Global Resilience Partnership: Solution Implementation Proposal

Meteorological Early Warning System to Build Resilience to Climate-Induced Shocks

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Photo credit clockwise from top left: Leah Tai (TAHMO), New Vision, Richard Tushimereirwe (ACLE), and Berhane Gebru (CHAI).

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EXECUTIVE SUMMARY

The Problem

Low-income and rural agricultural populations in the Horn of Africa are extremely vulnerable to climate-related hazards that cause loss of life and livelihood. Agricultural workers, which include smallholder farmers, fishermen, and pastoralists, constitute 80% of the labor force in Uganda. Studies show that Ugandan farmers lose USD$750 annually per household from crop failures due to climate related hazards such as drought, pestilence, and flooding (Gebru et al. 2015). Over 70% of households in the Ugandan 'Cattle Corridor' were affected by drought between 2012 and 2014 (Gebru et al. 2015). The 136,000 Ugandan fishermen and over 1 million men and women in the fisheries industry around Lake Victoria are also subject to unique weather-related hazards (Kjaer et al. 2012). The region experiences 285 thunderstorm days per year which cause lightning, high winds, and heavy rains (Mary and Gomes 2014). An estimated 5,000 drownings per year occur on the lake and 136 reported lightning-related injuries and deaths occurred in the basin between 2010 and 2012 (LVBC 2014, Mary and Gomes 2014).

Throughout June and early July of 2015, our team surveyed over 100 fishermen and conducted Q-sort surveying of 120 fishermen and project stakeholders. This work confirmed that vulnerable populations in Uganda lack timely and localized information to take action in response to severe weather and climate-induced impacts. The survey results have guided the formulation of our effective and economic solution.

The Solution

Early Warning Systems (EWS) are a critical tool for saving lives and reducing economic losses from floods, droughts, storms, and other weather-related hazards (Golnaraghi 2009). Five and ten-day forecasts have been shown to increase farmers' resilience and increase incomes in the face of drought conditions (Gebru et al. 2015). The implementation of EWSs generate benefit-to-cost ratios between 4:1 and 36:1 in developing countries, but are often non-functional because of a lack of weather data, partitioned efforts by different agencies, and unsustainable long-term funding (WMO-No. 1153). Our team proposes to address the impacts of weather-related hazards on target populations in Uganda by establishing an early warning system (EWS) that is:

George, a TAHMO technician, installs an experimental weather station at Wanyange Girls School in Jinja, Uganda in July 2015.

- **A complete end-to-end solution**: Weather information will flow from our network of stations all the way down to millions of vulnerable agriculturalists in Uganda.
- **Scalable**: Immediately after the launch, all 16 million+ mobile phone owners in Uganda will have on-demand access to weather information and all 8 million Airtel subscribers will have free access. As importantly, the partnership model we have with Airtel in Uganda is replicable in every other African country.
- **Sustainable**: Our solution will continue to operate, independently of donor funding, for the foreseeable future.
- **Impactful**: The partners in our consortium have a proven track record at delivering services that have measureable financial and social impact.

Currently the Uganda National Meteorological Authority (UNMA) operates 44 active weather stations nationwide, but it recognizes the urgent need for an expanded network to be installed, operated, and regularly maintained by trained personnel (Majugu 2015). Collaborating with the UNMA, our team will:

1. Install a robust automatic observation network

The network will include lightning detection capabilities to produce kilometer-scale predictions using innovative low-cost technologies designed specifically for Africa. We have already successfully installed six experimental stations at schools and local government offices during the GRP solution development stage to demonstrate the feasibility and economy of this technology in Uganda (see map in Appendix 6.7). We propose to install an additional 80 automatic weather stations and establish a remote-sensing network that generates early warning of severe weather across the drought prone Cattle Corridor, the accident prone areas of Lake Victoria, Kyoga, and Wamala, and the flash flood prone Rwenzori highlands.

2. Determine end-user preferences

Through comprehensive outreach and surveying, our team will integrate the preferences and information needs of farmers and fishermen into timely, localized, and actionable weather forecasts and severe weather alerts.

3. Make weather related information available, on-demand for all Ugandan cell phone users

Leveraging high rates of cell phone adoption, messages will be disseminated through the free and proven 321 service, allowing any Ugandan (including low-literacy users) to call at a specific moment of need and hear information to enhance their decision making capacity. Our team has developed prototype messages to demonstrate the functionality of this service to end-users. We encourage GRP reviewers to call +1 202 600 4563 to test the prototype for themselves. We will assess the gender-specific benefits and coverage that Information Communications and Technologies (ICTs) provide in comparison to traditional channels such as radio by developing a comprehensive communication plan.

We propose a cross-subsidization model – we will market weather information services to various industries at commercial rates and use the revenue generated to maintain the network of weather stations and data services required to generate current weather conditions, two-week forecasts, and storm alerts. Airtel will offer the weather related information to their subscribers free of charge and on-demand to promote customer loyalty. We will provide business development training to spur the generation of value-added products for end-users. Cross-subsidizing sustainability partners that have shown interest in weather data include the aviation, insurance, and research industries. This business framework will ensure that long-term resources are available for the continued operation and maintenance of the system, a crucial component lacking in the implementation of many failed EWS (Golnarahgi 2012).

GRP reviewers! Dial:

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to test our prototype 321 weather alert service for Uganda.

