The Role of ICTs in Downscaling and Up-scaling Integrated Weather Forecasts for Farmers in Sub-Saharan Africa

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ABSTRACT
Despite global advancements in technology and inter-trade volumes, Sub-Saharan Africa is the only Region where cases of hunger have increased since 1990. Rampant and frequent droughts are one of the major causes of this. Monumental and mostly donor-funded projects have been mounted to counter this but with little success. One of the latest strategies being experimented is a community-based early warning system that seeks to integrate indigenous knowledge with western climate science. This initiative is informed by the realization that, though crucial, weather forecast information provided by the national meteorological departments has little utilization amongst small-scale farmers. Though having generated promising results, the integration project still faces the challenges of scaling up across communities as well as the lack of micro-level weather data. In this paper, we describe how the adoption of mobile phones and wireless sensor networks technology is being used to address these two challenges. Use of denser wireless sensor networks to collect local weather data and mobile phones to disseminate forecasts brings information closer to the farmers that need it most. To ensure that the non-mystical aspects of indigenous knowledge are portable across communities, language technologies (part of artificial intelligence) are used in the design of our system.

Categories and Subject Descriptors
I.2.11 [**Distributed Artificial Intelligence**]: Intelligent Agents – *the Belief-Desire-Intention Model (BDI)*; J.2 [**Physical Sciences and Engineering**]: Earth and Atmospheric Sciences – *wireless sensors-based weather station;* J.7 [**Computers in Other Systems**]: Weather/Climate Forecasting

General Terms
Documentation, Human Factors

Keywords
Seasonal climate forecasts, indigenous knowledge weather forecasts, Nganyi clan of Western Kenya, wireless sensor networks, Sub-Saharan Africa

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1. INTRODUCTION
Of all climate-related disasters, droughts contribute over 90% of environmental, health and social negative impacts on people living in the Sub-Saharan Africa (SSA), [1]. Though droughts have affected flora and fauna since time immemorial, there is evidence [2] that droughts in SSA have become more frequent and severe. The SSA and especially the Eastern Africa is for example currently (2011) facing a drought catastrophe that has been described as "the worst since 1950". However, droughts and indeed disasters resulting from extreme climate variations are not unique to SSA. The frequency, magnitude and duration of such disasters are on the rise globally, thanks to events such as climate change, global warming and population growth. The uniqueness of the problem in SSA is to be found in the inadequacy and ineffectiveness of the Region's preparedness to these disasters. The most conspicuous pointer to this sorry state of affairs is the fact that most of the drought-relief efforts are mostly left in the hands of international aid organizations. Why the governments in these countries do not have early warning systems in place is the one million dollar question. The issue of early warning systems for droughts is a complex terrain to maneuver; such systems are in fact the most complex of all warning systems to build [3]. Adopting a community-driven approach to the design of an early warning system is one way of ensuring system's adoption.

Information is power and ensuring that the local communities have access to tailor-made information on weather is one way of giving them power to protect themselves from negative effects of extreme variations in weather/climate. For instance, prior knowledge on rainfall and dry periods patterns will enable farmers to manage their crops/livestock in a way to minimize risks and maximize opportunities. For example, selling-off animals while they (animals) are still healthy enough to fetch more money and planting more of a given crop when anticipating more rainfall [4]. Though governments in most of the SSA countries have always provided regular weather/climate forecasts especially in form of Seasonal Climate Forecasts (SCFs), the usefulness of this information to the small scale farmers whose crops/livestock depend solely on rainfall has always been doubted ([5] [6]). On the other hand, the indigenous knowledge on which these communities have relied on since time immemorial is facing challenges from various quarters especially from climate change, urbanization and population growth.

On the realization that the scientific and traditional indigenous climate/weather forecasting approaches compliment each other, a number of initiatives (within SSA) have been spawned around the idea of integrating the two systems. This integration was for instance been implemented and tested within a locality in Western

Kenya. Though still underway, the success of this initiative can be accelerated as well as ported (to other communities) through the use of ICTs. The contribution of this paper is a system prototype that achieves this through the use of mobile phone application, wireless sensors-based weather stations and intelligent agents.

The remaining part of the paper is structured as follows: Section 2 describes the integration of modern and indigenous weather forecasts case study carried out among the Nganyi Clan in Western Kenya. Section 3 explains how mobile phones, WSNs and intelligent agents are used to achieve scaling up/down of the case study (in 2). We present the integrated system prototype in Section 4 while testing and evaluation is in Section 5. Finally, conclusions and further work is in Section 6.

2. INTEGRATING INDIGENOUS AND WESTERN CLIMATE SCIENCE – THE NGANYI CLAN CASE STUDY

2.1 Weather Forecasts – Current Practice

In many other countries in the SSA, national level Seasonal Climate Forecasts (SCFs) are a mandate of a government department such as the Kenya Meteorological Department (KMD), Tanzania Meteorological Agency (TMA) and Zambia Meteorological Department(ZMD). SCFs are released about a month before the onset of each of the rain seasons. As indicated in below, these forecasts are usually in form of probabilistic figures indicating the total rainfall expected in each climatic regions/zones.

