working relationship should be established between the farmers, agricultural extension officers and meteorological staff.

Evidence based mitigation measures against farmers perceived and real threats of climate variability impacting on crop yield need to be clearly outlined by both county and national governments ministries concerned. Some of the mitigation measures include farmer’s utilization of climate and weather information and also crop diversification and substitution. Substituting the growing of maize or wheat with other cereals (beans, millet, sorghum and others) that are able to do well even with poor rains or growing all these crops is important. This can be achieved through sensitization programmes to maize and wheat farmers on available mitigation measures for them and allowing them to champion such innovative approaches geared towards cushioning them against losses as this will ensure ownership and sustainability of the mitigation approaches.

The national government need to take the lead in engaging the development of a robust communication strategy at the national and county levels to ensure efficient and effective dissemination of agro-climate information to users. Appropriate means of dissemination of weather and climate information that ensure that farmers are reached, and are presented in a language that farmers can understand is important. Farmers need support in terms of information access and the infrastructural facilitation so that the information produced by Kenya Meteorological Services is delivered to them closer to a point where they can use it.

Agro-meteorological services including delivery of climate and weather information should target the use of mobile phones to disseminate their products and services especially to the farmers in form of SMS alerts as demanded by nearly all the farmers interviewed in addition to vernacular radio broadcast. Since mobile phones are easily accessible to many farmers, they are likely to remain the key information medium as they have been used to provide agricultural advice in the form of voice and text messages in some studies.

The developed climate information communication model (I-farm Application) to relay climate and weather information to farmers in this study is a noble innovation that needs government support. It can be implemented and scaled up to include other agricultural information and propagated in other counties of Kenya with the aim of empowering farmers with information to enable them avoid losses in their agricultural enterprise. A robust communication approach using mobile phones to reach farmers with weather alerts is a timely contribution to knowledge and fast-tracking its role out is crucial.

National Meteorological and Hydrological Services need to consider the use of mobile phones to deliver agro-climate information and other advisories to famers and other local communities who may be impacted by climate variability and other disasters that may affect people's livelihoods as mobile phones have now become the single most used communication tool globally and more so in developing countries including Kenya at communities where infrastructure development is slowly penetrating.

6.3 CONTRIBUTION TO SCIENCE

(a) The researcher in this study has designed a web based communication model that will interact with farmers on a real-time basis. I-farm application is a mobile phone web based application for relaying SMS alerts or advisories to farmers developed to meet the needs of farmers at both county and even national level due to its scalability. The system is versatile enough to be applied in other areas beyond advisories like managing and marketing of all types of crops, advice on livestock farming, fish farming environmental management, community based organizations and other institutions to manage communication and service delivery. It can be used as a monitoring tool to track progress of interventions and development at communities.

(b) This study has found out that the state of climate and weather information today is not being well utilised by farmers and other users due to its adaptability, format and timing challenges and addressing this challenges through downscaling and repackaging of the information to make sense among the farmers is crucial for ownership and sustainability. This will be realised by use of appropriate channels of dissemination that include mobile phone SMS alerts.

(c) This study suggests that there is need to integrate both traditional knowledge systems and scientific information for synergy forecasting to generate reliable climate information useful to farmers. Incorporating farmers perspectives by slightly modifying and using them to meet current needs and situations will help address the needs of farmers and may be a motivator in embracing the use of climate and weather information as their traditional knowledge system perspectives have been incorporated.

(d) Relying only on traditional weather forecasting to predict weather phenomena by farmers is catastrophic now due to changes that have happened on the environment associated to environmental degradation, ecosystem disturbance and climate variability. Important traditional predictors or indicators have disappeared or gotten lost completely from the farmers environment. Some of these indicators are meteorological related, those related to trees, birds, animals or insects all are not reliable now due to a disturbed ecosystems that no longer favours their habitat.

(e) Development of a strong communication link, including feedback loops between scientists, advisory agents and farmers is crucial for communicating climate information and facilitating access by local communities. It is important for the meteorologists to understand farmers (real and perceived) needs as the farmers know what they need at what point in time and not what the meteorological scientists think is needed by farmers. A policy guideline on a closer working relationship should be established between the farmers, agricultural extension officers and meteorological staff.