By the end of the two year GRP project, we estimate that over 1.75 million Ugandans will access weather forecasts and opt-in to receive emergency weather alerts. Given our sustainability plan, our EWS will continue to deliver weather information to target groups into the foreseeable future, years after the GRP funding comes to an end. Our model is also replicable: TAHMO, Earth Networks and HNI already have similar agreements in place in neighboring countries. We see the GRP as a catalyst for funding that will jump-start our partnership in Uganda and beyond. Thank you for your consideration.

1 BASIC PROJECT DATA

Title: Meteorological Early Warning System to Build Resilience to Climate-Induced Shocks
Region: Horn of Africa
Lead Organization: Trans-African Hydro-Meteorological Observatory (TAHMO)
Target start and end dates: October 2015 – October 2017

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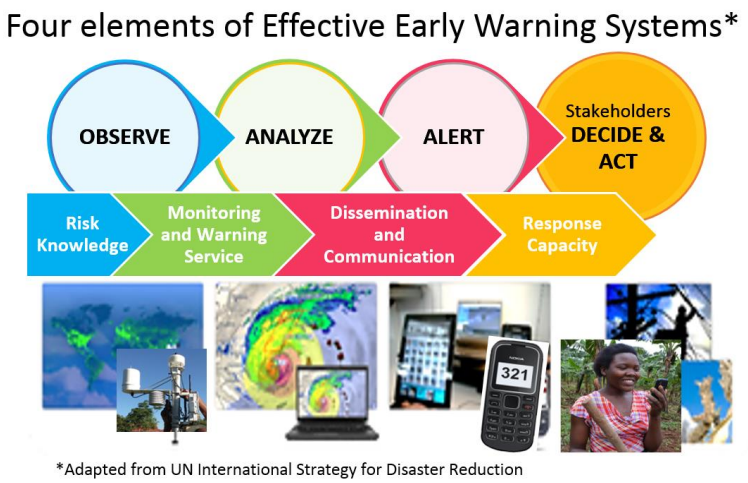
2 INNOVATION AND IMPACT PATHWAY

2.1 SOLUTION STATEMENT AND THEORY OF CHANGE

In Uganda, the lack of informational alerts and education on weather-related hazards for low-income communities is a critical problem. The root cause of this problem is the increased prevalence of severe events such as droughts, floods, thunderstorms, and lightning in Uganda as a result of climate change, exacerbating existing economic, institutional, and social conditions for underprivileged populations (MWE 2015). Low-income communities are highly vulnerable to climate-related hazards because they lack diverse income sources and have low-asset capital to invest in farming implements and boat maintenance (USAID 2013). Government agencies have insufficient capacity, in terms of human resources and infrastructure, to collect, analyze, and deliver actionable weather information to these populations. Cultural belief systems are also an obstacle. Some fishermen attribute lightning to spiritual or superstitious causes, removing them from a role in avoiding the impacts of these events.

Our team aims to address these challenges by creating an Early Warning System (EWS) that can successfully collect and deliver severe weather information to vulnerable populations in Uganda while sensitizing these communities to response strategies they can use to become more resilient. End-to-end EWSs involve a chain of (1) hazard detection, monitoring and forecasting; (2) risk analysis and

emergency planning; (3) dissemination of timely and "authoritative" forecasts and warnings; and (4) community response planning and preparedness (Golnaraghi 2012). Our solution to this problem employs fundamental innovation in monitoring technology (ten-fold improvement in reliability, cost, and price) and a public-private business model that extends to all citizens with income reflecting the value of this information.



Previously, several EWS and large-scale weather network projects have been launched in East Africa and Uganda to address this need, though none have succeeded. For example, Kofi Annan's 'Weather Information For All' (WIFA) Initiative started with tremendous motivation, but unfortunately lost funding after two years. Lessons from the WIFA project indicate that a successful EWS in the Horn of Africa requires the involvement of national hydrological and meteorological services, a business plan for long-term financing, appropriate equipment, and clear processes for data collection, analysis, and transformation into actionable information (Snow 2013). Our project will create systematic change to hazard response by addressing critical gaps in the chain of regional EWSs. We will do this in four steps: 1) provide state-of-the-art technical infrastructure; 2) create new communication channels to increase access to weather forecasts and alerts for the entire Ugandan population; 3) employ innovative sustainable financing solutions and; 4) integrate sensitization and education of end-users into our system design.

Systematic change will result from explicitly engaging end-users in the EWS design and by developing an economically sustainable system through public-private partnerships and market-based revenue generation. Our team has solicited feedback from end-user stakeholders and information intermediaries through workshops and focus groups in Uganda. We will create alert content and weather information based on end-user information demands and disseminate response action advice based on strategies developed in collaboration with target populations, ensuring these populations have a vested interest in the EWS product.

Early coordination with information intermediaries to discuss market-based data uses for our weather observations will identify 'Sustainability Partners' who require weather information. We will create a financially sustainable economic model for the operation and maintenance of the EWS with fees from these partners and social marketing to end-users, based on our team's business experiences in South America (Earth Networks) and Kenya (TAHMO). These innovative components, robust technologies, sustainable financing, and end-user integrated design, will create a long-term sustainable model of resiliency for target populations and serve as a model in the Lake Victoria Basin and surrounding nations.

