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I-farm System: A Climate Smart Mobile Phone Based Agro-Weather Tool for Farmers in Uasin Gishu County, Kenya

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Abstract

Due to climate and weather variations brought about by climate change, maize and wheat farmers have constantly faced greater risks throughout the growing season in the farming calendar in Kenya and more specifically Uasin Gishu County where this study was conducted. The unpredictable nature of the order and seasons known to farmers, rainfall onset, frequency, intensity and cessation of rainfall has led to drastic variations in yield or widespread loss of crop in Uasin Gishu County. To navigate such risks, timely access to climate information and related technologies for adaptation is essential to enable actors to anticipate long–term risks and make the appropriate adjustments. This will help farmers increase their resilience at the farm and household level. To understand these challenges, a study was conducted in Uasin Gishu County that adopted a mix of purposive, stratified and random sampling techniques to select 399 maize and wheat farmers and 12 key informants for interview. Based on the challenges of access to the required timely and downscaled climate and weather information, an innovative "I-farm system" was developed to relay timely climate information to farmers. I-farm system developed adopted the incremental build model methodology during its gradual development. The product was designed, implemented and tested incrementally to its current functional level. The findings in the study show that in Uasin Gishu County, about 60% of the farmers do not access climate and weather information although Kenya Meteorological Services produces agro-meteorological information regularly. More than 50% of the farmers further were not aware of any organization producing such information. Similarly, farmers have incurred maize and wheat crop losses due to lack of adequate rain during growing period as reported by 78.6% of the farmers. Maize and wheat yield loss due to too much rain during growing season, near harvest and harvest period was reported by 66.1% of the farmers. These findings portray a vulnerable group of farmers who have incurred losses in their farming enterprise and therefore need urgent interventional measures that include timely access and usage of climate information in farming decisions. The study findings also point to existence of a significant relationship between access and usage of information (Chi = 87.263, P < 0.001). The dissemination modes of climate information to farmers in Uasin Gishu County are largely through radio as stated by 79.8% and television affirmed by 68.4%. Almost all the farmers (96.3%) however preferred to receive or get updates (SMS Alerts) on climate and weather information through their mobile phone handsets. I-farm system developed is designed to deliver climate information to farmers via their mobile phones (SMS alerts). The system is a web based interactive application designed to inform farmers on prevailing weather patterns, advisory alerts, best practices all geared towards supporting a farmer's decision at the farm level. The system serves farmers in rural areas where internet access is limited. Farmers on the other hand can raise issues of concern by writing an SMS back to the I-farm help desk where a staff designate can attend to queries raised by farmers. The feedback loop is important as farmers perspectives are incorporated hence ensuring ownership and sustainability of the innovation.

Key Words: Climate variability, weather and climate information, I-farm System, Mobile phone, agro-weather tool, SMS Alerts, information dissemination, maize, wheat, Uasin Gishu County, Kenya

Introduction

The primary weather and climatic information need of a farmer is to know 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. Inadequate or non-access to climate and weather information to aid the farmers in their farming decisions at the farm level is a major challenge in the farming enterprise. According to the World Development Report 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 (World Bank, 2010). The same is true for Kenya and its counties, Uasin Gishu County included. The information may be available from the Kenya Meteorological Services but farmers do not largely integrate such information in their farming decisions due to adaptability, format and timing challenges of the information. This view is supported by Hansen (2002) and Hammer *et al.* (2001) who argue 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 because the available information in most cases may be poorly channeled and its timing, format and modes of communication may not enhance farmers' planning and farming efficiency. There are constrains in the optimal use of seasonal climatic information by farmers generally. According to Walker *et al.* (2001), some of these constraining factors include provision of information that is general and not specific to certain areas thus its use is limited. Similarly, the information may be received when it is too late for use or often too difficult for the user to understand and apply.

There is lack of a clear coordination and information flow with user feedback loops between scientists, advisory agents and farmers in communicating crucial climate information. Facilitation of access to such information by the local communities has been a major challenge due to available modes of communication that do not tailor such information to a particular farmer. Farmers usually do not know what climatic conditions to expect in the prevailing growing season leaving them very disadvantaged in their decision making process (World Bank, 2010). According to Bryan and Behrman (2013), as cited from Vogel and 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.

The prevailing climate variability related to climate change has greatly influenced the nature and pattern of farming among farmers in Kenya and more so in Uasin Gishu County where maize and wheat growing are among the major crops grown by farmers for sustainable livelihoods (Uasin Gishu County profile report, 2013). The Global Humanitarian Forum and World Meteorological Organization report (WHO/WMO, 2012) states that with the prevailing changes in weather patterns due to climate change, traditional knowledge relating to agriculture, otherwise reliable for centuries, could be rendered ineffective. The order and seasons known to farmers over time have changed hence making farmer's knowledge and experience difficult to comply with as the case has always been. This phenomenon has created a great need for climate and weather information to be delivered to those engaged in farming activities.

To cope with such risks, access to timely climate and weather information and the allied technologies for adaptation is essential to enable actors to anticipate long–

term risks and make the appropriate adjustments to increase their resilience at the farm and household level. There is a need to make climate information more accurate, accessible, and useful for rural communities to be able to realize the potential benefits associated with utilization of such information (Bryan & Behrman, 2013). I-farm system was developed to help address such challenges through relaying of timely climate and weather information for use by farmers in the rural based farms.

