IMPLEMENTATION ROADMAP FOR DOWNSCALING DROUGHT FORECASTS IN MBEERE USING ITIKI

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ABSTRACT

Mbeere is in Eastern Kenya and it has an average of 550 mm annual rainfall and therefore classified under Arid and Semi-Arid Lands. It has fragile ecosystems, unfavorable climate, poor infrastructure and historical marginalization; the perennial natural disasters here are droughts. Of importance to this paper is the fact that despite its vast area of 2,093 km2, there is no single weather station serving the area. The main source of livelihood is rain-fed marginal farming and livestock keeping by small-scale and peasant farmers who rely mostly on the indigenous knowledge of seasons in making cropping decisions. ITIKI; acronym for ***I****nformation* ***T****echnology and* ***I****ndigenous* ***K****nowledge with* ***I****ntelligence is a bridge that integrates indigenous drought forecasting approach into the scientific drought forecasting approach. ITIKI, a framework initiated by the authors of this paper was adopted and adapted from the word itiki which is the name used among the Mbeere people to refer to an indigenous bridge used for decades to go across rivers. ITIKI makes use of mobile phones, wireless sensor networks and artificial intelligence to downscale weather/drought forecasts to individual farmers. ITIKI implementation project in Mbeere commenced in August 2012; this paper describes the implementation roadmap for this project.*

Keywords— ITIKI, Indigenous Knowledge, Indigenous Knowledge Weather Forecasts, Mbeere, Drought Early Warning System

1. INTRODUCTION

The Arid and Semi-Arid Lands (ASALs) of Kenya make up more than 80% of the Country's landmass. The latter is prone to harsh weather; this, among other reasons has seen the Country consistently contribute the highest number of people affected by natural disasters in Africa for the last two decades ([5] and [6]). Effective drought early warning systems (DEWS) have high potential in making a contribution towards tackling the current cycle of droughts in Mbeere, Kenya and the larger Sub-Saharan Africa (SSA). However, successful DEWS rely on weather forecasting systems; implementation of the latter in most countries in SSA is hampered by among other things, inadequate coverage by weather stations. Further, the content, format and dissemination channels of the scientific Seasonal Climate Forecasts (SCFs) do not address the farmers' needs; the farmers have in turn continued to rely on their now endangered indigenous knowledge forecasts (IKFs) to derive critical cropping decisions ([1] and [2]).

ITIKI; acronym for **I**nformation **T**echnology and **I**ndigenous **K**nowledge with **I**ntelligence is a bridge that integrates indigenous and the scientific drought forecasting approaches. ITKI was developed as a novel bridge that combines the strengths of SCFs and IKFs to deliver a DEWS composed of four elements: (1) Drought Knowledge (2) Drought Monitoring and Prediction; (3) Drought Communication and Dissemination; (4) Response Capability.

To tackle the diverse characteristics of these two knowledge systems, ITIKI is oiled using three ICTs: (1) mobile phones; (2) Wireless sensor networks; (3) Artificial intelligence (agents, fuzzy logic and artificial neural networks) ([3] and [4]). In order to collect real data to test ITIKI, a case study of two communities in Kenya (Mbeere from eastern and Abanyole from western) was carried out. On completion of the system prototype, participants from the two communities evaluated it; based on content and format of the integrated forecasts, up to 90% of Mbeere respondents gave a score of 'excellent' and also gave commitment to participate in post-tests system's deployment phase. From these findings, a decision was reached in August 2012 to implement ITIKI among the Mbeere people.

The Mbeere people occupy the former Mbeere District, which is classified under the ASALs. With a population of 168,000, the Mbeeres are the majority in the Region which has a population of about 220,000[7]. Mbeere is about 2,093 km^2 and it is located in Eastern side of Kenya. It lies between Latitudes 0^o 20' and 0^{o}50' South and Longitude 37^0 16' and 37^0 56' East. Other aspects of data analysis of the case study revealed that the Mbeeres were far more disadvantaged than the Abanyoles and the Community was therefore selected for the first phase of ITIKI implementation. In order to ensure a people-drive implementation, a purely community-based approach was adopted. To this end, collaboration with Community-Based-Ogranisation, Kiritiri Orphans and Vulnerable Children Advocate (KOVCA) was established. An Advisory Board currently made up of an ITIKI expert, a representative from the Kenya Meteorological Department and a church (Catholic Church) representative was set up to advise on the project direction. This paper describes how the various components of ITIKI have been pieced together in creating the on-going DEWS implementation in Mbeere.