Our project will create change by working with a diverse group of institutions to merge technological innovation with local contexts and capacities for a highly collaborative EWS. Our team consists of international experts in weather, storm forecasting and observation, and we have already engaged the Uganda National Meteorological Authority (UNMA), local district governments, and other key entities in the formulation of this implementation plan. We will continue to work with these groups and solicit feedback and collaboration so that the ownership of our activities lies with a large and diverse set of stakeholders to ensure project success.

2.2 IMPACT PATHWAY DIAGRAM

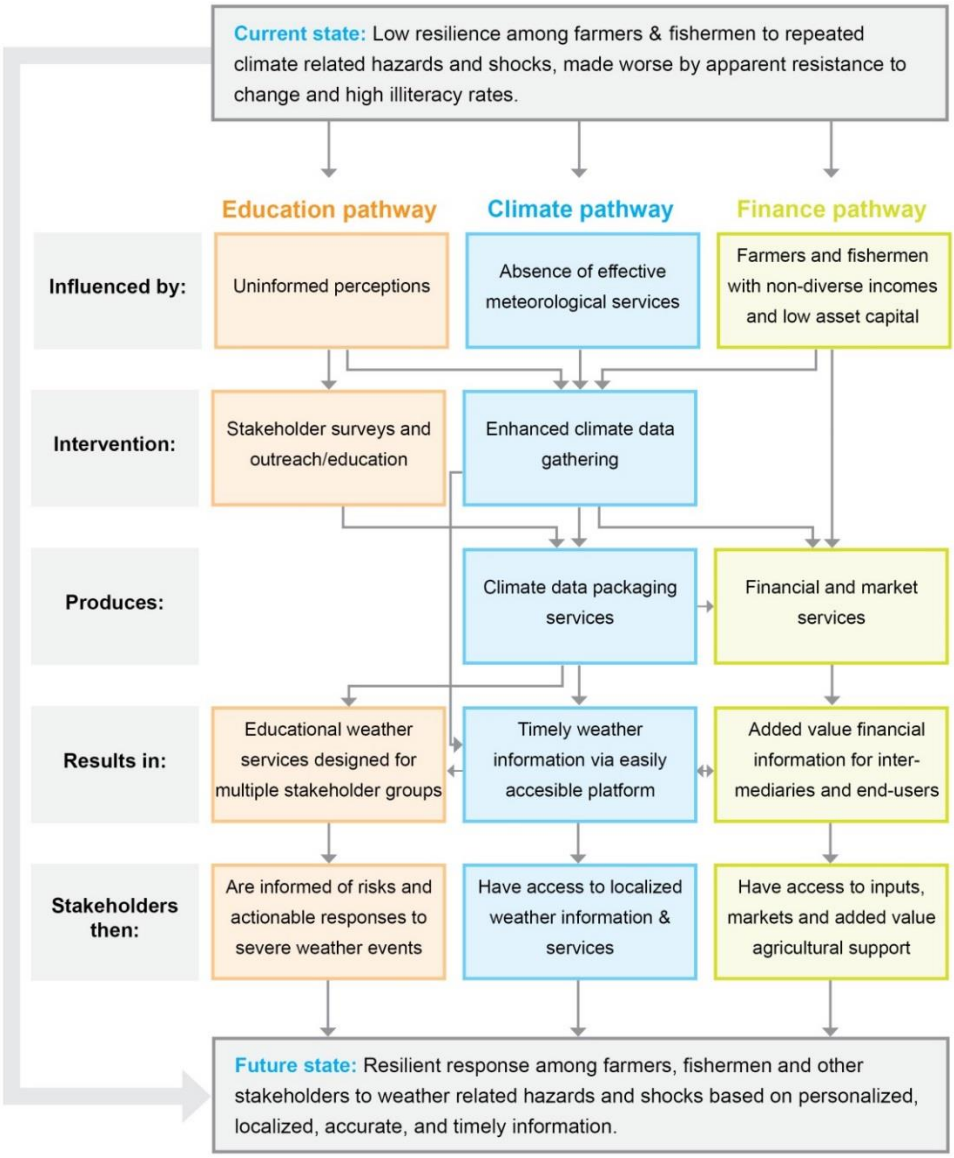
In our project, vulnerable populations will build resilience along three impact pathways:

1. Integrated education: To overcome uninformed perceptions, our team will work with target groups to identify information needs and feasible response strategies for each target group. Understandable and actionable content will be mass communicated and repeated interventions will reinforce learning.

2. Improved Technology: To overcome the absence of effective weather services, our team will work with UNMA to design meteorological monitoring and prediction infrastructure that fills current geographical and infrastructural gaps. We will create actionable information for our target audience to help them mitigate the effects of severe storms, droughts, and other climate-induced shocks.

3. Financial Solutions: To address the financial fragility of farmers and fishermen, our team will enable the development of value-added services such as weather insurance and locally tailored agriculture extension information. Over 300,000 farmers in East Africa are already insured against drought through index insurance products enabled by robust meteorological data in Kenya and Rwanda. Insured farmers are more likely to access credit markets and use high-yield seeds and fertilizer, leading to 16% higher incomes (Greatrex et al. 2015). Smallholders in Uganda will benefit from access to these insurance options and other services while data sales will finance the EWS operations.

Figure 1: Impact Pathway Diagram demonstrating the improved technology, sustainable financing, and integrated education impact pathways.