As depicted in figures 1, 2, and 3, meteorological terminologies such as '*below/above normal rainfall*' are used and information is passed through very formal channels and formats. Apart from being inadequate and incomprehensible to the small-scale farmers, the forecasts do not aid in decision making because farmers are interested in more than just total rainfall expected. They need

Seasonal Rains (November 2011 – April 2012) Outlook:

The November to April rainfall (Seasonal rains) is more important for the Western, Central, Southwestern highlands, Southern regions and Southern coast. The rains are likely to be normal to above normal over most of unimodal regions. However, parts of southern Lindi, eastern parts of Ruvuma and Mtwara regions rains are expected to be mainly normal during October to December, 2011.

The western areas: (Tabora, Rukwa and Kigoma regions):

- Rains are expected to start during the third and fourth week of November and are expected to be normal to above normal.

Central (Singida and Dodoma regions):

- Rains are expected to start during the fourth week of November and are likely to be normal to above normal

Figure 1. Extract from a SFCs report for Tanzania [source: Tanzania Meteorological Agency Website].

Outlook for the Period October, November and December 2011

The November to Western, Southern, Lusaka, the western parts of Central and the southern districts of Eastern provinces have an increased chance of receiving normal to below normal rainfall. The rest of Zambia has a high likelihood of receiving normal rainfall.

Figure 2. Extract from a SFCs report for Zambia [source: Zambia Meteorological Department Website].

Outlook for the "Short Rains" (October-November-December (OND)) Season:

The Climate Outlook for the "Short Rains" (October-November-December (OND)) 2011 season indicates that much of the country is likely to experience near-normal rainfall. This will tend to above-normal (enhanced) rainfall in much of the southern parts of the country except the western areas. The expected enhanced seasonal rains will be driven by the warming Indian Ocean in areas adjacent to the East African coastline. The distribution of the rainfall in time and space is expected to be generally good over most places.

Figure 3. Extract from a SFCs report for Kenya [source: Kenya Meteorological Department Website].

localized information on the quality, onset-termination, temporal and spatial distribution of the rainfall as well as the timing and frequency of the actual patterns of the rainfall/dry spells. This obvious gap among other reasons has led to the current slow pace in adoption of SCFs by the majority of communities in SSA. Consequently, they continue to rely on indigenous knowledge on weather/climate forecast (IKFs) in making important decisions such as when, how and what to plant. The latter is preferred because it is based on the local ecological and socio-cultural contexts of the farmers.

2.2 Indigenous Knowledge Vs. Modern Science Weather Forecasts

In [7] indigenous/traditional knowledge (IK) is described as the knowledge of an indigenous community accumulated over generations of living in a particular environment. It is traditional cultural knowledge that includes intellectual, technological, ecological, and medical knowledge. In IK forecasting, the local weather and climate is assessed, predicted and interpreted by locally observed variables and experiences using combinations of plant, animals, insects and meteorological and astronomical indications [8].

Traditionally, small-scale farmers in Africa have always based their major decisions on Indigenous Knowledge on weather and climate patterns (IKFs). They observed changing seasons as well as lunar cycles (shape/position of the moon and patterns of stars). They also observed the natural environment (behavior of animals/birds and looks of some plants) and like the weathermen of today, IK also involved studying the meteorological parameters such as air/temperature intensity, clouds color/direction and wind direction. Some of IK is however so intertwined with the communities' cultural and religious beliefs that it is impossible to put it into conventional reasoning based on modern science. Though this is changing, this nature of IK has made the modern scientists brand it as '*primitive'* over the years. On the other hand, SCFs cover such large areas that the forecast usually lack localized meaning. Further, unlike IKFs, SCFs do not provide for adequate and localized intervention mechanisms and consequently, the farmers do not have faith in them. As shown in the table 1, both SCFs and IKFs have their own share of strengths and weaknesses.

Table 1. Comparisons between IKFs and SCFs (adapted from [4]).

IKFs	SCFs
Use biophysical indicators of the environment as well as spiritual methods	Use of weather and climate models of measurable meteorological data
Forecast methods are seldom documented	Forecast methods are more developed and documented
Up-scaling and down-scaling are usually complex	Up-scaling and down-scaling are relatively simple
Application of forecast output is less developed	Application of forecast output is more developed
Communication is usually oral	Communication is usually written
Explanation is based on spiritual and social values	Explanation is theoretical
Taught by observation and experience	Taught through lectures and readings
Adapted to local conditions and needs	Formulated at a larger scale and lacks relevance at local level

Below are some examples of IK indicators for weather forecast:

Examples of IK Indicators for Weather Forecasting

Monze and Sinazonmgwe in Zambia from [14]):

- ***Good Season***: Presence of certain types of birds/insects, mist in hills during the dry season; plenty of wild fruits; abundance of leaves on fig trees; too many girl children born in that season; high temperatures; frost around end of year; and dark and heavy clouds.
- ***Bad Season***: Less wild fruits; mukololo tree does not flower; sparse leaves in fig trees; too many boy children born in that season; and very cold winters between May and August.