The rest of the paper is organized as follows: Section 2 discusses the theoretical literature on which the paper is hinged while ITIKI's Architecture is described in Section 3. Section 4 details the methodology we have adopted and Section 5 introduces the Implementation Roadmap being followed in the Mbeere case study. Discussion, Conclusion and Further work are presented in Section 6

2. BACKGROUND LITERATURE

2.1. Droughts Prediction and ICTs

Among other things, drought prediction plays a critical role in mitigating the negative effects of droughts. Parametric indicators of drought commonly computed are: (1) duration; (2) severity; (3) location of the drought in absolute time (initial and termination time points); (4) area of the drought coverage; (5) magnitude/density of the drought computed by getting the ratio of severity to duration[8]. There are several well-developed indices for quantifying effects of droughts in terms of these parameters; among these is the Effective Drought Index (EDI) which differs from the rest of the indices in a number of ways, one being that it calculates drought on a daily basis. The others use scales such as weekly, monthly bi-monthly, and so on ([6] and [9]).

ICTs can be used to significantly improve drought prediction. The ITU acknowledged the critical role of ICTs, especially in addressing food insecurity (mostly a consequence of drought) and suggested that ICTs can be used: (1) to provide the remote sensing infrastructure, such as Wireless Sensor Networks(WSNs); (2) as the equipment (software and hardware) for analysis of drought data, including statistics, modeling and mapping, for example; laptops, servers, databases, GIS, data mining and neural networks; (3) as the communication infrastructure to disseminate the relevant information to farmers/consumers, for example Internet and mobile phones[10].

2.2. Seasonal Climate Forecasts

The main climate variables of interest for societal applications are atmospheric temperature, rainfall and humidity[11]. The current approaches used for producing Seasonal Climate Forecasts (SCFs) include the use of: (1) Physically based dynamical global/general climate models GCMs); (2) Regional Climate Models (RCMs); (3) Empirically based statistical; and (4) A combination of dynamical and empirical models. All these models generally produce forecast information at 'coarse' spatial resolution (of the order of 100–200 km), which is presented as the probability of the seasonal rainfall being in the 'above normal', 'below normal', or 'normal' compared with historical trends ([12] and [13]). This may have contributed to the current status where the utilization of such forecasts in SSA is still dismal. In West Africa, for example, efforts to disseminate and apply forecasts are at an experimental stage[14]. There is need for downscaling the forecasts produced by climate models to the desirable level of details required in real-life application models ([15] and [16]).

2.3. Indigenous Knowledge on Droughts

IK a body of knowledge existing within or acquired by local people over a period of time through accumulation of experiences, society-nature relationships, community practices and institutions, and by passing it down through generations[17]. In IK drought forecasting, the local weather and climate are assessed, interpreted and predicted by locally observed variables and experiences using combinations of plant, animals, insects and meteorological and astronomical indications [18]. The entry point for the forecasting is the amassed knowledge of exact arrival of the rainy season. IK on drought forecasting in the tropics falls into six general categories: (1) patterns of seasons (cold, dry, hot, rainy and so on); (2) animal, insects and bird's behaviour; (3) astronomical; (4) meteorological; (5) human nature and behaviour; and (6) behaviour of plants/trees, for example fruit and flower production[3].

Researchers ([1], [19] and [20]) today concur that IK and modern science weather forecasts complement each other; they are not mutually exclusive but significant discordance between the two is still apparent. Clear understanding and careful integration of IK present opportunities especially in the dissemination process of weather forecasts to farmers in SSA because this supports ways that are culturally appropriate and locally relevant to the people. There is a common departure that, generally (not just in climate and weather information), integrating IK into modern science can improve livelihoods ([17], [21], [22], [23], [24] and [25]).