2.3 INNOVATION AND IMPACT

Innovative Approach: End-to-End Solution

Our innovative approach addresses the entire EWS chain, from hazard detection to end-user response capacity including feedback from the end-user, creating an end-to-end solution. Many times, different agencies and groups are responsible for different steps along the EWS chain and are not incentivized to collaborate and integrate their efforts. Our team brings together stakeholders and partners at every step of the EWS to leverage experience and create excellent value for money.

The solution is *transformational* in that it introduces total IT-based situational awareness of impending hazards and weather conditions across the Lake Victoria Basin, cattle corridor, and Rewenzori highlands.

Real-time tracking and automated timely alerting through mass dissemination methods enable localized decisions and actions by stakeholders and the general public. To bring this information the last mile, we will link to experts in sectors such as public health, agriculture, fisheries, infrastructure, transportation, tourism, and education to provide sector-specific messages that contextualize weather date into actionable information. For example, malaria and cholera prevention can be improved with access to temperature and rain projections for localized areas which help officials prepare for proliferation of disease-carrying insects. Surveys of schools done at the same time as equipment installation will allow donors in the ACLE lightning safety program to sponsor lightning protection systems for schools, often the most substantial building in villages.

Weather and climate change affect everyone. This end-to-end solution will be easily transferrable to communities across Africa. Our project will utilize model outputs in expansion of the EWS network to other countries in the Lake Victoria Basin, including Kenya, Tanzania, and Rwanda, where pilot operations have already been explored by our team.

Innovative Technology: Total Lightning Detection as Proxy for Radar

Even a few minutes of warning give people time to flee from a flash flood or a tornado or to take refuge from lightning (Rogers and Tsirkunov 2013).

Traditionally, it was assumed that remote sensing radar technology was required to provide early warning systems for severe weather. Radar technology, however, is expensive and difficult to maintain, spurring research into more economical environmental and atmospheric sensing capabilities such as lightning detection. Recent advances in technology demonstrate that radar-like capabilities and even earlier warnings can be provided using more cost-effective and low-maintenance total lightning detection technologies.

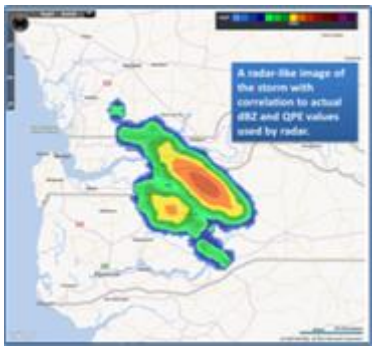
Total lightning detection systems use a passive sensor to remotely detect over long distances the electrical activity taking place in real-time within developing storms. Extensive research within the public, private, and academic meteorological community has demonstrated the correlation of these signals to early storm development and ongoing precipitation rates in convective storms (Venäläinen et al. 2015). Studies have shown an accurate correlation between lightning activity and radar reflectivity.

Availability of in-cloud lightning data, which is required to establish this correlation, creates an alternative radar solution for convective storms in which lightning is present (Garcia et al. 2013). This innovative technology is capable of coverage on local, national, regional, and continental scales and is a key innovation that can be implemented in countries large and small, with limited or fairly developed infrastructure. The following is a set of screenshots from an event that took place Friday, August 9, 2013 4-5pm UTC over The Gambia and Senegal. They show a severe storm that produced heavy rain and high

flash flood potential. Automated alerts were issued for areas expected to be impacted within the next hour, and officials using the system were notified of the hazard as it approached.

Alert Polygon

Proxy Radar



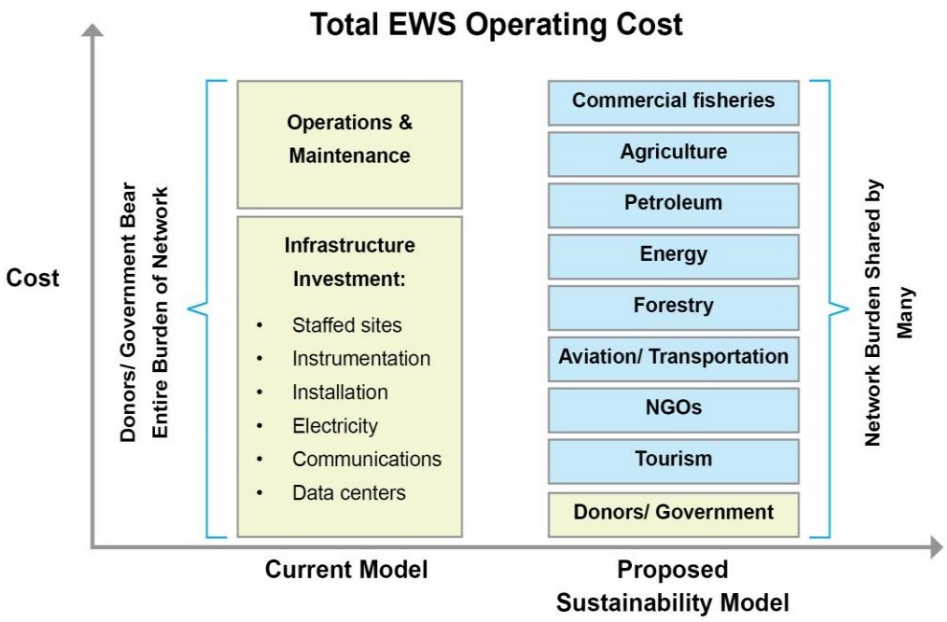
Rainfall Estimate

Innovative Financing: Sustainable Economic Model

The WMO states that a primary barrier to providing an EWS is the lack of long-term financing for system operation and maintenance (Golnaraghi 2012). Our proposed EWS is low-cost, robust, low-maintenance, and provides high-resolution data useful for national and local government audiences, private industry, and (most importantly) vulnerable populations such as farmers and fisherfolk.