Study Area

The study was conducted in Uasin Gishu County, Kenya as shown in the map in Figure1. The county has 6 sub-counties namely:-Turbo, Soy, Moiben, Anabkoi, Kesses and Kapseret. According to Uasin Gishu profile report (2013), the total area of the County is 3327.8 sq. km with arable land covering 2603.2 sq. km and non-arable land covering 682.6 sq. km. A selection criteria was arrived at to pick three sub-county areas of Moiben, Soy and Kesses out of the six sub-counties. A further selection of wards was done and the following constituted the area of study: Soy, Kipsomba and Ziwa wards in Soy sub-county; Moiben, Sergoit and Karuna/Meibeki wards in Moiben sub-county and finally, Kesses, Tarakwa and Megun wards in Kesses sub-county.

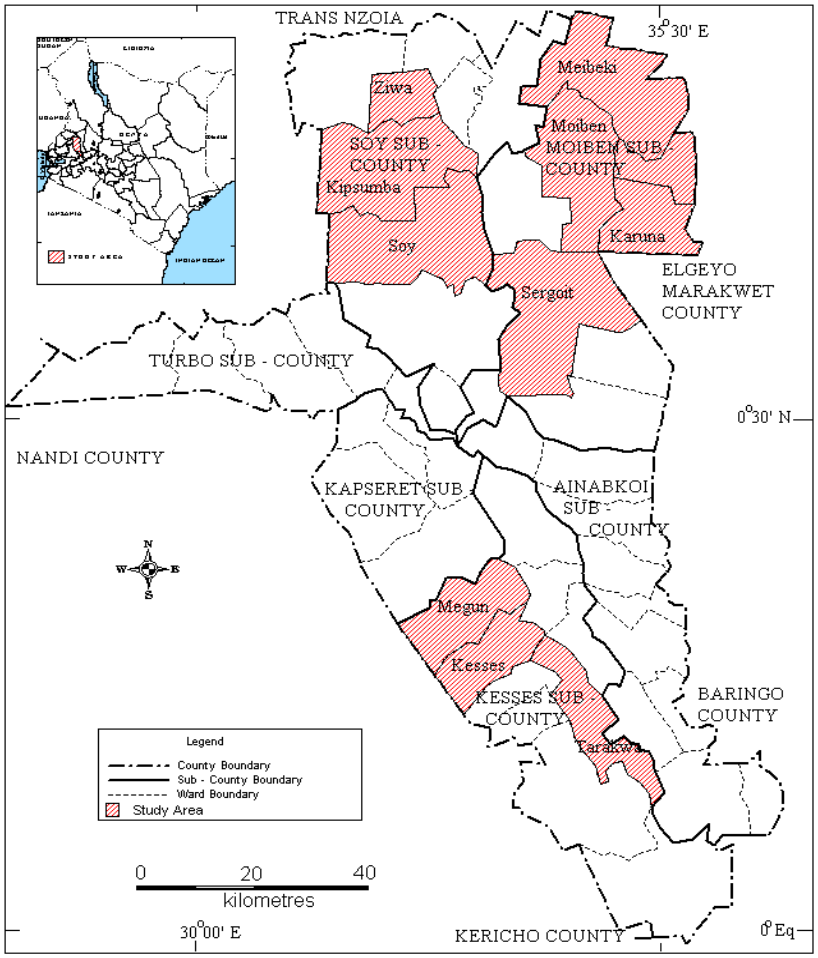

Figure 1. Map of Uasin Gishu County showing the Study Area
Source: Moi University Geography Department (2013)

Materials and Methods

This paper is a result of a research conducted in three sub-county areas of Uasin Gishu County. In particular, it is an investigation into climate and weather information dissemination from the primary producers of the information to the consumers of such information who are maize and wheat farmers at the farm level. Climate and weather information access by farmers, modes of dissemination, acceptability of mobile phones to receive climate and weather information and development of a web-based mobile phone system were the main topics of investigation during the research carried out between 2013 and 2014. The investigation involved interviewing farmers selected to participate in the study and some key informants.

The study adopted a mix of purposive, stratified and random sampling procedure to be able to capture a representative sample of farmers. The entire 6 sub-county areas of Uasin Gishu County were analysed 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 the ward level. Wards that grow both maize and wheat were purposively selected again resulting to selection of Soy, Kipsomba and Ziwa wards in Soy sub-county; Moiben, Sergoit and Karuna/Meibeki wards in Moiben sub-county and finally, Kesses, Tarakwa and Megun in Kesses sub-county.

A minimum of 399 farmers were included in the 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 and 1 from the Kenya Meteorological Services in Nairobi. 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) was utilised where the randomly generated census numbers from SPSS were used to pick the households (KNBS, 2010).

I-Farm System; a web-based mobile phone SMS platform was built through utilization of some applications in the open source global market. The system was developed incrementally based on the incremental build model methodology. The product was designed, implemented and tested incrementally (little more added each time) until the current complete system was realized. I-Farm system in its current state is able to deliver targeted Short Text Messages alerts or advisories to selected group of farmers through use of their mobile phones from any location in their respective farms.