6.4. AREAS FOR FURTHER RESEARCH

1. Indigenous knowledge system and scientific forecasting integration to mitigate climate change. Since the meteorological indicators in Indigenous knowledge system have some similarity with scientific parameter, can they be complementary?

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APPENDICES

Appendix I– Questionnaire and Consent Form

Daniel K. Murgor

University of Eldoret

School of Environmental Studies P. O. Box 1125 ELDORET

E-mail danmurgor@yahoo.com,

Dear Farmer,

I am carrying out a study on **"Farmers Access to Climate and Weather Information and its Impact on Maize and Wheat Production in Uasin Gishu County".** This is part of the procedural requirement for the award of Doctor of Philosophy (D.Phil.) in Environmental Studies (Human Ecology) degree of University of Eldoret. Please kindly assist in filling in the questionnaire provided below by following the given instructions. There are 53 questions though some have parts (a) and (b). The time taken to fill the questionnaire varies from 30 – 40 minutes. This exercise is extremely important as the findings from this research will be integrated in the national food security policy approach by the Kenya government and similarly, farmers will be able to understand their noble role in feeding the nation while they benefit economically through minimization of loses in agricultural practice brought about by changes in climatic conditions over time. Participation in this exercise is voluntary. The information you give will be regarded highly and treated as confidential.

Consent to participate

I, Sign ------------------------- agree to participate in this survey on a voluntary basis having understood clearly the purpose of this study

Thank you most sincerely for your kind response

Daniel K. Murgor

Doctor of Philosophy, University of Eldoret, School of Environmental Studies

Questionnaire

NB. *Don't be afraid! The questionnaire is thick and there are 51+ questions in, I promise that they will be interesting and that it can be completed in 30 Minutes!*

QUESTIONNAIRE ON FARMERS ACCESS TO CLIMATE AND WEATHER INFORMATION AND ITS IMPACT ON MAIZE AND WHEAT PRODUCTION IN UASIN GISHU COUNTY, KENYA

COMPLETE AND RETURN THE QUESTIONNAIRE TO THE RESEARCHER OR THE RESEARCH ASSISTANT CONDUCTING THE EXERCISE. PLEASE KINDLY MARK IN THE BLOCKS MARKED 1, 2, 3, 4 … (*what is applicable to you as a maize and wheat farmer*)

PART A: GENERAL INFORMATION

1. Area of Residence

(a). Sub County ----------------------------------- (b). Ward------------------------------------