On the question whether IK needs modern science, there is evidence that IK has been eroded and is slowly disappearing. Extreme variations never witnessed before by community members bring IK into disrepute; integrated approaches aimed at giving the communities several levels of risk-preparedness are desirable. Further, using IK alone, it is difficult to forecast beyond a season (say beyond two years); in modern science, this can be achieved by employing technologies such as Artificial Neural Networks. Some terminologies used in IK may sometimes be ambiguous, for example '*abundant rainfall*' may mean rainfall for the day or a season. Finally, unlike modern science, climate change may be difficult to foretell using IK alone.

2.4. Early Warning System for Droughts and ICTs

In [26], early warning (EW) is defined as "*the provision of timely and effective information, through identified institutions, that allows individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response.*" Effective early warning systems consist of four components; (1) gathering of the risk knowledge;

(2) monitoring and predicting the situation; (3) communicating the warning messages; (4) responding to the warning [27]. The phenomenal role of ICTs in all the four components cannot be overemphasized; this include remote sensing that enables real-time detection of hazards, SMS technology that allows for direct and individualized delivery of disaster alerts and the instantaneous access of diverse and voluminous information via the Web, just to mention a few.

3. ITIKI ARCHITECTURE

3.1. Overview

ITIKI was realised in form of an *Integrated Drought Early Warning System (DEWS) Architecture*; this framework provided the blue-print for the implementation of the system that integrates ICTs with the indigenous knowledge on droughts. The Framework design was guided by the four components that make up an effective early warning system.

3.2. Features of ITIKI

The overall goal of ITIKI was to come up with a ***relevant***, ***affordable***, ***sustainable***, ***integrated***, ***resilient***, ***useable***, ***effective***, ***generic***, and ***micro-level*** early warning system for droughts for the Sub-Saharan Africa and Africa at large. Below is how each of these attributes is achieved in our integrated framework:

3.2.1. Indigenous Knowledge

Going by the phrase by Stern[28], "*The effectiveness of forecast information depends strongly on the systems that distribute the information, the channels of distribution, the recipients' models of understanding and judgment about the information sources, and the ways in which the information is presented*." One way of achieving an ***effective*** early warning system for droughts is therefore to put into consideration the targeted users' coping strategies, cultural traits and specific situations. In the case of the Sub-Saharan Africa, this is easily achieved by incorporating the local people's indigenous knowledge on weather/climate forecasting([17], [21], [29] and [30]).

3.2.2. Effective Drought Index

As the name suggests, the Effective Drought Index (EDI), is a ***very effective*** index compared to other drought indices. Its uniqueness stems from the fact that it provides spatial and temporal distribution of droughts on a daily-basis[9]. EDI computes the intensity of droughts by using cumulative precipitation as a weighting function of time and also gives the Available Water Resources Index (AWRI); the latter is a measure of hydrological drought and can be used to assess the quantity of soil moisture. By incorporating it into our drought early warning system framework, it makes it possible to ***quantify and qualify droughts in micro scale*** (time and spatial distribution) as well as in ***absolute terms***[6].

3.2.3. Wireless Sensor Networks

A deeper look into the problem of early warning system for droughts in SSA reveals a grave situation where the meteorological institutions the National Meteorological Services (NMSs) charged with weather forecasting rely on weather stations that are thousands of kilometres apart ([31] and [32]). This sparse network makes it difficult to provide locally relevant information necessary for scaling weather information down to the local (say village level) communities. Furthermore, weather stations are very expensive and their operation may be difficult to sustain in many developing countries where the lack of expertise and high cost of maintenance may hamper operation after funding from donors. In our framework, the now readily available versatile and WSNs-based weather stations were employed to fill the gap. Further WSNs are used to automatically extend the available climate maps and prediction through (1) collection of climate data; (2) analysis of this data; and (3) modeling of climate change in the remote villages.

3.2.4. Mobile Phones

Africa has achieved a mobile phone penetration level much higher than that of computers[33]. With well-designed solutions, the use of these phones can be extended from the traditional use, as mere communication devices, to computing devices on which the much needed e-applications can be executed. Our DEWS utilises this window of opportunity by using the mobile phone to not only disseminate drought alerts but also as an input device for the IK. This way, the system is both ***affordable*** and ***sustainable***.