The completed questionnaires were analyzed using both access database and SPSS version 16. For quantitative data, frequencies, mean and standard deviation were used to summarize the data. Chi-square was used to check for significant relationship between categorical variables. Independent sample t-test was used to compare means. Significance level was set at $\alpha=0.05$ while qualitative data was analyzed by use of theme generation.

Conceptual Framework

Availability of improved global observation infrastructure and meteorological services capacity by the World Meteorological Organization (WMO) Global Telecommunication System (GTS) and other global forecasting centers is crucial for the Kenya Meteorological Services as it 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 and distributed via the WMO GTS allow the Kenya Meteorological Services to monitor the weather approaching effectively.

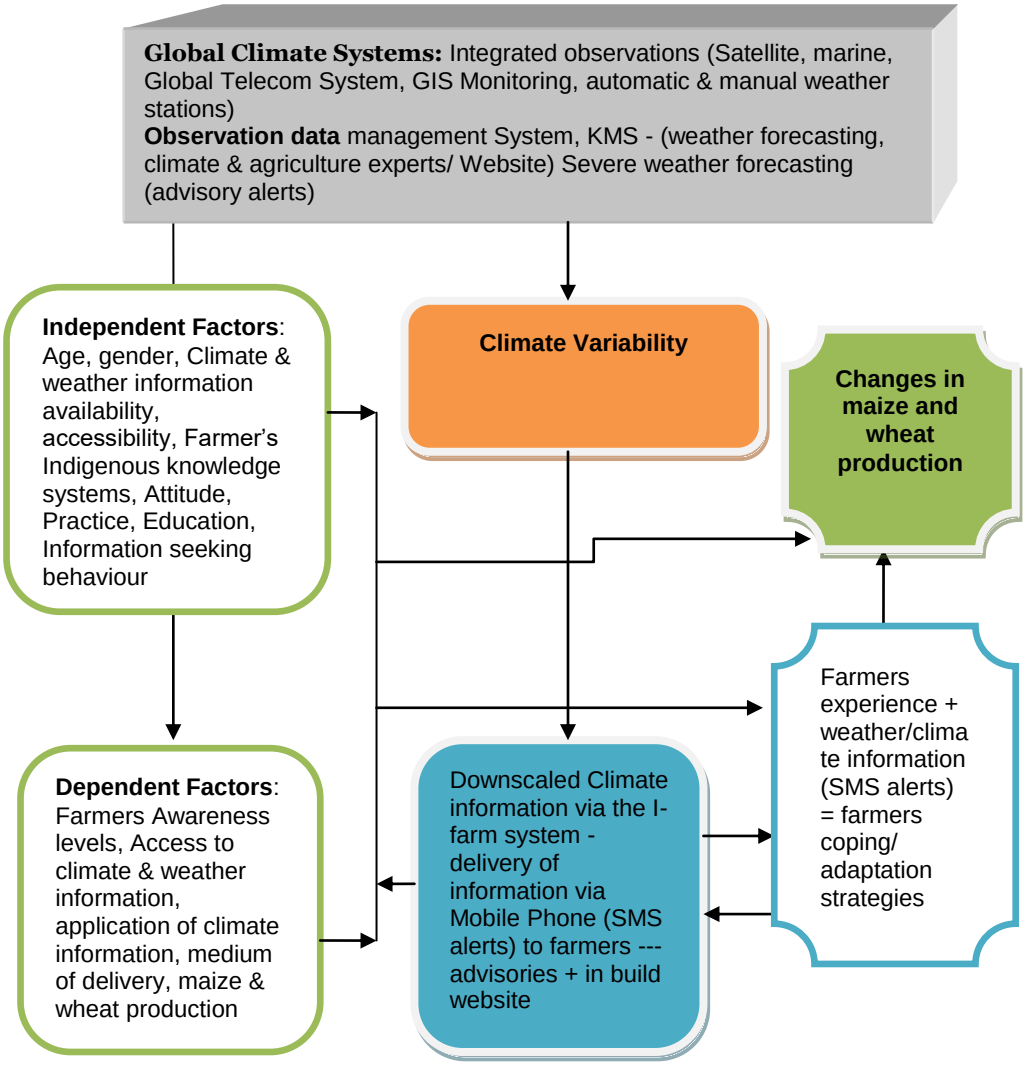

Figure 2. Conceptual Framework -Communicating Climate Information to Farmers Using Mobile Phones (SMS Alerts)

In this paper, the researcher argues that the farmers' indigenous knowledge systems in weather prediction and their experience gained over time in maize and wheat cultivation, become beneficial when access to climate and weather information (SMS alerts) are embraced today. This has been necessitated by the fact that the prevailing climatic variability brought about by climate change has distorted the timing of seasons familiar to farmers through experience in cultivating maize and wheat crop in the County. Farmers stand to benefit if they combine their experience and indigenous knowledge base with access to scientific information for better decisions at the farm level. Such combinations have led to better and beneficial adaptation strategies that enables farmers to realise 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. A

feedback enabled mechanism in the designed I-farm system will help in addressing farmer's needs or concerns in addition to a dedicated website that enhances climate and weather information access by maize and wheat farmers at the community.