PART B: DEMOGRAPHIC DATA

1. Gender

(a) Male ☐ (b) Female ☐

2. What is your age?

(a) Under 25 years ☐

(b) 26 – 46 years ☐

(c) 47 – 59 years ☐

(d) Above 60 years ☐

3. What is your occupation?

(a) Farmer – full-time *maize and wheat grower* ☐

(b) Farmer – Wheat growing only ☐

(c) Farmer – Maize growing only ☐

(d) Farmer – others -------------------------- Specify ☐

4. Educational levels

(a) Primary level ☐

(b) Secondary level ☐

(c) Tertiary (Diploma college) ☐

(d) University ☐

(e) Did not attend any school at all ☐

5. What is the size of your farm?

(a) Above 100 acres (above 41hectares) ☐

(b) 52.5 - 100 acres (21-40 hectares) ☐

(c) 2.5-51 acres (1-20 hectares) ☐

(d) Less than 2.5 acres (< 1 hectare) ☐

6. What is the exact size of your maize farm ploughed? --------------- Acres

7. What is the exact size of your wheat farm ploughed? ---------------Acres

8. What is the yield (No of bags) for maize per acre per year in your farm?

(a) 40 bags of 90kg per acre ☐

(b) 30 – 39 bags of 90kg per acre ☐

(c) 20 – 29 bags of 90kg per acre ☐

(d) 10 – 19 bags of 90 kg per acre ☐

(e) Less than 10 bags of 90 kg per acre ☐

9. What is the yield (No of bags) for wheat per acre per year in your farm?

(a) 40 bags of 90kg per acre ☐

(b) 30 – 39 bags of 90kg per acre ☐

(c) 20 – 29 bags of 90kg per acre ☐

(d) 10 – 19 bags of 90 kg per acre ☐

(e) Less than 10 bags of 90 kg per acre ☐

10. The cost of 90kg bag of maize sold during the last harvest was? KShs ----------- per bag

11. The cost of 90kg bag of wheat sold during the last harvest was? KShs ---------- per bag

12. from your own experience, over the last 5 years, the yield per acre of Maize production has been

(a) Increasing ☐

(b) Declining ☐

(c) Don't Know ☐

12b. What are the reasons for the maize yield increase?------------------------------------ -- -- -- ------------------------------------

12c. What are the reasons for the maize yield decrease?------------------------------------ -- -- -- ------------------------------------

13a. From your own experience, over the last 5 years, the yield per acre of Wheat production has been

(a) Increasing ☐

(b) Declining ☐

(c) Don't Know ☐

13b. What are the reasons for the wheat yield increase?------------------------------------ -- --

13c. What are the reasons for the wheat yield decrease?------------------------------------ -- --

14a. As a maize farmer, do you attend any of the following activities in the year?

(a) District agricultural shows (ASK) ☐

(b) Farmers field day organized by Kenya Seed/Ministry of Agriculture/University of Eldoret ☐

(c) Agricultural demonstrations by agricultural extension workers ☐

(d) Do not attend any of the above ☐

14b. As a wheat farmer, do you attend any of the following activities in the year?

(a) District agricultural shows (ASK) ☐

(b) Farmers field day organized by Kenya Seed/Ministry of Agriculture/University of Eldoret ☐

(c) Agricultural demonstrations by agricultural extension workers ☐

(d) Do not attend any of the above ☐

PART C: CLIMATE AND WEATHER INFORMATION, INDIGENOUS KNOWLEDGE SYSTEMS, MAIZE AND WHEAT PRODUCTION AND CLIMATE VARIABILITY/FARMERS ADAPTATION

15. Do you receive any climate and weather information or (climate forecasts) for use in your farming practice?

(a) Yes ☐

(b) No ☐

(c) No but I would like to ☐

(d)I don't know anything about climate and weather information ☐

16. Is the climate and weather information available to you when you need it?

(a) No ☐ (b). Yes ☐ (c). I don't know ☐

17a. To what extend do you need the following information service on seasonality provided to you in relation to maize production?

Use the following scale to rank the information service useful to your maize production:-

☐ Don't Know ☐ Low ☐ Moderate ☐ High ☐ Very High

Information Required	**Scale**
1. Rainfall onset and cessation dates	☐
2. Rainfall variability and Distribution/Drought & floods	☐
3. Temperature variability, Potential Evapotranspiration (PET), Solar Radiation	☐
4. Crop diseases/pests and adverse weather conditions	☐
5. 10-day summaries of crop and weather advisories (Dekad) data	☐
6. Plant density and soil moisture	☐

7. Normalized Difference Vegetation Index data in some instances (NDVI) ((***NDVI provides a crude estimate of vegetation health and a means of monitoring changes in vegetation over time)*** ☐

17b. To what extend do you need the following information on seasonality provided to you in relation to wheat production?

Use the following scale to rank the information service useful to your wheat production:-

☐ Don't Know ☐ Low ☐ Moderate ☐ High ☐ Very High

Information Required	**Scale**
1. Rainfall onset and cessation dates	☐
2. Rainfall variability and Distribution/Drought & floods	☐
3. Temperature variability, Potential Evapotranspiration (PET), Solar Radiation	☐
4. Crop diseases/pests and adverse weather conditions	☐
5. 10-day summaries of crop and weather advisories (Dekad) data	☐
6. Plant density and soil moisture	☐

7. Normalized Difference Vegetation Index data in some instances (NDVI). (***NDVI provides a crude estimate of vegetation health and a means of monitoring changes in vegetation over time)*** ☐

18. The following outlined information services on climate and weather can be availed to maize and wheat growing farmers in Uasin Gishu County. Please select the organization providing the type of information outlined below.