Lupane and Lower Gweru in Zimbabwe (from [14]):

- ***Good Season***: Rhus Lancea and Lancea discolor trees produce lots of fruits; Azanza garikeana do not fruit well; heat waves experienced characterized by a lot of cicardas; early haziness soon after winter; North easterly winds; prevalence of whirl-winds; frogs turning brownish; rain birds making a lot of noise; and butterflies seen hovering in the air form north starting in October.
- ***Bad Season***: Rhus Lancea and Lancea produce few fruits; lancea discolor produces fruits but aborts them before the rains; extended winter period; north easterly winds dominant; white frogs appear in trees; lots of thunderstorms without rains; and early rains starting from early October.

Nganyi Clan in Western Kenya:

- If river water is warm, then rain is close and when it's cold, rain is not near.
- Migration of some birds and insects is a sign of either dry or wet weather. E.g. Safari ants move around when the rains are about to fall.
- Movement of swarms of locusts and butterflies means a prolonged dry period is about to occur.
- The quail birds migrate to maize/wheat plantations during dry seasons and it indicates no rainfall.
- The croaking of frogs indicates the rain season is about to commence.
- The cattle usually run around and jump up with their tails raised to show rain is soon to start.
- The presence of dew in the mornings a long dry period is a sign that the rains season is about to begin.
- When the leaves start spouting it indicates rain is to fall. E.g. mvule tree and Nandi flame.

Figure 4. Examples of IK weather forecasting indicators.

In [14], after observing a positive relationship between forecasts based on IK and those based on modern science, the authors recommended that the two knowledge systems should be integrated. Though not related to the recommendation in[14], such an initiative[1], spearheaded by the IGAD (Intergovernmental Authority on Development) Climate Prediction and Applications Centre (ICPAC) was started in September 2008. The integration was geared towards maximizing the strengths of the SCFs and IKFs and by extension to improve the adoption of weather forecasts by small-scale farmers. The project brought together meteorologists and the Nganyi indigenous knowledge forecasters to build 'reconciliations' between SCFs and IKFs. The reconciled forecasts have been carried out for 7 seasons (September 2008, March 2009, September 2009, March 2010, September 2010, March 2011, and September 2011) and results disseminated through the locally available (existing) communication channels such as chief barazas and churches. The outcome of the project has been rated 'very good' by the two parties. After September 2010, KMD committed resources to ensure the success of the project. However, KMD still faces a number of challenges in this project some of which well-thought ICTs solutions could address. Two of these challenges are described in the subsection below.

2.2.1 *Scaling-Down*

In order to carry out effective weather forecasting, an organization needs to be equipped with a number of synoptic stations. These have the capability to observe and record all the surface meteorological data; rainfall, temperature, wind speed and direction, relative humidity, solar radiation, clouds, atmospheric pressure, sun shine hours, evaporation and visibility. Out of about 5,175 of such stations that are found in the world (and recognized by the International Civil Aviation Organisation (ICAO)), only 11% are found in Africa. This gives a very sparse coverage of 53,600km^2 per station. Kenya has 27 of such stations; this translates to a density of 21,495 km^2. Though this is better than many countries in the SSA (South African - 27,751 km^2, Tanzania – 42,959 km^2 and Zambia 50,174 km^2), it is far from being as good as the coverage in the developed countries (e.g. UK – 1,168 km^2, Germany – 3,607 km^2 and USA - 6,664 km^2). With this kind of sparse network, it is not possible to provide locally relevant information necessary for scaling weather information down to the local (say village level) communities.

2.2.2 *Scaling-Up*

Accurate weather forecast information is more critical for communities living the semi-arid areas of SSA where a slight variation in the forecast leads to devastating effects on the communities living there. The integrated weather forecast described above will therefore have greater impacts in such areas. Consequently, the ability to port the Nganyi success story across other communities in SSA is a key to the success of the SCFs - IKFs Integration Project. However, this is currently a daunting task; first, some aspects of the IKFs are based on myths and religious beliefs that may not apply across communities. Two, the common aspects of the IK (observational) such as observing flowering patterns trees and positions of the sun/moon/stars, has

[1] Integrating Indigenous Knowledge in Climate Risk Management to Support Community Based Adaptation in Western Kenya (http://www.africa-adapt.net/aa/ProjectOverview.aspx?PID=PUXVdbXh9bM%3D)

not been formally (say in a searchable database) documented anywhere. This makes it difficult to scale-up the project to regional, national and international levels. The project leaders are currently struggling with this issue as they try to start similar initiatives among the Maasai (in the Rift Valley) and the Somali (in North Eastern) communities in Kenya

In order to address the two challenges above, the authors of this paper have come up with a framework that integrates the use of mobile phones, wireless sensor-based weather stations and the rich language technologies supported within artificial intelligence discipline of computer science.

3. SCALING DOWN/UP IKFs-SCFs INTEGRATION

3.1 Using WSNs to Scale-Down

A wireless sensor network (WSN) is a collection of millimeter-scale, self-contained, micro-electro-mechanical devices which have sensors, computational processing ability wireless receiver and transmitter technology and a power supply [9]. These devices are commonly referred to as ***node*** or ***mote***, and they have a general structure as shown in Figure 5.