Results

Perception of Farmers on Climatic/Weather Variability in Recent Years

In order to understand what farmers perceive or believe in relation to climate variability and its resultant effects to maize and wheat growing activities, they were asked to use rainfall parameter to explain the changes observed in their farming enterprise as this parameter 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*". The findings stated in Figure 3. showed that over 87.9% 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.

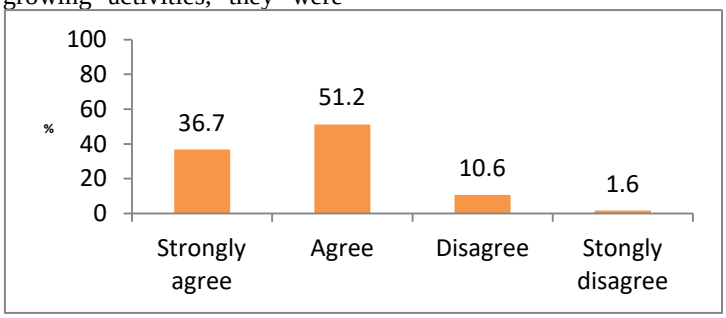

Figure 3. Farmers Perception on Climate Variability (Rainfall Changes) in the Recent Years

The findings outlined in Figure 3 seem to agree with Global Humanitarian Forum and World Meteorological Organization report (2012) 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 inadequate. This phenomenon 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 challenging and unpredictable. 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 is crucial.

Farmers were asked further to state whether they had ever incurred any crop loss or damage during their farming period to determine their vulnerability to unpredictable weather patterns in the recent years. The following were their responses: Maize and wheat crop damage due to lack of adequate rain during growing period was reported by 78.6% of the farmers in both crops. Maize yield loss due to too much rain during growing season, near harvest and harvest period was reported by 66.1% of the farmers. The same farmers reported that the same phenomena applied to wheat growing and 74.2% affirmed this as shown in table 1.

Table 1. Crop Loss and Damage due to the Prevailing Rainfall Variabilty

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 maize and wheat growing farmers confirm that they have incurred losses both during the growing season due to lack of rain and during 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 climatic variability. Farmers may not have responded well to proper utilization of information on climate and weather to assist them in their farming decision making. Using climate and weather information have been shown to increase crop yield by up to 30% as seen in the findings from Anuforo (2009). The utilization of the 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 indicates to farmers the most marketable crop in respective times.

To demonstrate further what losses farmers have encountered during their farming activities, maize farmers were asked about the climatic parameter responsible for major maize crop loss or damage. Inadequate rain during planting/ germination period was reported by 67.6% of the farmers. Too much rain during harvest/storage period was reported by 49.3% of the farmers as shown in Figure 4. For wheat crop losses, too much rain during harvest/storage period was cited by 59% of the farmers as the major cause of loss or damage to the wheat crop. Inadequate rain during planting was reported by 55.8% of the farmers as a cause for losses experienced in the wheat crop farming activity as shown in Figure 5. Wheat crop is sensitive to too much rain during drying and harvest period as any slight wetness during such times may cause crop germination in the husks hence damaging the yield or reducing the quality in case the damage is not great.

