ITIKI:
Bridge between African Indigenous Knowledge and Modern Science on Drought Prediction

By
Euphraith Muthoni Masinde

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Supervised by
Dr Antoine Bagula

and

Prof. Nzioka Muthama
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 forty 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

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
</tr>
<tr>
<td>ANFIS</td>
<td>Adaptive Neural Network-based Fuzzy Inference System</td>
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<tr>
<td>ANNs</td>
<td>Artificial Neural Networks</td>
</tr>
<tr>
<td>AWRI</td>
<td>Available Water Resources Index</td>
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<tr>
<td>BDI</td>
<td>Belief, Desire and Intention</td>
</tr>
<tr>
<td>DEWS</td>
<td>Drought Early Warning System</td>
</tr>
<tr>
<td>DFAS</td>
<td>Drought Forecast and Alert System</td>
</tr>
<tr>
<td>DMSNN</td>
<td>Direct Multi-Step Neural Network</td>
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<tr>
<td>EAC</td>
<td>East African Community</td>
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<tr>
<td>EDI</td>
<td>Effective Drought Index</td>
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<tr>
<td>EW</td>
<td>Early warning</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organisation</td>
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<tr>
<td>FEWS-Net</td>
<td>Famine Early Warning System Network</td>
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<tr>
<td>FMF</td>
<td>Fuzzy Membership Function</td>
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<tr>
<td>GIEWS</td>
<td>Global Information and Early Warning System on Food and Agriculture</td>
</tr>
<tr>
<td>GMT</td>
<td>Greenwich Mean Time</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile</td>
</tr>
<tr>
<td>GPRS</td>
<td>General Packet Radio Service</td>
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<tr>
<td>HEWS</td>
<td>Humanitarian Early Warning Service</td>
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<tr>
<td>HPI</td>
<td>Hasso-Plattner Institut</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
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<tr>
<td>ICT4D</td>
<td>Information Communication Technologies for Development</td>
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<td>ICTs</td>
<td>Information Communication Technologies</td>
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<tr>
<td>IDE</td>
<td>Integrated Development Environment</td>
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<tr>
<td>IK</td>
<td>Indigenous Knowledge</td>
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<tr>
<td>IKFs</td>
<td>Indigenous Knowledge Forecasts</td>
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<tr>
<td>IRMA</td>
<td>Intelligent Resource-bound Machine Architecture</td>
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<tr>
<td>ITIKI</td>
<td>Information Technology and Indigenous Knowledge with Intelligence</td>
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<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
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<tr>
<td>IVR</td>
<td>Interactive Voice Response</td>
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<tr>
<td>JADE</td>
<td>Java Agent Development</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>KMD</td>
<td>Kenya Meteorological Department</td>
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<tr>
<td>MAM</td>
<td>March-April-May</td>
</tr>
<tr>
<td>MAPE</td>
<td>Mean Absolute percentage Error</td>
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<tr>
<td>ME</td>
<td>Mean Error</td>
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<tr>
<td>MobiGrid</td>
<td>Mobile Phone Grid</td>
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<tr>
<td>MobiSoc</td>
<td>Mobile Phone Service Oriented Computing</td>
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<tr>
<td>MODIS</td>
<td>Moderate Resolution Imaging Spectroradiometer</td>
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<tr>
<td>NMSs</td>
<td>National Meteorological Services</td>
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<tr>
<td>OND</td>
<td>October-November-December</td>
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<tr>
<td>PiCEEs</td>
<td>Pilot, Exploratory and Confirmatory Experiments</td>
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<tr>
<td>PRS</td>
<td>Procedural Reasoning System</td>
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<tr>
<td>RMSE</td>
<td>Root Mean Square Error</td>
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<tr>
<td>RMSNN</td>
<td>Recursive Multi-Step Neural Network</td>
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<tr>
<td>RPC</td>
<td>Recursive Participatory Experiments</td>
</tr>
<tr>
<td>SCFs</td>
<td>Seasonal Climate Forecasts</td>
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<tr>
<td>SMS</td>
<td>Short Message Service</td>
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<tr>
<td>SPATSIM</td>
<td>Spatial and Time Series Information Modelling</td>
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<tr>
<td>SPI</td>
<td>Standard Precipitation Index</td>
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<tr>
<td>SSA</td>
<td>Sub-Saharan Africa</td>
</tr>
<tr>
<td>UCT</td>
<td>University of Cape Town</td>
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<tr>
<td>WFP</td>
<td>World Food Programme</td>
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<tr>
<td>WMO</td>
<td>World Meteorological Organisation</td>
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<tr>
<td>WSNs</td>
<td>Wireless Sensor Networks</td>
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