3.2.5. Artificial Intelligence

In order to create an ***integrated*** system that can juggle all these myriad moving parts at the macro and micro-level, some reasoning was necessary; use of intelligent agents achieved this. Further, IK on weather and drought is so rich; it has been said to be holistic[34]; in order to model this aspect of IK and ensure preservation of its richness, we employed the use of Fuzzy Sets[35]. In order to build a ***complete*** early warning system, forecasting/predicting future droughts was crucial; ***Artificial Neural Networks (ANNs)*** were used for this purpose.

3.3. ITIKI Architecture

ITIKI Architecture is shown in Figure 1 below:

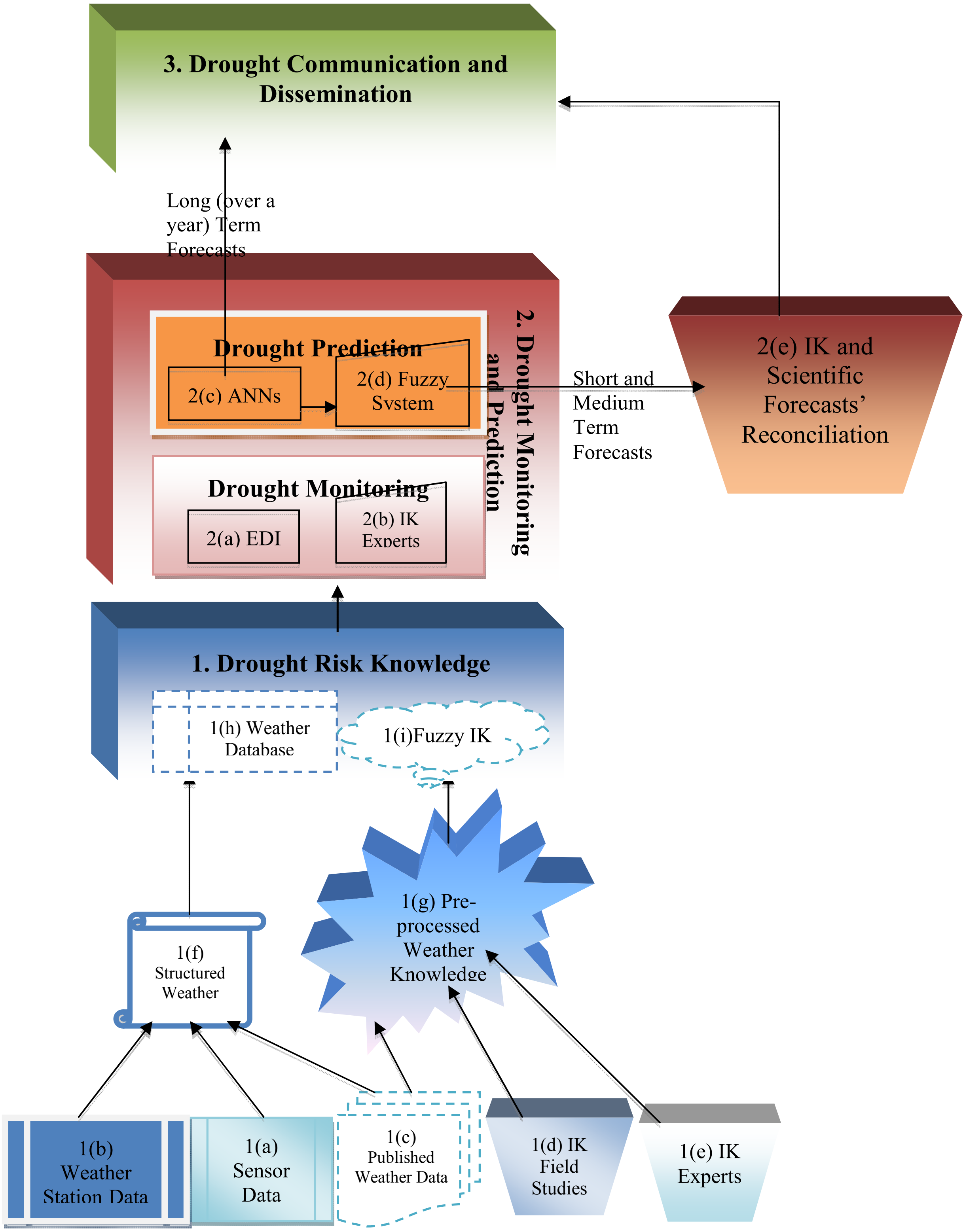

Figure 1. ITIKI Architecture

3.3.1. Element 1: Drought Risk Knowledge

1(a): Using wireless sensors that are capable of sensing temperature, humidity, atmospheric pressure, wind (direction and speed), precipitation and soil moisture, weather data is automatically collected and sent to a structured store ***1(f)*** in form of text messages (SMS).

1(b): Rainfall data observed from rainfall stations (contains only rain gauges, the Mbeere case) stations is manually entered into the system and stored in the same database as the sensors' data.

1(c): Other data elements (IK) are retrieved from various publications available in print and on-line. These are in form of limited studies on IK in Mbeere and SCFs by KMD. Out of these, the structured elements are stored in ***1(f)*** while the unstructured ones are stored in ***1(g)***.

1(d): IK on droughts collected during various field studies is stored in 1***(g)***.

1(e): This is the real-time IK from the IK Experts.

1(h) and **1(i):** the structured data is stored in a database ***1(h)*** while the pre-processed indigenous knowledge is represented as Fuzzy Sets ***1(i)***.

3.3.2. Element 2: Monitoring and Prediction

This was implemented using two sub-components: (1) Drought Monitoring that pre-processes the data to detect suggestive patterns as well minimise duplicates and other errors. This is achieved through EDI Monitor (**2(a)**) and IK Experts (**2(b)**) ; and (2) Drought Prediction using Artificial Neural Networks ((**2(c)**) and Fuzzy Logic System ((**2(d)**). In **2(e)**, the resulting forecasts are reviewed by both the scientists