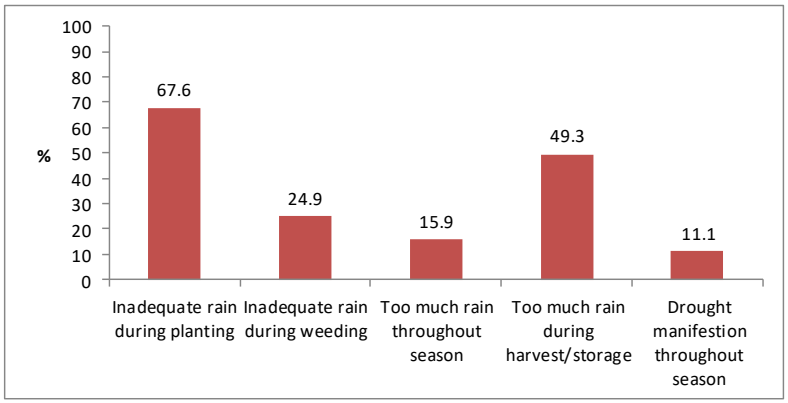

Figure 4. Maize Crop Loss due to the Prevailing Rainfall Phenomena

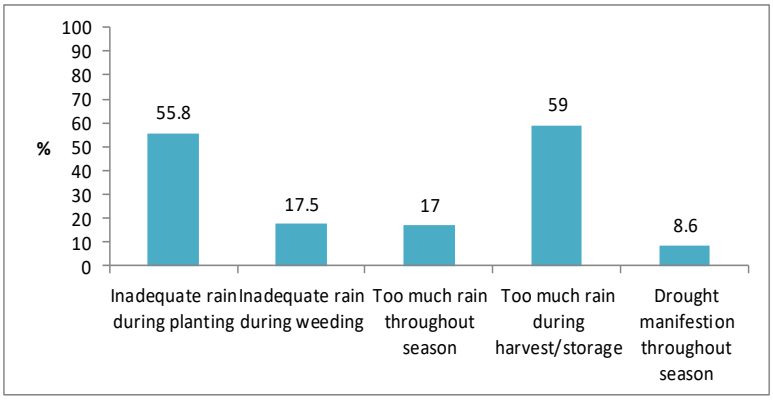

Figure 5. Wheat Crop Loss due to the Prevailing Rainfall Phenomena

The results presented in Figure 4 and Figure 5 indicate clearly how maize and wheat farmers have fallen victim to unpredictable weather patterns(changes in rainfall onset and cessation dates) brought about by climatic variability prevailing. As farmers stick to their known "calendar of events dates" in their farming calendar, they have run into weather related problems that were not foreseen or predicted. As seen earlier, adequate use of climate and weather information by farmers' has seen them realize increased yields because losses that may have occurred during planting and during harvest time are minimized or largely avoided. The utilization of the information reduces farmers' vulnerability to weather related risks as informed decisions are made on time. The decisions may include planting alternative crops suitable for the prevailing weather conditions.

Access to Climate and Weather Information by Maize and Wheat Farmers

In Uasin Gishu County, the findings in the study show that 60% of the farmers do not access climate and weather information although Kenya Meteorological Services produces agro-meteorological information. Similarly, more than 50% were not aware of any organization producing such information.

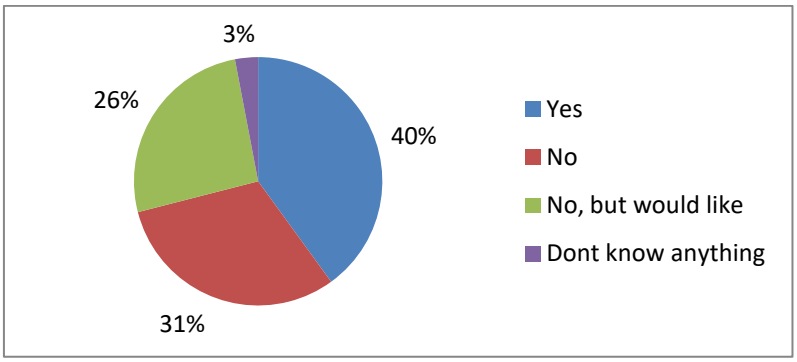

Figure 6. Access to Climate and Weather Information by Maize and Wheat Farmers

The findings here are similar 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. Enabling such farmers to access climate and weather information to complement their experiences and indigenous knowledge system will help them cope with climatic variability brought about by climate change. They will be able to deliberately delay planting to commence when rains start; harvest early when crop is ready and when rainfall is imminent; and plant other crops that are draught tolerant or short duration crops that are equally able to provide the much needed food and the cash economy at household level. This has been stated by 52.7% of the farmers who agreed that they would substitute the growing of maize or wheat with other crops suitable in the prevailing circumstance to avoid any risks that may arise either with delayed rainfall onset or too much or inadequate amounts and intensity.

Table 2. Information Product and Organization Producing It

Information Product	**1KMS**	**2 MoA**	**3KSC**	**4NGO**	**5None**
	Multiple responses in percentage (%)				
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 Agriculture, 3. Kenya Seed Company, 4. Local NGO, 5 No organization Produces such information

Farmers were asked to state whether they received the outlined information product and from which organization they received it from if at all they ever received any. Over 50% of the farmers in all the outlined products in table 2 reported that no organization produced and delivered such information to them. More precisely, the responses were as follows based on each product outlined. For the Farmers guide, 55.1% affirmed that no such information was provided to them. The Dekad (10-day) agro-meteorological bulletin was not received by 70.4%, annual climate review was not accessed by 55.6%, Annual or seasonal rainfall prediction was not accessible to 55.5%, Newspaper caption on farmers activities was not accessible to 53.1% and targeted info for maize and wheat farmers was never accessed by 52.5% as indicated in table 2. Similarly, those who accessed climate information through Newspaper advertisement (Newspaper caption) on weather/climate information and crop production/food security around the county in general were 33.5% of farmers. It is clear thus that KMS produces climate and weather information but most farmers acknowledge the fact that no organization produces such information. This is a clear indicator that such information has not been repackaged and tailored to the intended users in the right format and at the right time.

This phenomenon has to be addressed effectively through facilitation of downscaled and tailored climate information to maize and wheat farmers at the County level and ultimately at the national level to avoid losses incurred that may contribute to food insecurity at the household level.

Disseminating Information on Climate and Weather to Farmers

The dissemination modes of communicating information on climate and weather to maize and wheat farmers in Uasin Gishu County is largely through radio as stated by 79.8% and television affirmed by 68.4% of the farmers as shown in Figure 7.