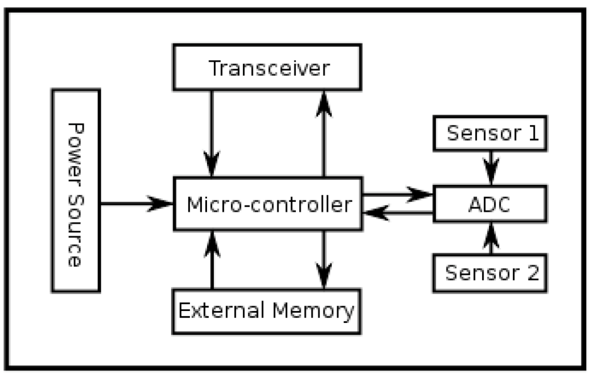

Figure 5. The typical architecture of the sensor node.[2]

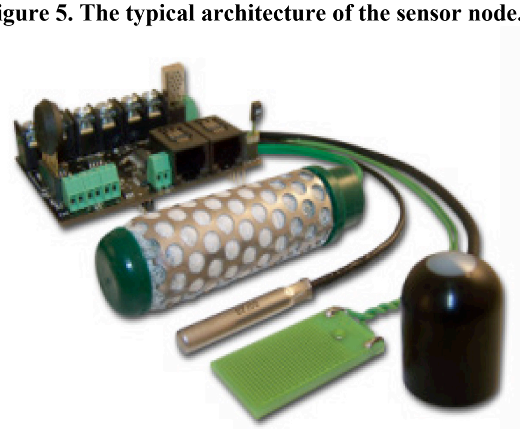

Figure 6. Libellium's agriculture sensor board.

Figure 6 is an example of a sensor board (Agriculture Sensor Board by *Libellium*[3]) capable of sensing temperature, relative humidity, atmospheric pressure, soil moisture, soil temperature, solar radiation, among other things.

Wireless Sensor Networks (WSNs) based applications have been successfully deployed for: weather forecasting and prediction, health-care monitoring, habitat monitoring, precision agriculture, and tsunami warning systems, among others. A WNS-based application can be used to accurately predict droughts and reduce the impacts of droughts. They are recommended for use in SSA because they precipitate the following desirable features:

(a) Limited power requirements that can be easily harvested (e.g., solar power) or stored (e.g., batteries)

(b) Able to withstand harsh environmental conditions

(c) Fault-tolerant and designed to cope with high possibility of node failures,

(d) Support for mobility

(e) Dynamic network topology

(f) Able to withstand communication failures

(g) Heterogeneity of nodes, and

(h) Large scale of deployment.

Climate monitoring is one of the main drought mitigation strategies. The latter is currently implemented in SSA using macro-infrastructures based on expensive and well-calibrated weather stations. The stations are then sparsely deployed by governmental organizations in form of relatively small number of fixed locations to provide climate maps for droughts and other natural disasters prediction. This creates a feasibility gap that needs to be addressed through complementary technologies, systems and strategies. WSNs technology has the potential to bridge this gap. These can then be deployed in the environment to improve the weather station density by collection and analyzing weather data. Compared to the traditional weather station technology used by government meteorological departments, sensor based weather applications deployed in community sensor networks are appropriate because:

(a) They are cheaper. For instance, Libelium (http://www.libelium.com/) offers sensor weather station at a cost of +/- 1,000€, which insignificant compared to professional weather station that costs between 100,000 and 600,000€.

(b) They are highly scalable; additional sensors can be plugged in easily and others removed with no need for application redesign.

(c) They allow collection and dissemination of micro level drought/weather parameters. They can also be integrated with mobile phone and web applications to deliver tailor-made information to stakeholders.

(d) The mobility nature of WSNs allows them to cover wider geographical areas than traditional weather stations. For example, a mobile weather station can be mounted on a country-bus and relay information as the bus travels into the country interior.

E-weather stations based on WSNs can be deployed in their 10s to capture micro-level weather data. This way, the weather data has relevance at the local level. The data collected from the sensors will come in handy during the evaluation of previous season's

[2] http://en.wikipedia.org/wiki/Sensor_node

[3] http://www.libelium.com/

forecasts. In the current implementation of the SCFs - IKFs Integration Project, the stakeholders normally meet to evaluate the correctness of the previous forecast. This is for example achieved by comparing the actual amount of rainfall recorded with the predicted amounts. Currently, the actual figures are estimated from the sparsely distributed weather stations; the local values are impossible to get. Use of WSNs will alleviate this problem and make it possible to get localized and accurate readings, and hence achieving 'scaling-down' that is currently missing in the Project.

3.2 Role of Mobile Phones in Scaling-Up

Although still experiencing a mobile phone penetration lag[4] of close to 10 years, Africa has achieved an average penetration level of 41% [10], which is much higher than that of computers. For instance, according to Kenya's 2009 population sensors [11], only 3.6% of households owned at least one computer in comparison with 63.2% of households that owned at least one mobile phone. In Kenya, mobile phones have been incorporated in many aspects of lives including that of farmers; phones have been used to source market prices for agricultural produce and as well as weather information. In our work, we seek to use a mobile phone based application for disseminating the reconciled (between SCFs and IKFs) forecasts to farmers. The application incorporates text-to-speech ability in order to read out forecasts to illiterate farmers as well language translation facility to translate the content to various local languages. This generic application therefore achieves the much-needed scale-up by extending the use of the reconciled weather forecast beyond the original target (Luhya) community of the project.