(Please Tick the appropriate box that apply to your case using the numbering provided below)

1=Kenya Meteorological Department 2. District Agricultural Office 3. Kenya Seed Company 4. Farmers who understand better the climatic and weather patterns prevailing in the year.

5. No information is provided to me by any of the organizations)

1. Rainfall onset and cessation dates ☐

2. Rainfall variability and Distribution/Drought & floods ☐

3. Temperature variability, Potential Evapotranspiration (PET), Solar Radiation ☐

4. Crop diseases/pests and adverse weather conditions ☐

5. 10-day summaries of crop and weather advisories (Dekad) data ☐

6. Plant density and soil moisture ☐

7. Normalized Difference Vegetation Index data in some instances (NDVI). (***NDVI provides a crude estimate of vegetation health and a means of monitoring changes in vegetation over time)*** ☐

19. Through which media do you receive climate and weather information (rainfall distribution, temperature range) etc?

(a) Television ☐

(b)) Mobile phone ☐

(c) Newspaper/printed pamphlet ☐

(d) Radio ☐

(e) Internet /E-mail ☐

(e) Fax or fixed telephone ☐

(f) In a "village barasa" headed by agricultural extension worker and village elders ☐

(f) Other – (*please specify*) ---

20. Through what media would you prefer to receive climate and weather information (rainfall distribution, temperature) etc?

(a) Fax / fixed telephone ☐

(b) News paper/printed pamphlet ☐

(c) Television ☐

(d) Radio ☐

(e) E-mail/internet ☐

(f) Mobile phone ☐

Other - Please specify.. ☐

21. Do you own or have a mobile phone?

(a) Yes ☐

(b) No ☐

22. Which of the following mobile phone communication network are you connected to?

(a) Safaricom ☐

(b) Airtel ☐

(c) Orange ☐

(d) Other ----------- (*Please Specify*) ---

23a. Do you use your mobile phone to receive and read your short text messages (SMS)?

(a) Yes ☐

(b) No ☐

23b. If the answer to 23a is YES, would you prefer to receive or get updates on climate and weather information to help you in numerous decisions on maize and wheat growing in your county?

(a) Yes ☐

(b) No ☐

(c)I don't know anything about climate and weather information ☐

23c. If the answer to 23a above is NO, what are the reasons for not using the mobile phone to receive the said information?

(a) I don't know how to read ☐

(b) There is no network coverage here ☐

(c) There is no power supply to charge the phones ☐

(d) Other ----------- (*Please Specify*) --

24. Who receives and control the climate and weather information for the planting season whether at home or via any media?

(a) I receive and control the information and decide what should happen ☐

(b) My wife receives and controls the information as she is usually in the farm ☐

(c) My husband receives and controls the information as he is usually in the farm ☐

(d) The workers in the farm are responsible for what is to be done ☐

(e) The information provided does not change my activities planned at all ☐

(f) I do not receive any information at all on climate and weather for use therefore I do not use it at all. ☐

25a. The following are services or products used to communicate climate and weather information to farmers by meteorological organizations or Ministries of Agriculture and others. Please *select those that you received and used* in your maize and wheat growing period by ticking in the boxes provided

(a) Farmers' Guide - gives advisory on what to plant, where to plant, how to plant and when to plant and also contains onset and cessation dates of the rains etc ☐

(b). Dekad (10-day) Agro meteorological Bulletin – gives 10 day summaries of crop and weather advisories ☐

(c) Annual climate review – to show observed changes in climate parameters ☐

(d) Annual or seasonal Rainfall Prediction and Socio-Economic Implications bulletin - consists of Onset dates of the rainy season, Cessation dates of the cropping season, Length of the rainy season, total amount of rainfall expected for the season, and Socio-economic implications of the expected rainfall pattern and advisories in the various sectors such as agriculture ☐

(e) Newspaper caption on weather/climate information and crop production/food security around the country in general ☐

(f). Targeted information for maize and wheat farmers showing what variety to plant, where to plant, how to plant and when to plant and also contains onset and cessation dates of the rains ☐

(g). I did not receive any of the above listed products or service at all for use in my farming activities (maize and wheat growing) ☐

25b. The following are services or products used to communicate climate and weather information to farmers.

