ITIKI:

Bridge between African Indigenous Knowledge and Modern Science on Drought Prediction

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Extended Abstract

The now more rampant and severe droughts have become synonymous with the Sub-Saharan Africa where they are a major contributor to the acute food insecurity in the Region. Though this is not different from other regions in the world, the uniqueness of the problem in the Sub-Saharan Africa countries is the ineffectiveness of the drought monitoring and predicting tools in use in these countries. Accurate and reliable drought forecasts, when delivered in a timely fashion and in formats that are comprehensible to the targeted users, are a precursor to successful drought mitigation strategies. There is a link between weather monitoring and droughts; accurate weather monitoring can detect droughts occurrence long before they strike. In Sub-Saharan Africa, resource-challenged National Meteorological Services are tasked with this responsibility. Although these Services use well-calibrated weather stations that meet World Meteorological Organisation's standards, the high cost of acquiring the stations allows only a sparse deployment.

Despite this challenge, these institutions continue to provide regular climate forecasts especially in form of Seasonal Climate Forecasts. The utilisation of these forecasts by the small-scale farmers whose crops/livestock depend solely on rainfall is still very low; they instead continue to consult their Indigenous Knowledge Forecasts for their cropping decisions. This is partly because the Seasonal Climate Forecasts are too supply-driven, too 'coarse' to have meaning at the local level and the dissemination channels are ineffective. Why small-scale farmers? Economies of most countries in the Sub-Saharan Africa are agri-based with over 70% of food being produced by small-scale farmers practicing rain-fed agriculture. The latter in extremely responsive to weather patterns and a good rain season translates to bumper harvest and hunger and despair otherwise.

Though the robust Indigenous Knowledge Forecasts that these farmers have relied on since time immemorial has always worked, there is evidence that the knowledge is under serious threat from events such as climate change and 'modernisation'. Some of these threats can be countered by blending it with the Seasonal Climate Forecasts. On the other hand, incorporating Indigenous Knowledge Forecasts into the Seasonal Climate Forecasts will improve its relevance (both locally and culturally) and acceptability and hence boost their utilisation among the small-scale farmers.

The advantages of this mutual symbiosis relationship between the two forecasting systems have been recognised and pursued in a few initiatives, but with little success. The main challenge is the inability of these initiatives to scale-up beyond a region/community and two, the lack of micro-level weather data to validate the forecast outcomes. Information and Communication Technologies (ICTs) can

accelerate this integration; this is the focus of this research. The thesis describes a novel drought monitoring and predicting solution that is designed to work within the unique context of small-scale farmers in Sub-Saharan Africa. The research started off by designing a unique integration framework that creates the much-needed ***bridge (itiki)*** between Indigenous Knowledge Forecasts and Seasonal Climate Forecasts. The Framework was then converted into a Drought Early Warning System prototype made up of three components; (1) Drought Knowledge; (2) Drought Monitoring and Prediction; and (3) Drought Dissemination and Communication. To achieve sustainability, relevance and acceptability, indigenous knowledge was integrated in each of the three components while mobile phones were used as both input and output devices for the system. In order to facilitate collection and conservation of indigenous knowledge on drought monitoring, an elaborate Android-based mobile application was developed while text-to-speech and speech-to-text plug-ins were incorporated to cater for semi-illiterate farmers. Wireless sensor-based weather meters were acquired, calibrated against conventional weather stations and deployed as a compliment to the weather stations. This proved the hypothesis that, when deployed in hundreds, these sensors are capable of extending the weather network coverage to enhance weather forecasting by downscaling the reading of weather parameters to tens of meters.

Weather data is a 'gold mine' for many sectors of an economy and to allow public access to drought monitoring system data, a comprehensive web portal and an SMS-based component were also implemented. In order to collect real data for the indigenous drought forecast aspect, a case study of two communities in Kenya (Mbeere and Abanyole) 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, 90% of respondents gave a score of 'excellent'.

The complexity of the resulting system was enormous and to ensure that the above diverse parts worked together, artificial intelligence technologies were heavily used in developing the system. Artificial Neural Networks were used to develop forecast models whose accuracies ranged between 75 and 98% for lead-times of one day to four years. Fuzzy logic was used to store and manipulate the holistic indigenous knowledge while intelligent agents were used to integrate all the sub-systems into a single unit. After evaluating it using over fourty years of historical weather data from Kenya, Effective Drought Index was adopted for drought monitoring because of its ability to quantify and qualify drought in absolute terms.

List of Acronyms

AI	Artificial Intelligence
ANFIS	Adaptive Neural Network-based Fuzzy Inference System
ANNs	Artificial Neural Networks
AWRI	Available Water Resources Index
BDI	Belief, Desire and Intention
DEWS	Drought Early Warning System
DFAS	Drought Forecast and Alert System
DMSNN	Direct Multi-Step Neural Network
EAC	East African Community
EDI	Effective Drought Index
EW	Early warning
FAO	Food and Agriculture Organisation
FEWS-Net	Famine Early Warning System Network
FMF	Fuzzy Membership Function
GIEWS	Global Information and Early Warning System on Food and Agriculture
GMT	Greenwich Mean Time
GSM	Global System for Mobile
GPRS	General Packet Radio Service
HEWS	Humanitarian Early Warning Service
HPI	Hasso-Plattner Institut
ICAO	International Civil Aviation Organisation
ICT4D	Information Communication Technologies for Development
ICTs	Information Communication Technologies
IDE	Integrated Development Environment
IK	Indigenous Knowledge
IKFs	Indigenous Knowledge Forecasts
IRMA	Intelligent Resource-bound Machine Architecture
ITIKI	Information Technology and Indigenous Knowledge with Intelligence
ITU	International Telecommunication Union
IVR	Interactive Voice Response
JADE	Java Agent Development

KMD	Kenya Meteorological Department
MAM	March-April-May
MAPE	Mean Absolute percentage Error
ME	Mean Error
MobiGrid	Mobile Phone Grid
MobiSoc	Mobile Phone Service Oriented Computing
MODIS	Moderate Resolution Imaging Spectroradiometer
NMSs	National Meteorological Services
OND	October-November-December
PiECEs	Pilot, Exploratory and Confirmatory Experiments
PRS	Procedural Reasoning System
RMSE	Root Mean Square Error
RMSNN	Recursive Multi-Step Neural Network
RPC	Recursive Participatory Experiments
SCFs	Seasonal Climate Forecasts
SMS	Short Message Service
SPATSIM	Spatial and Time Series Information Modelling
SPI	Standard Precipitation Index
SSA	Sub-Saharan Africa
UCT	University of Cape Town
WFP	World Food Programme
WMO	World Meteorological Organisation
WSNs	Wireless Sensor Networks

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