Dissemination of weather forecast information is highly multi-dimensional; it traverses all sectors of a society. For example, the reconciled forecasts' implications on education, health, social services, security, agriculture, livestock and environment sectors have to be thought through and communicated to the communities through the relevant channels. For example, heavy rains wash away bridges hampering children from going to school (education sector) and breeding of mosquitoes brings more malaria (health sector) cases. All this exponentially increases the amount of information and the number of recipients and the now commonly used mobile phones can come handy to disseminate this information.

Further, the mobile phone-application is also used as an input device to capture the indigenous knowledge during the focus-group meetings. This information is then stored in a database from where the generic aspects of the knowledge can be used as input for the forecast in other communities.

3.3 Using Intelligent Agents to Scale-Up

Compared to SCFs, the nature of most of the aspects of IKFs makes it difficult to represent the knowledge using conventional computer data structures. Integrating SCFs and IKFs therefore requires some level of reasoning, autonomy, and distribution. Our project adopts the use agents' technology to achieve this. Among the various forms of agents' implementations available, the Beliefs-Desires-Intentions (BDI) agents would suffice. The elements of BDI are: (1) Belief – what the agent holds about the environment and about itself; (2) Desire and Intention – the state of affairs that the agent wishes to bring out. The difference between Desires and Intensions is that in the latter, there is a measure of commitment that leads and controls the future actions of the agent while an agent may have desires but never set out to fulfil them [12].

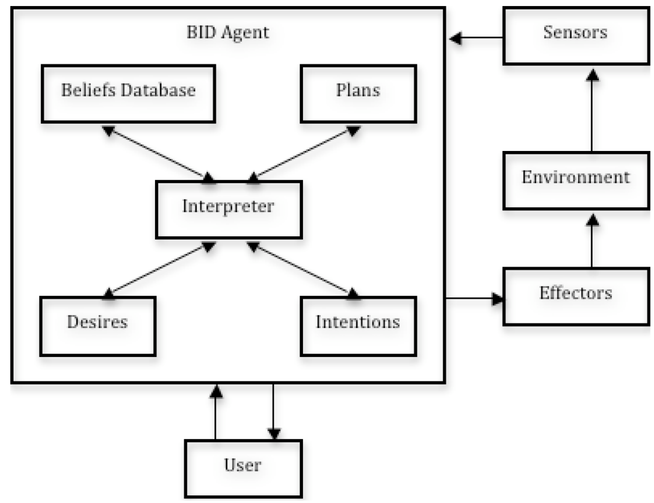

Figure 7. The BDI basic architecture.

The main components of BDI are:

(a) A database of beliefs consisting of world facts as well as data relevant to the agent's internal state

(b) A set of the agent's goals or objectives (desires)

(c) A set of plans necessary to achieve these goals; and

(d) An ordered set of these plans (intentions)

Our system prototype is implemented as a set of agents as per the BDI architecture. Once both the IKFs and SCFs for a given locality are captured in the beliefs database, it becomes easier to make some changes (in both the belief-set and the interpreter) to suit another (different) community/locality. This further promotes the scaling-up of the IKFs-SCFs weather forecasting system.

4. SYSTEM PROTOTYPE

4.1 System Architecture

Working from the following four elements (*figure 8*) of effective early warning systems [13], our approach involves building an early warning system for extreme climate variability. Our initial prototype does not take care of the 'Response Capability' Element. The system is build upon an already existing system (not automated) that integrates forecasts by the Nganyi Clan of Western Kenya and the Seasonal Forecasts by the Kenya Meteorological Department. The general objectives of the system are to:

(a) Automate the generic (not based on community myths) aspects of IK and apply this for forecasts across communities in SSA;

(b) Incorporate micro-weather data through the use of WSNs;

(c) Incorporate the use of mobile phone application for customized weather forecasts dissemination and IK input; and

[4] The time gap between mobile phone penetration level in Africa, and the year that same level of penetration was achieved globally.

(d) Make use of intelligent agents to ensure that all the components form an intelligent whole system.

Except for the 'Response Capability', our system prototype adopts and adapts the elements of an early warning system as described in the following subsection.