and IK Experts after which 'reconciled' forecasts are generated and passed to the Dissemination component. This is partially a manual activity where the meteorologists and the IK experts sit to reconcile SCFs and IKFs. However, the short-term forecasts (a few hours to two weeks) do not need the manual 'reconciliation'; the system intelligently reconciles the two (from IK and from ANNs) and sends them to the Drought Communication and Dissemination Component. Further, in line with fuzzy system, for purses of 'recovering' IK's original meaning/format, the output 2(e) is passed through 1(i) for Defuzzification

3.3.3. Element 3: Forecasts Dissemination

Mobile phones are used to send customized forecasts in form of test message and where possible, free phone calls to the farmers. Other forecasts are posted on websites while others are generated in audio formats that can be broadcasted via community radios stations and visual displays on strategically located village digital billboards. Though not implemented, the Framework is designed to support natural language processing to allow for translation of the forecasts into the local languages.

4. ITIKI IMPLEMENTATION - MBEERE CASE

4.1. Methodology

4.1.1. About the Mbeere People

With an average of 750mm (most parts receive less than 550 mm) annual rainfall, Mbeere is classified under Arid and Semi-Arid Lands (ASALs). A further classification of the ASALs places Mbeere under Category C; 50-85% of the land is arid (Republic of Kenya, 2008), Its terrain is characterised by scattered outcropping hills and its extensive altitudinal range of the area influences the temperature, which ranges from 15^{o}c to 30^{o}c. The main source (over 80%) of livelihood is rain-fed marginal farming and livestock (agro-pastoralists) keeping. This being the case, the farmers here rely mostly on the knowledge of seasons in making cropping decisions. Like most parts of Kenya, there are two main rain seasons experienced in Mbeere; the March-April-May (MAM) long rains and the October-November-December (OND) short rains. Crops grown include maize, sorghum, millet, beans, cowpeas, green grams, pigeon peas, cotton and tobacco on farms of average of 3.5 Ha. Livestock kept include Cattle (Zebu mostly), goats, sheep, poultry, donkeys and bees (http://www2.kilimo.go.ke).