Capital costs of the total lightning detection system is 5-10% the cost of radar and our automatic weather stations are less than 1/3 the cost of commonly used instrumentation. Additionally, we will pursue a modular financing mechanism which will involve social marketing strategies and direct data sales to industry partners to sustainably finance the long-term operation and maintenance of our observation network. Traditionally, weather information is a public good; however, various stakeholders are increasingly willing to pay for tailored, reliable, and accurate weather information. We will recruit **sustainability partners** from the private sector for whom our program develops weather services at a fee. The shared cost structure is illustrated below.

We expect to create a financially sustainable model by drawing upon the extensive first-hand experience of our team in developing end-user content using surface weather and climate observation networks for the education, research, energy, agriculture, insurance, and aviation industries. We will engage in the sale and marketing of these content services to private sector users. We have begun to engage in this key exercise by identifying and surveying potential sustainability partners in order to ensure the continued, ongoing maintenance of the EWS over the long term.



2.4 RESEARCH QUESTIONS AND METHODOLOGIES

The key research question and sub-questions addressed by our project are:

Can an end-to-end Early Warning System minimize the impacts of severe weather-induced climate shocks on vulnerable populations while ensuring long-term financial sustainability?

1. How does a hybrid financial model, integrating free EWS services with cross-subsidizing sustainability partners, need to be designed for financial sustainability in Uganda?
2. How does mass dissemination of EWS information via mobile phones and traditional channels compare to influence changes in resilient decision making and planning at the household and community level? What are the important intervening social, economic and environmental factors for an effective EWS?
3. What is the benefit-to-cost ratio of implementing innovative technologies for a multi-hazard end-to-end EWS in Uganda?

Analysis of our hybrid financial model will be done through a business case analysis of 5-year projected financial results from marketing and data sales to sustainability partners. A benefit-cost analysis (BCA) will examine the actual costs of system implementation, including technological infrastructure, human resource development, and message creation and delivery, and the benefits of avoided infrastructure and asset damage and avoided loss of life and livelihood at the household and community level. Detailed cost and revenue tracking will also allow an estimation of the EWS alert cost per user. A sensitivity analysis using the BCA framework will evaluate the importance of different EWS design components, such as communication channels or message frequency, on end-user benefits.

A continuation of the baseline surveying already initiated by our Team will selectively survey end-users in target populations for comparison with post-implementation surveying, assessing:

- Access to EWS information and knowledge of weather-related hazards and impacts;
- Perceived usefulness and monetary valuation of information for coping with hazards;
- Response actions taken by end-users, and;
- Valuation of life and property loss due to weather-related impacts.

Finally, unique users of the 321 service in target areas will be tracked to measure the expansion in weather and alert information dissemination during the two-year implementation phase.

2.5 OUTPUTS

Our team will produce several research outputs, including technical methods for the design of an accurate, low-cost severe weather observation network and a database of observed meteorological and hazard conditions. A broad-based alert dissemination model will be made available to next users, such as national institutions and information intermediaries. A BCA and business framework will also be provided to assist policy and decision-makers in the implementation of similar sustainable EWSs around Lake Victoria and the Horn of Africa. These outputs are detailed in the logical framework on page 9.

2.6 OUTCOMES

Direct beneficiaries of EWS information delivery include target groups such as farmers, fisherfolk, and school children. These end-users will receive messages from our broad-based alert dissemination model about impending severe weather, such as thunderstorms, and accurate 5-day and 10-day weather forecasts. Our outputs will also provide actionable recommendation on how to respond to the alerts so that end-users have increased knowledge of hazards and practice safer activities during storms or make