Please select by ticking in the box the organization that produced or delivered the information to you using the following list: - 1 - Kenya Meteorological Department, 2 - Ministry of Agriculture, 3 - Daily Newspaper, 4- Local NGO/INGO in the area, 5 - No organization produces and delivers such information to me.

(a) Farmers' Guide - gives advisory on what to plant, where to plant, how to plant and when to plant and also contains onset and cessation dates of the rains etc ☐

(b). Dekad (10-day) Agro meteorological Bulletin – gives 10 day summaries of crop and weather advisories ☐

(c) Annual climate review – to show observed changes in climate parameters ☐

(d) Annual or seasonal Rainfall Prediction and Socio-Economic Implications bulletin - consists of Onset dates of the rainy season, cessation dates of the cropping season, length of the rainy season, total amount of rainfall expected for the season, and Socio-economic implications of the expected rainfall pattern and advisories in the various sectors such as agriculture ☐

(e) Newspaper caption on weather/climate information and crop production/food security ☐

(f) Targeted information for maize and wheat farmers showing what variety to plant, where to plant, how to plant and when to plant and also contains onset and cessation dates of the rains ☐

26a. How much value do you attach to climate and weather information in relation to your maize growing?

(a) Very important ☐

(b) Important ☐

(c) Unsure ☐

(d) Not important ☐

26b. How much value do you attach to climate and weather information in relation to your wheat growing?

(a) Very important ☐

(b) Important ☐

(c) Unsure ☐ (d) Not important ☐

27. How often do you belief in seasonal climate and weather information?

(a) All the time ☐

(b) Most of the times ☐

(c) Some times ☐

(d) Not at all ☐

28a. How often do you rely on your experience/indigenous knowledge in maize production?

(a) All the time ☐

(b) Most of the times ☐

(c) Some times ☐

(d) Not at all ☐

28b. How often do you rely on your experience/indigenous knowledge in wheat production?

(a) All the time ☐

(b) Most of the times ☐

(c) Some times ☐

(d) Not at all ☐

29. Why do you believe in climate and weather information provided by the meteorological department/Ministry of agriculture/NGO?

(a). It is more accurate than my own judgment in maize and wheat farming ☐

(b) The information usually support what I already know about maize and wheat growing ☐

(c) I do not believe in the information usually as it conflicts with what I know about the maize and wheat growing season, the variety suitable and rainfall onset and cessation dates ☐

(d) I do not believe in the information because what is provided or predicted does not usually happen as predicted always ☐

30a. Do you use climate and weather information to plan maize growing activities?

(a) YES ☐

(b) NO ☐

(c) I use my experience over time (Indigenous Knowledge) ☐

30b. Do you use climate and weather information to plan your wheat growing activities?

(a) YES ☐

(b) NO ☐

(c) I use my experience over time (Indigenous Knowledge) ☐

31. Do you make a deliberate effort to obtain climate and weather information to assist you in maize or wheat growing activities during the season?

(a) All the time ☐

(b) Most of the times ☐

(c) Some times ☐

(d) Not at all ☐

32a. Who do you contact for support to explain more about climate and weather information utilization in maize and wheat farming?

(a). Agricultural extension officer ☐

(b). someone from the meteorological department ☐

(c) Someone from the media ☐

(d) An officer from the UN/NGO ☐

(e) My fellow farmer as we discuss what seed variety to plant and when to start planting ☐

(f) I do not consult anybody at all for any support because I know what and when to plant ☐

32b. Who comes to visit you to explain more about climate and weather information utilization in maize and wheat farming?