4.1.2. Sample Data and Sampling Phases

The data used in this research was collected in 2 phases:

Phase I: This took place between August and December 2010 and the aim was to identify the prevalent IK indicators used by the Mbeere people. A guided interview involving 44 respondents was carried out with the help of representatives from the community.

Phase II: This was carried out between June and July 2012 and the objective was to evaluate the usability and relevance of the integrated drought monitoring system. Like in Phase I, guided interviews were conducted and the same (as for Phase I) respondents were approached. During this survey, sample output from the integrated system (output from the mobile application) was demonstrated to the respondents for feedback.

4.1.3. Data Analysis

Weather Observations Equipment: There is no synoptic station in Mbeere; the area is served by one located over 20 kilometres away. The location of this station does not do justice in reporting the weather for the entire Mbeere because it is located in a completely different climatic zone. The explains why over 90% of Mbeere respondents gave a value of between 0 and 1 (out of 3) for both accuracy and relevance of weather forecasts issued by KMD.

Respondents' Geographical Distribution: The respondents in both surveys were drawn from several villages covering over a third of the region

Knowledge and SFCs: Most respondents knew about the services but did not link it to KMD.

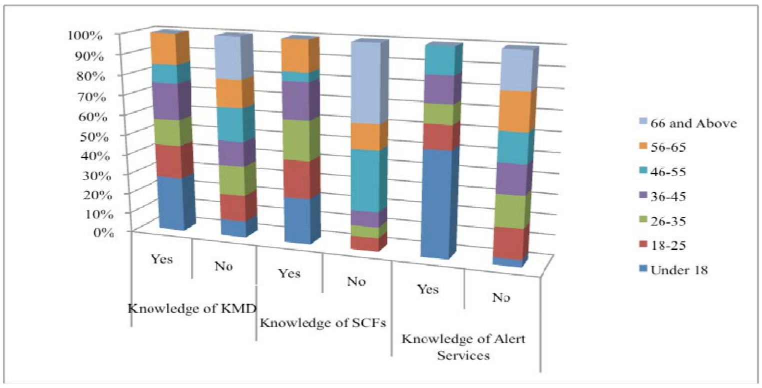

Figure 2. Respondents' Knowledge of SCFs

Distribution by Gender and Age: The respondents were mostly semi-literate small-scale/peasant agro-livestock female farmers over 20 years old.

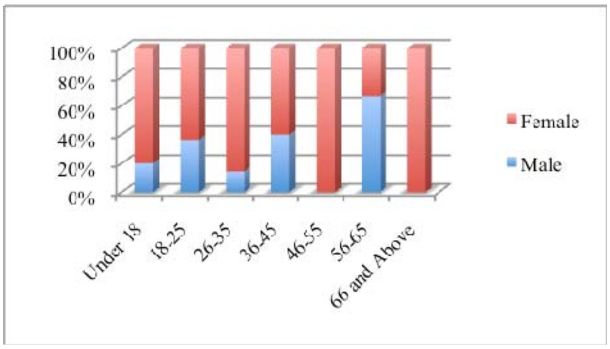

Figure 3. Respondents' Distribution by Age and Gender

Distribution by Level of Education: There were way more literate men than women; the number of illiterate people dropped with decrease in age.

Mobile phone ownership and use: There are generally more men who own phones than women, hoewever, all (except one) the people that did not have a phone did use phones mostly from relatives.

Phones for Weather Forecasts' Dissemination: The lack of relevant weather information among the respondents motivated their willingness to receive forecasts over the mobile phone. 89% of them said that they would like to receive weather information via mobile phones

Other Findings

- More than 50% of these preferred that such forecasts be sent to them via an authority such as Chiefs and Village Elders. Further, over 80% of the respondents preferred that the messages in the local language (Kimbeere);
- Like in most other communities/regions, the indigenous weather/drought indicators among the Mbeere people are associated with seasons. The diversity, level of details and systematic nature of the indicators from the respondents confirmed that the community has very rich IK systems that help the people cope with and adapt to the environment; for example, mixed agriculture. An elaborate list of these indicators was compiled and classified according to five main seasons: January-February dry season, March-April-Mary long rains, June-July Cold Season, August-September dry season and October-November-December short rains;
- The number and category of IK indicators reported by the respondents varied with gender and age brackets. For example, women mostly till the land and they go to fetch water, hence they are able to notice more indicators; and
- Using various examples, respondents expressed concerns that some IK indicators are no longer easy to notice because of biodiversity degradation.