2.6.1 Logical Framework

Narrative summary	Indicators	Data Sources	Assumptions
Primary Goal: Improved and sustainable resilience to severe weather events by stakeholders, including low-income populations such as fishermen and farmers, and the transport, health, aviation, and education sectors.	**Goal Indicators:** 1. Enhanced capacity of target audiences to monitor extreme weather events and climate change. 2. Decreased stakeholder loss of life and livelihood due to severe weather events.	1. Surveys of government collaborating institutions and targeted populations. 2. Feedback surveys from stakeholders on life and livelihood.	1. External socio-economic factors remain stable. 2. Conducive stakeholder agreements.
Project Purpose: 1. Provide a multi-hazard EWS with timely, relevant hydro-meteorological information to stakeholders in at-risk areas. 2. Provide capacity building to local organizations on climate resilient responses and EWS operation. 3. Provide sustainable financing solution to maintain and scale-up EWS system.	**Purpose Indicators:** 1. Functional EWS delivering information to target end-users. 2. Increased local institutional capacity to maintain and operate the EWS. 3. Framework and agreements in place for sustainable system financing.	1. Grantee's self-reporting of statistics from EWS portal. 2. Surveys of government collaborating institutions and targeted populations. 3. Projected revenue and costs analysis of system.	**Affecting the purpose-to-goal link:** 1. Installation of EWS infrastructure and data analysis is fully funded. 2. EWS is integrated into government and society use. 3. End-user ability to pay for value-added products. 4. Fee-for-service contracts from Sustainability Partners are forthcoming.
OUTPUTS: 1. Database of continuous surface meteorological observations in target areas. 2. Data collection, Quality Assurance / Quality Control, and archiving. 3. Collection of end-user identified needs. 4. Broad-Based Alert Dissemination Model. 5. Stakeholders trained in EWS use and operations. 6. Alert messages describing appropriate response actions for vulnerable groups. 7. Sustainable business model. 8. BCA report/publications.	**Output Indicators:** 1. Proportion of high-quality data reported from observation network. 2. Proportion of decision-makers and the population receiving timely and actionable alerts. 3. Amount of revenue generated through financial sustainability strategy. 4. Increased stakeholder adoption of safer practices in response to severe weather alerts.	1. Grantee's self-reporting from observation network. 2. Statistics from EWS portal. 3. Surveys of government and general public. 4. Periodic knowledge assessments of local organizations and stakeholders. 5. Feedback surveys from stakeholders on life and livelihood.	**Affecting the outputs-to-purpose link:** 1. Availability of secure locations with power and communications for observation network. 2. Adequate in-country telecommunications infrastructure. 3. Availability of trainable staff at community-based institutions. 4. Full reapplication of generated revenues toward program needs. 5. Behavior change of stakeholders in response to improved climate and severe weather information.
INPUTS: 1. Funding approval and project initiation. 2. Support of national government agencies. 3. Sufficient absorptive capacity of the grantee. 4. Partnerships with paying industries. 5. Technical and programmatic subcontractors.	**Output Targets:** 1. Quality observational data reporting per every 900 km2 over target areas. 2. 50% of mobile consumers notified of extreme weather events. 3. Positive feedback 80% of workshops. 4. 100% sustainable financing of operation and maintenance in 2 years. 5. 100% of end-users report resilient response actions from EWS use.	1. Statistics from EWS portal. 2. Surveys of government and general public. 3. Periodic knowledge assessments 4. Financial audits. 5. Follow-up surveys of baseline target groups in high-risk locations and professions.	**Affecting the input-to-output link:** 1. Stakeholders sufficiently informed of program components, value, and expected sustainability. 2. External socio-economic factors remain stable. 3. Adequate communication and cooperation among all parties.

more productive farming and fishing decisions. Urban dwellers and truck or car drivers will also benefit from our EWS by accessing up-to-date local weather conditions, enhancing their knowledge of potential road flooding or landslides in at-risk areas.

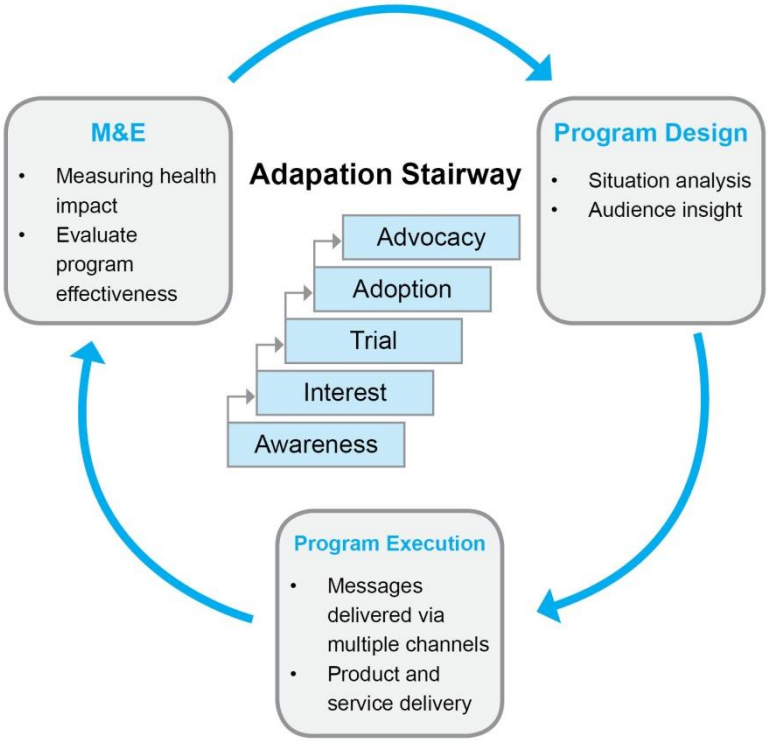
2.6.1 Table of Outcomes for Direct Beneficiaries through EWS alert delivery