(a). Agricultural extension officer ☐

(b). someone from the meteorological department ☐

(c) Someone from the media ☐

(d) An officer from the UN/NGO ☐

(e) My fellow farmer as we discuss what variety to plant and when to start planting ☐

(f) No one visits me to talk about the information ☐

33. If a drought is forecast by Kenya Meteorological Department and shown that it will really occur during the period you expect to start planting maize or wheat, can you substitute the growing of maize and wheat with other crops?

1. YES ☐

2. NO ☐

3. I do not follow what they say because it is never right ☐

34a. Which of the crops mentioned below have you planted at one point in your farm to substitute maize growing because of weather forecast report or climate and weather information advisory service?

(a). Sorghum ☐

(b). Finger Millet ☐

(c). Beans ☐

(d). Cassava ☐

(e). Potatoes ☐ (f). Amaranth species ☐

(g). Other --- (Please specify)

34b. Which of the crops mentioned below have you planted at one point in your farm to substitute wheat growing because of weather forecast report or climate and weather information advisory service?

(a). Sorghum ☐

(b). finger Millet ☐

(c). Beans ☐

(d). Cassava ☐

(e). Potatoes ☐

(f). other --- *(Please specify)* ☐

35. Do you get advice from the ministry of agriculture or the Kenya Seed Company on the maize and wheat variety suitable for growing in your area?

(a). YES ☐ (b). NO ☐ (c). I don't know ☐

36. How often do you take samples of your soil to the ministry of agriculture laboratory in Eldoret or University laboratory at the University of Eldoret to be advised on the right fertilizer to use after determining acidity levels of your soils due to continued use of fertilizers in maize and wheat growing?

(a). I have not taken any soil samples for analysis ever since ☐

(b). every year, I do soil analysis ☐

(c). every after 2 years ☐

(d). every after 5 years ☐

37. In the recent years, there has been a change in rainfall patterns and even the timing for maize and wheat growing is uncertain. This has led to declines and loses in maize and wheat production.

(a) Strongly Agree ☐

(b) Agree ☐

(c) Disagree ☐

(d) Strongly Disagree ☐

38. What determines your farming calendar (when to start land preparation, planting, type of crop to grow, weeding, top dressing, spraying of weeds, fungus or bacterial infection on crops and even harvesting)? Etc

(a) Particular dates in the farming calendar I have observed over time. Land is prepared in December – February and planting for maize starts in March and April. For wheat, Land is ploughed in December – February like maize but harrowing continuously up to June – July when planting of wheat starts. Other crop activities follow as per what I see and know over time ☐
(b) Signs that the rains are about to fall e.g. wind direction, cloud movement and high sunshine intensity during the day based on our experience over time in maize and wheat growing activity ☐
(c) I look around to see if people have started land preparation, planting, weeding, spraying and all other activities including harvesting ☐
(d) We get announcement from the Kenya Meteorological Department delivered over the radio/Television/News paper about the need to start land preparation and subsequent activities in maize and wheat growing ☐
(e) We are advised by Ministry of Agriculture officials and Kenya Seed Company field officers on the need to start land preparation and all activities during maize and wheat growing ☐

39. What do you think are signs that rain is about to fall in your area from your own experience over time? (*Choose or tick all that apply to your experience)*

(a) Lightning flashes around the Lake Region or Tindiret area in Nandi South ☐

(b) Cloud cover and intense sunshine during the day ☐

(c) Wind direction (Towards western side and sometimes eastwards) ☐

(d) Very warm night periods ☐

(e) It has been very difficult to predict when the rain is about to fall in the recent years ☐

40. Do you understand the terminology used in presentation of climate and weather information by the Government for example the use of the word "Normal Rainfall is expected" etc?

(a) Yes, I Understand ☐

(b) Not understandable ☐

(c) A bit understandable ☐

(d) Needs to be explained ☐

41. What do you suggest should be the most convenient method of presenting climate and weather information for maize and wheat farmers in the county?