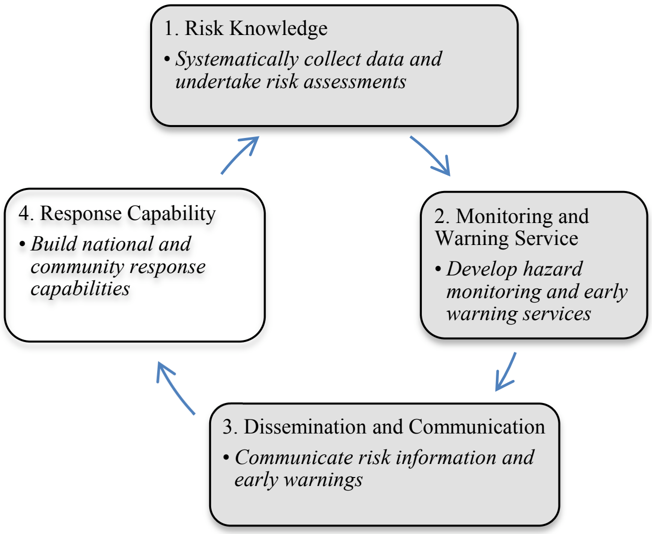

Figure 8. Elements of an early warning system (adopted from [13]).

4.1.1 Element 1: Climate Variations Risk Knowledge Engine

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 database in form of text messages (SMSs). This is achieved through a GPRS module that is part of the sensor equipment that is being used for this project. On the other hand, data from the indigenous knowledge experts is collected using a mobile phone application.

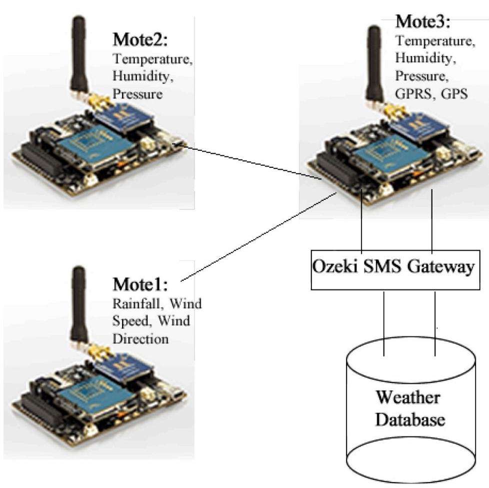

Figure 9. System prototype – WSN design.

In the above design, all the 3 motes take readings at an interval of 30 minutes and stores the data in an SD card. After every hour, Mote 1 and Mote 2 forwards (via ZigBee) their hourly average readings to Mote 3. Mote 3 is equipped with GPRS/GSM module which it uses the to send (as text messages) the readings to the database via SMS gateway. Once in the database, further processing (such as displaying the weather data on the website) is carried out.

As shown in *figure 10*, IK too is sent to the same database as the weather data from the sensors. Once in the database, queries are used to retrieve data in the required formats and presented to Integrated Weather Monitoring Engine. Collection of the IK is via a mobile phone application that is implemented on an Android Phone. The knowledge is collected during the focus groups (similar to the ones in place in the Nganyi Clan project) meetings. In the enhanced system, an intermediary will be selected from the group to act as an interface between the mobile application and the group. This person will be IT literate, able to fully understand the local language as well possess general knowledge on climate science. The intermediary will sieve through the discussions, translate, format and key in the information on to the mobile application. As shown in *figure 11* the mobile phone application is designed such that each record entered is transferred to Traditional Knowledge Database via WAP. In scenarios where the WAP is not active, the data is stored locally on the phone and the intermediary can then transfer the data later by connecting to the system's website from the local internet kiosks. Once collated, the data will be used as input to the next step in the weather forecasting process.

4.1.2 Element 2: Monitoring and Warning

In our system, this is implemented using two Engines: (1) Integrated Weather Monitoring Engine and (2) Reconciled Weather/Climate Forecasting Engine.

4.1.2.1 Integrated Weather Monitoring Engine

This receives both IK and weather data from sensors in pre-defined formats. This Engine then preprocesses the data to detect suggestive patterns as well minimize duplicates and other errors. Once this is done, the generated indicators are presented to the Reconciled Weather/Climate Forecasting Engine.

4.1.2.2 Reconciled Weather/Climate Forecasting Engine

This partially automates the forecasting stage where the meteorologists and the IK experts sit to reconcile SCFs and IKFs. The improvement here is that the system avails the Global Weather patterns (in of XML and RSS formats), Regional Weather Forecasts (from other Climate Zones in the Country) and also the National Weather Forecasts. This integration was initially difficult to achieve but since the data pertaining both the IKFs and SCFs resides in a relational database, supplementing it with other forecasts (equally stored in databases/structure formats) is now much easier. Another new addition is the system's ability to 'learn'. 'New Knowledge' generated from new/subsequent forecasts is ploughed back to the 'Integrated (IKFs & SCFs) Weather Knowledge' for use in the future. This can also be used to detect phenomena such as climate change.