Beneficiaries	Output	Outcome	Timeline, assumptions
Fishermen 	Localized alert messages regarding thunderstorm, high wind, and lightning potential and appropriate response measures.	Fishermen have increased knowledge of risks and safety measures to be taken. Fishermen will refrain from frequenting areas with storms when severe weather is imminent. Fishermen will be incentivized to invest in increased boat maintenance (no regret action), with greater understanding of risks.	Implement <1 year Assumes adoption of safe practices when well informed of risks and understand EWS.
Smallholder farmers and commercial farmers 	Improved weather information and 5-day and 10-day forecasts. Localized messages regarding weather forecast and actions to increase crop yield.	Farmers, including woman smallholders, will have increased knowledge of weather conditions and practices to increase their productivity under current conditions (timing of planting, harvesting, processing, etc.). Farmers will adopt more resilient practices attuned to weather conditions.	Implement <1 year Assumes adoption of better practices when well informed of weather and understand EWS.
Schools 	Localized alert messages regarding lightning potential and appropriate response measures. Educational workshops and building surveys during weather station installations.	- Students have increased knowledge of risks related to severe weather. - Students will avoid traveling outdoors in areas of high risk during severe weather events. - School buildings will be assessed for potential lightning arrestor installation.	Implement <1 year Assumes adoption of safer practices when well informed of risks through EWS.
Government Agencies · UNMA, Emergency service providers, Ministry of Health 	Improved, more reliable, and timely weather information and alerts for areas affected by severe weather events. Capacity development activities.	Agencies have more rapid response and support services to areas affected by severe weather events. Agencies are able to provide more reliable, localized, and timely weather and climate information. Agencies have improved institutional capacity.	Implement in year 2

2.7 NEXT USERS AND USE

Vulnerable communities in the Horn of Africa, researchers, policy-makers, educators, and health and environmental specialists are all identified next users of our project outputs. Additionally, collaborative activities with industry, government, and non-profit groups have been explored to identify information needs and uses of these groups to multiply the utility of collected weather data. Project outputs will also serve as financial models and technology implementation guides for policy-makers and agencies throughout the Horn of Africa.

Use by vulnerable populations:



Localized and reliable weather forecasts in Uganda can reduce crop loss and damage by up to 65% (Gebru et al. 2015). Meanwhile, EWS have decreased the loss of life caused by severe weather events globally by a factor of 10 since 1956 (WMO 2012). Our project will build on these successes to increase the resilience of target groups in Uganda by promoting behavior change based on the Trans-theoretical Model.

The Transtheoretical Model of Behavior Change posits that progress toward desirable behaviors occurs in stages: pre-contemplation, contemplation, preparation, action, and maintenance (Prochaska 1997). Many mass media approaches – including text and email messages – are not ideal during the preparation or research stage because people need access to information that is:

1) Retrievable on demand;
2) Detailed, such as hourly lightning alerts for fishermen or 5-day local rain forecasts for farmers;
3) Accessible, using commonly available technology such as mobile phones which are used by 90% of our target audience;
4) Affordable, and;
5) Linked to actionable next steps, such residing in safe spaces during thunderstorms, or planting seeds before multiple days of rainfall.

The 321 service works like a search engine where there is no internet, enabling this preparation and research stage. Users can proactively retrieve information by dialing the toll-free number "3-2-1" anytime, anywhere, and listen to the welcome message:

"*Would you like to know about: Agriculture?* Press 1. *Weather Forecast?* Press 2. *Public Health?* Press 3. *Gender Equality*? Press 4. *Water and Sanitation?* Press 5. *Family Planning?* Press 6."

Callers use their telephone keypad to select from among hundreds of pre-recorded voice and text messages. Messages are founded on formative research, written by national and international experts, approved by the appropriate Government departments and updated according to feedback. Callers choose from three channels to access the information (SMS, voice, and USSD). Illiterate audiences can listen to pre-recorded messages. Literate users can choose text-based channels.

By distributing actionable weather information through the 321 service, we can inform and prepare millions of Ugandans for the severe weather-related impacts they may face. Users will also have the opportunity to opt-in to enroll in value-added products for a small fee. Premiums for these services will ensure greater value and use by subscribers. For example, farmers can receive information such as advice about when to dry, process and store products, comparison of market costs for their goods, and access weather insurance opportunities. Fishermen can check fuel at market prices.

Since 2010, more than 4 million people in Madagascar have used the 321 service to conduct over 50 million information queries. Only four months after its launch in Malawi, 500,000 people have made more than 1.1 million queries. Airtel/Uganda and HNI signed an agreement in June 2015 and plan to

launch the 321 service in Q4 2015. Airtel has 8 million subscribers in Uganda. Airtel will also make the 321 service available at an affordable cost to telephone subscribers from other networks. This means that all 16 million mobile phone owners in Uganda will have access to the 321 service.

Telephone companies are eager to provide the 321 service to their subscribers because users of the 321 service are 16% less likely to switch to another telephone company. We estimate Airtel will donate the equivalent of more than $586,000 in airtime minutes, SMS and USSD sessions during the project period. The 321 service is an effective, sustainable and cost-effective intervention provided at national scale by the telephone company without donor dependency. GRP Reviewers can dial +1-202-600-4563 to experience the demonstration 321 service for themselves.

The 321 service gives 24/7 immediate mobile phone access to a simple, easy to use search engine, where any caller can proactively search for the information they need. Armed with this information, they can act to improve their health, development and economic outcomes.