(a) Vernacular FM Radio ☐ ***Please give the name of the radio station***--------------------

(b) Mobile phone messages on climate/weather information for maize/wheat growing ☐

(c) Daily Newspaper ☐ P***lease, give the name of the newspaper***--------------------------

(d) Local youth trained in agricultural production/climate and weather information utilization ☐

(e) Agricultural extension workers in the ministry of agriculture ☐

42a. Are you aware of the maize seed varieties suitable for growing in your area?

(a) Yes ☐

(b) No ☐

(c) Don't Know ☐

(d) Kindly list the maize varieties you prefer growing in your farm---------------------------
----

42b. Are you aware of the wheat seed variety suitable for growing in your area?

(a) Yes ☐

(b) No ☐

(c) Don't Know ☐

(d) Kindly list the wheat varieties you prefer growing in your farm----------------------------
----

42c. If your response is YES above in 42 a & b, explain how you became aware of the different seed varieties of maize and wheat and their soil, water and sunshine requirements.

(a). Personal experience over time practicing maize and wheat cultivation ☐

(b). Information provided through newspapers and pamphlets by Kenya Seed Company ☐

(c). Information given by Agricultural extension officers ☐

(d). Information obtained from retailers or stockists of farm inputs ☐

(e). Information from other farmers who know certain wheat or maize variety doing very well around the neighborhood. ☐

(f). Information obtained from attending agricultural shows or farmers field day organized by organizations dealing with crop production ☐

(g). I am not aware of the suitable seed variety of maize and wheat, their soil, water and sunshine requirements ☐

43. Would you consider paying for climate and weather information for use in your farming activities?

(a) Yes ☐

(b) No ☐

(c) Will consider ☐

(d) Depends on cost ☐

44. Please kindly give me your maize production yield per acre for the last 5 years as follows:-

Maize Production 2012 - 2008:

Year	Number of 90 kg bags per acre
2012	-
2011	-

2010 -

2009 -

2008 -

45. Please kindly give me your wheat production yield per acre for the last 5 years as follows:-

Wheat Production 2013 - 2009:

Year	Number of 90 kg bags per acre
2013	-
2012	-
2011	-
2010	-
2009	-

46a. Have you ever incurred losses in maize production activity (crop damage) caused mainly by lack of rain during planting or growing period?

(a) . Yes ☐ (b). No ☐ (c). I don’t know ☐

46b. Have you ever incurred losses in maize production activity (yield lose) caused mainly by too much rain during harvest and storage period?

(a) . Yes ☐ (b). No ☐ (c). I don’t know ☐

46c. Have you ever incurred losses in wheat production activity (crop damage) caused mainly by lack of rain during planting or growing period?

(a) . Yes ☐ (b). No ☐ (c). I don’t know ☐

46d. Have you ever incurred losses in wheat production activity (yield lose) caused mainly by too much rain during harvest and storage period?

(a) . Yes ☐ (b). No ☐ (c). I don’t know ☐

47a. Please state the climatic parameter that led to the type of loss or damage you may have incurred during your maize growing

(a). lack of adequate rain during planting/germination period ☐
(b). Lack of adequate rain during weeding period/maturation time ☐
(c). Too much rain including floods during the whole period of crop growing ☐
(d). Too much rain during harvest period/storage time ☐
(e). Drought manifestation throughout the growing period ☐

47b. Please state the climatic parameter that led to the type of loss or damage you may have incurred during your wheat growing

(a). lack of adequate rain during planting/germination period ☐
(b). Lack of adequate rain during weeding period/maturation time ☐
(c). Too much rain including floods during the whole period of crop growing ☐
(d). Too much rain during harvest period/storage time ☐
(e). Drought disaster manifestation throughout the growing period ☐

48. If the loses were incurred due to lack of rain or drought, what was the resultant yield per acre for maize and wheat?

	Maize	**Wheat**
(a). No yield at all	☐	☐
(b). 0 - 5 bags of 90kg	☐	☐
(c). 5-15 bags of 90kg	☐	☐
(d). 15-30 bags of 90kg	☐	☐

49. If the loses were incurred due to excess rain during the period under crop, what was the resultant yield per acre for maize and wheat?