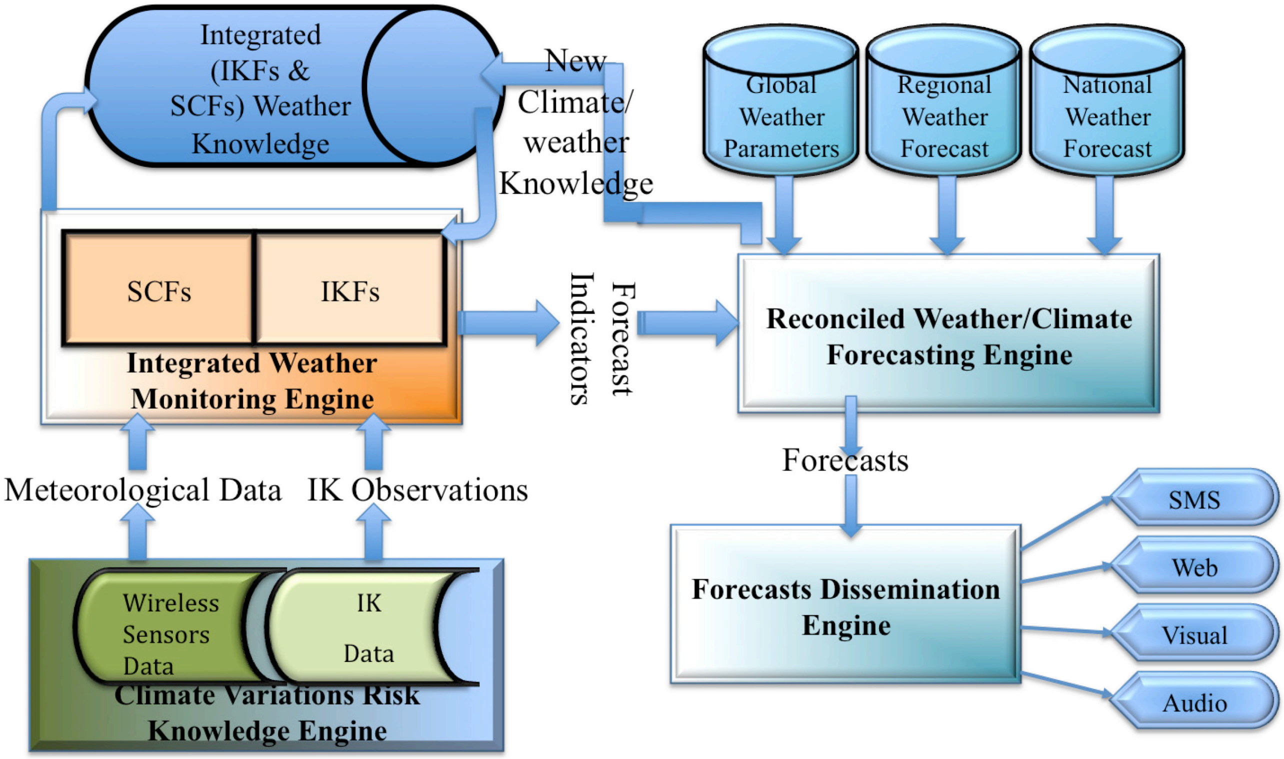

Figure 10. SCFs-IKFs integration - System architecture.

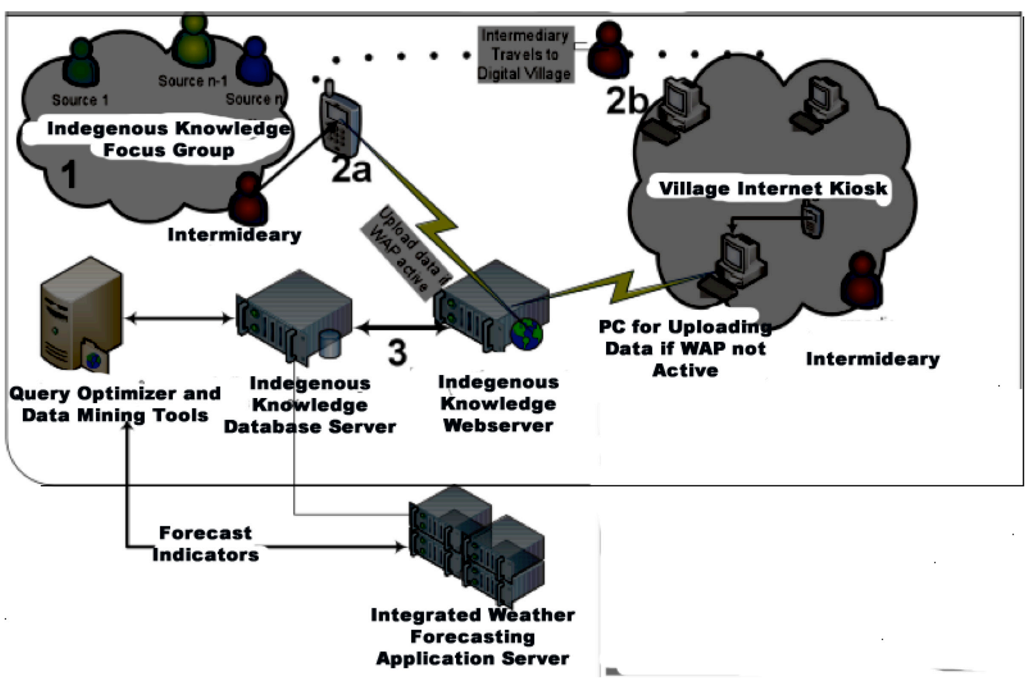

Figure 11. A framework for collecting IK on weather.