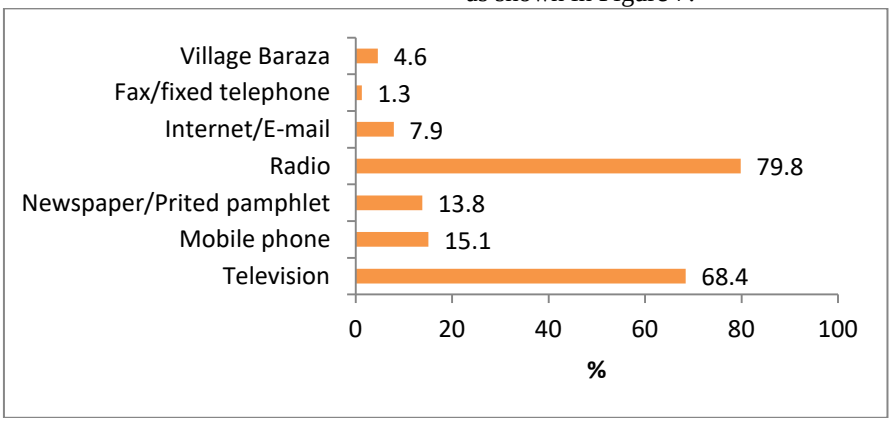

Figure 7. Media for Communicating Information on Climate and Weather to Farmers

The results obtained in this study corresponds with studies by Walker *et al.* (2001) and WMO (2000) which showed 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 and television. This phenomenon is clarified further by Wanungwa of the Agromet section at KMS in Nairobi during a key informant interview session. The agro meteorologist explained that seasonal forecasts are disseminated through the media and are downscaled by the County Meteorological Director to specific regions. Similarly, 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).

To test this phenomenon further, maize and wheat farmers in Uasin Gishu County were asked to name their preferred mode of delivering climate and weather information to them at their farm level. The following responses were obtained as shown in Figure 8.

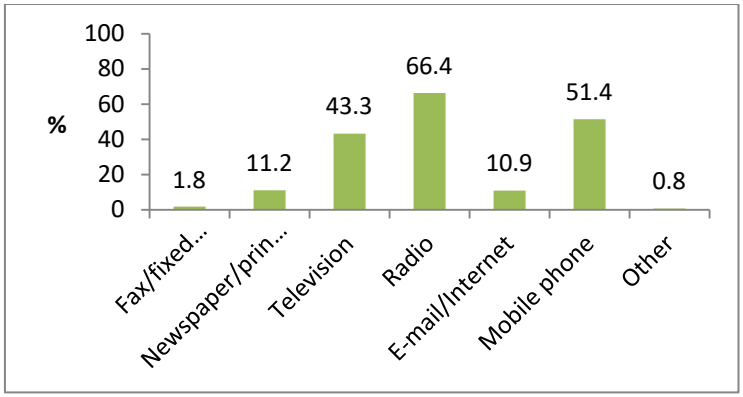

Figure 8: Preferred Media to Receive Climate and Weather Information by Farmers

Majority of farmers in Uasin Gishu County prefer to receive climate and weather information through radio 66.4%, mobile phone 51.4% and television 43.3%. The findings slightly differ with findings by Walker *et al*. (2001) and Wilhite, Sivakumar and Wood (2000). The preference on use of mobile phone by 51.4% of the farmers to receive weather updates is a new phenomenon. Farmers in this study were enthusiastic and eager about receiving direct SMS alerts through their mobile phones as explained during data collection exercise.This trend is supported by findings in CGIAR study on mobile phones and climate adaptation (CGIAR, 2011) that clearly shows 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. Based on the responses by farmers and their new interest in use of mobile phone handset to receive climate and weather advisories, an innovative I-farm System was formulated and requirements examined and drawn down to be able to come up with an interactive system that farmers can send and receive climate and weather information via their mobile phone handset.

I-Farm System: A Web Based Mobile Phone Interactive SMS System

I-farm system 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. 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. The application system basically improves farmer's farm management capabilities under conditions of climate risk. The system will help farmers to plan and manage weather risks, maximize productivity and link farmers to markets to enable them attain maximum profits in the farming enterprise. The system entails the delivery of climate-smart agro-advisory information using SMS alerts to farmer's mobile phones.

The system is designed to inform farmers through message 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.

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.

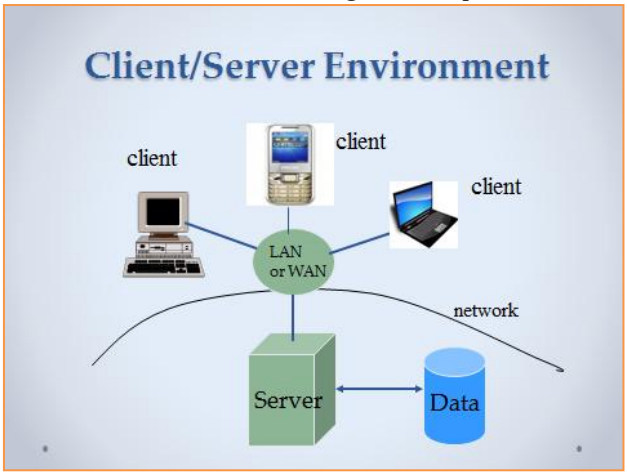

Figure 9: Client/Server Model

I-farm system adopted a client/server model or environment in its architecture. 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.