	Maize	**Wheat**
(a). No yield at all	☐	☐
(b). 0 - 5 bags of 90kg	☐	☐
(c). 5-15 bags of 90kg	☐	☐
(d). 15-30 bags of 90kg	☐	☐

50a. From your experience, has utilization of climate and weather information improved your production levels in maize and wheat and helped avoid loses?

(a) . Yes ☐ (b). No ☐ (c). I don't know ☐

50b. If your answer to question 50a above is YES, state what was the yield of maize and wheat per acre?

	Maize	***Wheat***
(a). 5-10 bags of 90kg	☐	☐
(b). 10-20 bags of 90kg	☐	☐
(c). 20 – 30 bags of 90 kg	☐	☐

51. After utilizing climate and weather information, I was able to do the following activities successfully hence avoiding losses.

(a). I was able to avoid lack of adequate rain during planting/germination period by waiting a little longer till the onset of rains announced by the meteorological department. ☐

(b). Application of fertilizer/top dressing, weeding, application of agro chemicals were done successfully following the advice. ☐

(c). Loss during harvest period/storage due to heavy rains were avoided as harvest activity was done promptly before the unusually heavy rains started ☐

(d). I was able to substitute the maize and wheat varieties to suit the situation explained by climate and weather information from the Meteorological department/Ministry of Agriculture ☐

(e). All the climate and weather information received from the Meteorological department/Ministry of agriculture did not help me at all in my maize and wheat growing activity ☐

(f). No information was received from the Meteorological department/Ministry of Agriculture ☐

52. Please kindly estimate the amount of maize per acre that you produced with use of climate and weather information and with non-use of the same:-

Year	No of bags per acre	
	With Information on climate	*Without Information on climate*
2012	-	-
2011	-	-
2010	-	-
2009	-	-
2008	-	-

53. Please kindly estimate the amount of wheat per acre that you produce with use of climate and weather information and with non-use of the same:-

Year	No of bags per acre	
	With Information on climate	*Without Information on climate*
2013	-	-
2012	-	-
2011	-	-
2010	-	-
2009	-	-

THANK YOU

Appendix 2. Key Informant Interview schedule

Kenya Meteorological Department staff, Uasin Gishu County Directorate of Agriculture and farmers

- Does Kenya Meteorological Department produce climate and weather information for use by farmers in the county? KMD/Directorate of Meteorology/Agriculture UG County/Farmers
- What about climate and weather information specifically targeted for maize and wheat farmers in the counties? KMD/Directorate of Meteorology/Agriculture UG County/farmers
- What are the types and sources of climate and weather information produced and made accessible to maize and wheat farmers? KMD/Directorate of Meteorology/Agriculture UG County/farmers
- What are the modes of communicating climate and weather information to the farmers (Maize and wheat farmers) at both National and County levels by the Kenya Meteorological Department? KMD/Directorate of Meteorology/Agriculture UG County/farmers
- What is the perception of farmers towards the use of climate and weather information in their maize and wheat production activities? Directorate of Agriculture/Meteorology UG County/farmers
- What informs maize and wheat growing farmers farming calendar or decision to commence all the activities in their farms? Directorate of Agriculture/farmers
- Does farmer's traditional knowledge system in weather prediction influence their farming decisions and uptake of climate and weather information services produced by KMD? Directorate of Agriculture UG County/farmers
- What are some of the key indigenous knowledge indicators for rainfall prediction among the farmers in the Uasin Gishu County? Directorate of Agriculture UG County/farmers
- How can KMD and Ministry of Agriculture support the design of climate and weather information communication model to relay climate and weather information to maize and wheat farmers using SMS alerts via their mobile phones? KMD/Directorate of Agriculture/Meteorology UG County

Appendix 3. Research Approval by County Directorate of Agriculture

Appendix 4. Letter of Support from University of Eldoret

Appendix 5: Weather Outlook in Uasin Gishu County for March – May 2015 Rainfall Season and Advisories

Produced by Ministry of Environment, Water and natural Resources, Kenya Meteorological Services (KMS) and Agricultural Sector Development Support Programme (ASDSP) Uasin Gishu County