4.1.3 Element 3: Forecasts Dissemination Engine

Our system seeks to automate and compliment the current dissemination methods through which the integrated forecasts in the Nganyi community project are done. Mobile phones are used to send customized forecasts in form of SMS while other forecasts are posted on websites. These two may not meet all the needs of the local communities and plans are underway to implement audio forms of forecasts that can be broadcasted via community radio stations. Finally, visual displays will also be implemented and displayed on strategically located village digital billboards. All these will be in local language(s) used within the respective communities.

5. TESTING AND EVALUATION

Though the system has been thoroughly tested in laboratory environment, its performance in the field is scheduled for September 2011 when KMD carries out the next seasonal forecasts. The evaluation will then be carried out between January and February 2012 after the end of October-November-December rain season.

6. CONCLUSION AND FURTHER WORK

Like any other domain, weather information system that is tailored to the user needs is more likely to be embraced. This has proven to be the case in the locality (the Nganyi Clan of Western Kenya) of the project because farmers now use weather forecast information to make decisions such as when to plant, what methods of crop husbandry to adopt, what crops to plant and even when to harvest. This success story will only create socio-economic impacts for Kenya and SSA if replicated in other communities and regions. ICT solutions build around the now commonly used mobile phones and the less costly (than professional weather stations) wireless sensors provide an avenue for achieving the much-needed scaling-up and scaling-down of the integration between scientific Seasonal Climate Forecasts and the traditional Indigenous Knowledge-based forecasts. In this paper, we have presented an integrated system design and prototype that scales up the existing integrated weather forecasting system in use in Western Kenya.

The system described here makes use of mobile phone application to scale up the weather forecasts dissemination channels, hence making them more generic and applicable beyond one community (the Nganyi Clan). Scaling up is also achieved through the use of intelligent agents through which IK patterns are 'learned' and applied across communities/regions. Finally, using the cheaper wireless sensor technology, scaling down of the project has been made possible because more localized weather data is now available for use to validate the local forecasts. This was initially difficult through the more expensive and sparsely distributed (and in some cases manual) professional weather stations.

Due to the nature of forecasts (predictions), testing of the proposed system will require that season(s) elapse before results are available. At the time of writing this paper, the first field-testing of the system is still on schedule and will be completed in February 2011.

7. REFERENCES

[1] The International Federation of Red Cross and Red Crescent Societies. World Disaster report 2010 – Focus on Urban Risk; www.ifrc.org/Global/Publications/disasters/WDR/WDR2010-full.pdf

[2] Mishra, A. K., and Singh, V. P. (2010), A review of drought concepts. Journal of Hydrology (In Press), doi:10.1016/j.jhydrol.2010.07.012

[3] Veronica F. Grasso; Early Warning Systems: State-of-Art Analysis and Future Directions; United Nations Environment Programme (UNEP); http://na.unep.net/geas/docs/Early_Warning_System_Report.pdf

[4] Ziervogel G. and Alfred Opere, 2010; Integrating meteorological and indigenous knowledge-based seasonal climate forecasts for the agricultural sector: Lessons from participatory action research in sub-Saharan Africa; IDRC, http://web.idrc.ca/uploads/user-S/12882908321CCAA_seasonal_forecasting.pdf

[5] Ziervogel, G.; Bharwani, S.; Downing, T.E. 2006. Adapting to climate variability: pumpkins, people and policy. Natural Resource Forum, 30: 294–305.

[6] Ziervogel, G.; Calder, R. 2003. Climate variability and rural livelihoods: assessing the impact of seasonal climate forecasts in Lesotho. Area, 35(4): 403–417.

[7] Steiner, A. 2008. Indigenous Knowledge in Disaster Management in Africa. UNEP: UNEP

[8] Boef, W.de., Kojo A., Kate W. and Anthony, B. (1993). Cultivating Knowledge; Genetic Diversity, Farmer Experimentation and Crop Research. London: Intermediate Technology Publications.

[9] Eiko Yoneki and Jean Bacon, 2005; A survey of Wireless Sensor Network technologies: research trends and middleware's role; University of Cambridge, computer Laboratory.

[10] ITU 2010; The World in 2010: ICT Facts and Figures; Available: www.itu.int/ITU-D/ict/material/FactsFigures2010.pdf

[11] KNBS 2009; The Kenya Census 2009: Population and Housing Census Highlights; Available: www.knbs.or.ke/Census%20Results/KNBS%20Brochure.pdf

[12] GREG, M., P., O'HARE AND NICK, J. 1996. Foundations of distributed artificial intelligence. John Wiley & Sons, Inc., New York, NY, USA.

[13] ISDR 2006. Developing Early Warning Systems: A Checklist. Third International Conference on Early Warning: From concept to action. EWC III:1-13.

[14] Mugabe, F.T., Mubaya, C.P., Nanja, D.H., Gondwe, P., Munadawafa, A. Mutswangwa, E., Changonda, I., Masere, P., Dimes, J., and Murewi, C., 2010. Use of Indigenous Knowledge Systems and Scientific Methods for Climate Forecasting in Southern Zambia and North Western Zimbabwe; Zimbabwe Journal Technological, Vol 1, No 1 (2010), ISSN: 2079-8997.