I-farm is a system whose client application is mainly developed using Java Server Pages (JSP). 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 to allow communication to be complete. I-farm system utilizing client/server model is run on a web server (Servlet container-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).

In I-farm system, 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 in-built SMS gateway. I-farm, however, allows utilization of proprietary gateways for scalability purposes hence enabling it have greater potential for wider use nationally.

Data Type and Flow Mechanism

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 information on climate and weather 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 and 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 downscaled to solve adaptability, format and timing challenges of climate and weather information. Information shall be repackaged in formats that farmers access, understand and use for ownership and sustainability. This will be delivered via I-farm system to a farmers' mobile phone 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.

Climate and weather 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 to useful organizations that may provide important information to meet farmer's needs have been provided also from the I-farm Application website. 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 10 depicting I-farm outbound messages to farmers and Figure 11 showing I-farm inquiry messages from farmers.

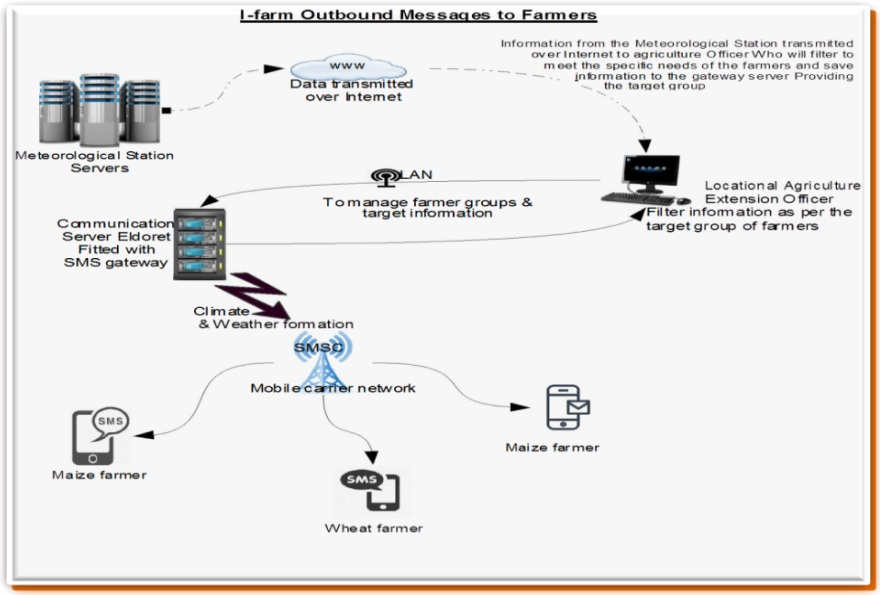

Figure 10: Data flow System Configuration (I-farm Outbound Messages to Farmers)

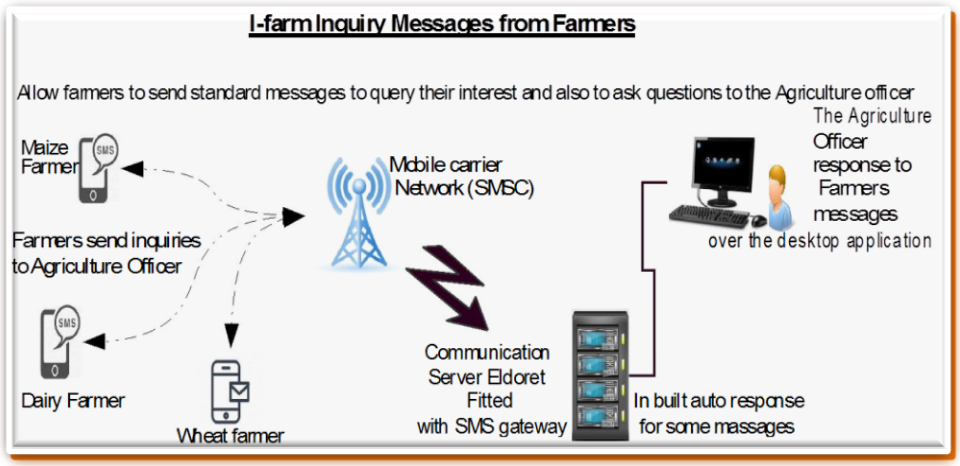

Figure 11: Data Flow System Configuration (I-farm Inquiry Messages from Farmers)

Systems Requirements for I-farm System
The following infrastructure, hardware and software shall constitute the model thus making communication through mobile phones (SMS alerts) effective.

The Client Side: Minimum Requirements - Hardware and Software Platform

- Personal computer (core 2 duo)
- RAM of 4 Giga Bytes (GB)
- 250 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

The Server Side: Minimum Requirements - Hardware and Software Platform

- Personal computer (core 2 duo)
- RAM of 4 Giga Bytes (GB)
- 500 Giga Bytes (GB) of Hard Disk.
- Internet Connectivity
- UPS power backup
- Power outlets/extension cables
- Backup server with similar specifications

The redundant server (backup server) has to be updated so that if the main server 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 I-farm system 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 system application, user credentials are created to be able to login to the system hence allowing access to the required platforms. A list serve for personnel responsible with the management of I-farm system who is the systems administrator, the person populating the system at the data source level (Agricultural Officer/or 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 list serve for members (maize and wheat farmers) with their mobile phone numbers is created and uploaded to the system in readiness for the delivery of climate and weather information in form of SMS alerts or advisories. Provisions are given for utilization of social media in I-farm system hence Twitter, WhatsApp and Facebook icons are provided and can just be enabled for operationalization to provide additional information to farmers.