5. IMPLEMENTATION ROAD MAP

5.1. Objective

The objective of the implementation project is to make use of ITIKI to downscale weather and drought forecasts to an individual small-scale farmer in Mbeere.

5.2. Implementation Strategy

(i) A focus group made up of 12 people representing 12 villages was formed in the first week of September 2012; these were selected from the list of 44 people that participated in piloting the ITIKI's prototype;

(ii) Weekly focus group discussions are held during which reporting and deliberations on various weather/drought indicators are done;

(iii) Though not very relevant to Mbeere, the October-November-December Seasonal Climate Forecasts issued by the Kenya Meteorological Department have been translated, customized and disseminated to the Mbeere people via ITIKI prototype;

(iv) In collaboration with KMD, plans are under way to install and operationalize a minimum of 5 rainfall stations;

(v) Once funds are available, plans under way to install and operationalise a minimum of 5 sensor-based weather stations;

(vi) Use ITIKI to create a drought early warning system using data from (i), (iv) and (v) for Mbeere

5.3. Current Operational Structure

This is purely a community-based initiative and the Mbeere people (through the representatives in the focus group) will spearhead the project. As such, a Community-Based-Ogranisation; KOVCA (Kiritiri Orphans and Vulnerable Children Advocate) will be the main outfit to spearhead the implementation. An Advisory Board initially made up of an ITIKI's expert (Muthoni Masinde), a representative from KMD and a church (Catholic Church) representative has been set up to advise on the project.

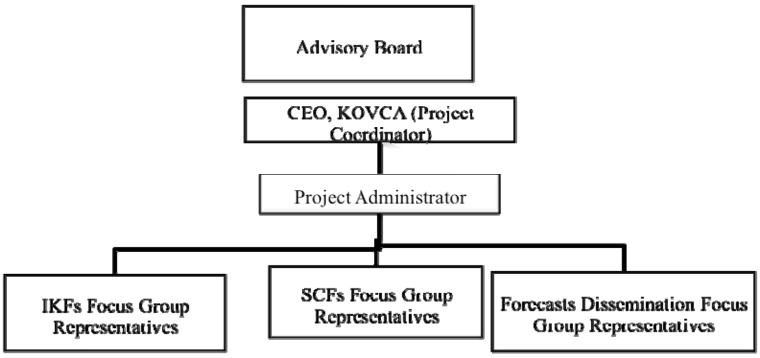

Figure 4. Project Operational Structure

6. CONCLUSION AND FURTHER WORK

Mbeere people occupy a semi-arid area that has hostile terrain and unpredictable rainfall. The main source of livelihood is subsistence crop farming and livestock keeping. So dependant is the community to rainfall that a good season translates to a healthy community and doom and misery otherwise. Modern weather forecasts are alien to the Community; there is no single weather station in the region. As such, the Community has continued to rely on IK to reach critical cropping decisions. With extreme weather variations being witnessed in the area and elsewhere in the globe, it has become increasingly difficult to use IK alone and a survey in the Community revealed dire need of reliable and relevant weather and drought forecasts. This made the authors reach a decision to pilot the recently developed ITIKI[3] framework and prototype among the Mbeeres. Starting off with a step-by-step explanation of ITIKI Architecture, we have explained the 'how', the 'what' and the 'when' of the pilot project currently underway.

We have just started; the rainfall stations will be installed before the next rain season due to start by mid-October 2012. For the first time, the Seasonal Forecasts by KMD have been translated into Kimbeere and widely disseminated to the Community. A follow-up study to find out if this improved the usage of the forecasts is scheduled for early 2013. Further, the number of weather parameters observed will be improved by the planned installation of sensor-based weather meters along-side the rainfall stations.

Lastly, during the development of ITIKI, it emerged that there is no single source known to the authors that provides a systematically collected and stored IK on weather. ITIKI implementation in Mbeere will provide one such information source.

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