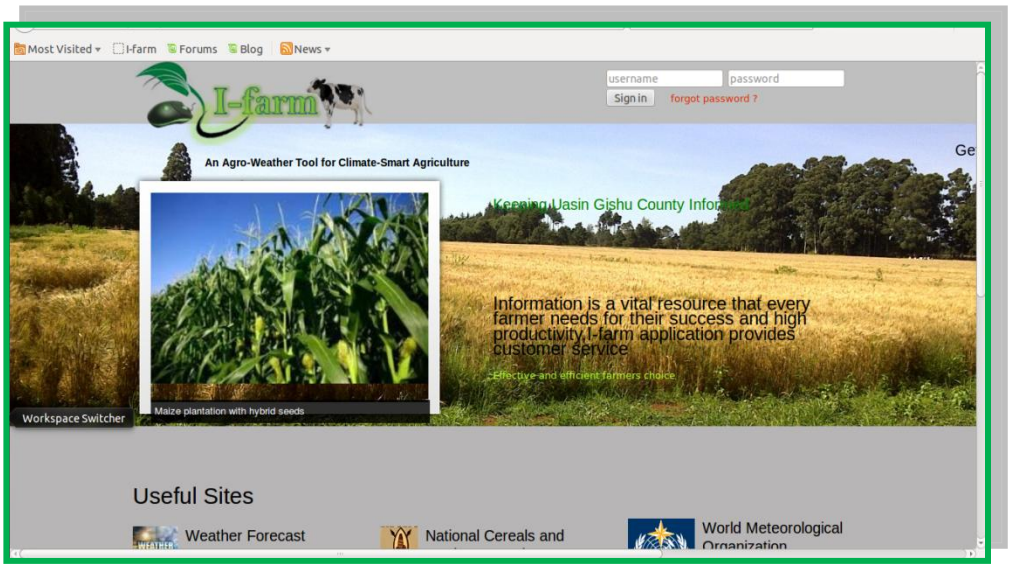

Figure 12: I-farm User Interface

Data Control and Security

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.

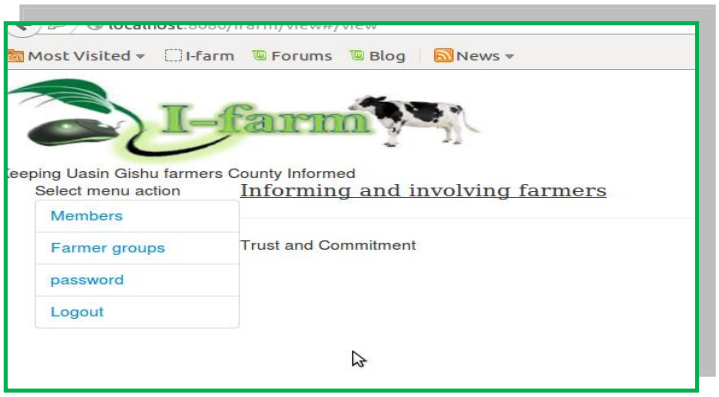

Figure 13. Login Level 1 Main Menu Page

Login level 1 main menu page contains four main menus (i) Members (ii) Farmer Groups (iii) Password and (iv) Logout. The page provides 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 groups 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. The password and logout are administrative functions of the system that ensure security is maintained.

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 provision for messages that have been acted upon. 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.

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.

Ownership and Financial Sustainability

The main custodians of I-farm system shall be the Directorate of Agriculture under the Agricultural Sector Development Support Programme (ASDSP). This will be agreed by the developer and the County Government of Uasin Gishu and other interested counties. Innovator profitability can be realized through increased collaboration with partners. Agricultural Sector Development Support Programme is best suited because it conducts regular climate and weather participatory scenario planning jointly with the Kenya Meteorological Services and other stakeholders. The costing and pricing strategy will include seeking for partnership to support the noble idea. Revenue can also be generated through access fees and registration and membership renewal once the system is fully operational and embraced fully by farmers. The idea is tenable because farmers access climate and weather information in a timely manner hence being able to avoid inherent losses related to climate variability.

Recommendation

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.

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 have become extinct 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.

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. Targeting such outlet points with climate and weather information tailored for farmers should be a priority for the County government. 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. This calls for revision of agricultural frameworks and policies to integrate such best practice recommendations.

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.

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 this study. This can greatly be complemented by the use of existing vernacular radio broadcast like Kass FM in Uasin Gishu County to sensitize the farmers on availability of climate and weather information access through their mobile phone by simply registering their details with I-farm system services. 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.

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 I-farm system fits well to the farmer's demands and there is need for Uasin Gishu County government to champion the scale up of I-farm system services for the benefit of farmers and the country at large.

The developed I-farm system, a climate and weather information communication model, 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.

The Kenya 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.

Acknowledgement

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