Use by Sustainability Partners:

The current global weather services market is estimated at USD$1 billion, 10% of which exists in developing and emerging countries. Our team will leverage in-kind support from mobile phone companies to reach a massive scale of information dissemination. We will also use first-hand experience from involvement in successful public-private partnerships to market weather data from the EWS to various sectors in Uganda where it can be utilized for improved services and productivity. A summary of our in-kind donations and revenue prospects is detailed below:

	321 Callers accessing info	Donated Airtime Minutes	Donated SMS	Donated USSD Sessions	Retail value of Airtel's donation in USD	Revenue from Sustainability Partners
Yr 1 (9 mo.)	750,000	1,900,000	1,000,000	500,000	$250,000	$50,000
Yr 2 (12 mo.)	1,000,000	2,500,000	1,400,000	700,000	$336,000	$200,000
Total	**1,750,000**	**4,300,000**	**2,400,000**	**1,200,000**	**$586,000**	**$250,000**

The sector-specific needs of these sustainability partners have been identified in the following table:

Beneficiaries	Sector Needs and Potential Service	Improved Service Outcome	Funding Opportunity for Sustainability
Utilities · UETCL, UEDCL, UMEME · Hydroelectric	Utilities will have weather data delivered in GIS for their operational use.	Utilities will be able to prevent electricity outages due to severe weather, target repair crews, and have information to enhance renewable (hydropower) energy generation opportunities.	Monthly or annual subscription services; user licenses. Estimate of $40,000 per organization per year.
Agriculture · Ministry of Agriculture · Plantations · Commercial farms · Fishing businesses · International Ag NGOs	National scale precipitation estimates; local, specialized weather data and forecasts.	Farmers will enlist in weather insurance programs to protect their investments of time, seeds, and agricultural inputs and receive reimbursement for failed crops. - Farmers will plant appropriate crops for the rainfall and temperature conditions expected. Lightning data will be used for improved safety of farm workers as well as improvements in weather forecast models.	Monthly or annual subscription services; user licenses. Estimate of $100,000 total revenue in fees.
Aviation sector · Civil Aviation Authority · United Nations flight operations · International and domestic airlines	Airports will have access to information about microbursts that lead to turbulence, strong winds and lightning.	Airport personnel will have increased knowledge of real-time severe weather issues. Pilots will be rerouted to avoid areas of high risk during severe weather events or delayed to avoid risk.	Monthly or annual subscription services; user licenses. Estimate of $10,000 - $20,000 per organization per year.

Energy sector · Ministry of Energy & Mineral Development · Mining Companies · Oil projects	Access to cloud-to-ground lightning monitoring, prediction, and alerting.	Energy and mining operations will have severe storm warnings to improve safety at operations. Alerts will improve logistical support for transportation of works to and from oil rigs.	Monthly or annual subscription services; user licenses. $1,500-$2,500 per site per month for lightning data feed alone.

Use by Policy-Makers and Researchers:

The results of our BCA, technical system design, and modular financial sustainability model will be documented and published through traditional academic channels as well as in more popular venues such as policy forums, newsletters, and agricultural, disaster preparedness, and development conferences as well as to the public via newspaper reports, radio and television stories.

2.8 WORKPLAN AND TIMELINE

Our Project will consist of (1) an initial surveying, planning, and coordinating phase with local and national stakeholders, which is well underway, (2) a technology installation and implementation phase, and (3) an outreach, dissemination and feedback phase.

The initial phase consists of surveying for baseline information on the effects and response capacities of low-income end-users to severe weather events and their willingness-to-pay for improved information services. Baseline, Q-sort surveying, and planning and initiation activities have already commenced to bring together partners from key national authorities. Kick-off meetings with government collaborators will allow us to leverage institutional knowledge and ensure the most efficient execution of our solution.

The technology installation and implementation phase includes an observation network designed in collaboration with UNMA to meet the data needs of our target areas, outline procedures to convert raw data measurements into actionable weather alerts, and implement nowcasting and forecasting. The installations will occur in phases to allow accompanying outreach. The data from our environmental sensors will undergo processing, including quality assurance and quality control procedures, and input into a severe weather modelling system to produce weather information.

Outreach and education will involve early sensitization to teach intermediaries and end-users about the functionality of the EWS and solicit input. Education on personal safety from lightning, floods, and other weather hazards will be provided. Quarterly workshops and feedback sessions will help to improve the EWS outputs for optimal end-user decision-making capacity. Information will be made available through the 321 service, as well as through value-added products and educational work with teachers. Our team will help develop value-added products that supply information to users for a fee, and package and distribute weather data to private and public sector intermediaries. Systems costs and revenue from these cross-subsidizing sustainability partners, or data clients, will be monitored and assessed using a BCA and business analysis tool.

We will survey target intermediaries and end-users after two years to compare with baseline conditions and evaluate the project goals. The 321 service will also provide statistics on system use and the number of unique users receiving alerts. An activity workplan and timeline is on the following page and a detailed version is included in the Appendices.

2.8.1 Workplan and Timeline

			Sep' 15	Oct '15	Nov '15	Dec '15	Jan '16	Apr' '16	Jul '16	Oct '16	Jan '17	Apr' '17	Jul '17
1. Mobilisation, planning, and administrative oversight	$60,000	TAHMO											
2. Initial Environment Examination (IEE)	$5,000	ACLE, CHAI											
3. Baseline and needs surveying 3.1 Baseline surveys re: life, livelihood, current response capacity, needs, and EWS knowledge for target populations in selected sample regions with large fishermen and farmer populations. 3.2 School data collection re: fatality and property damage due to severe weather, teacher/student knowledge of severe weather dangers. 3.3 Sector-specific willingness-to-pay assessment for Sustainability Partners. 3.4 End-user needs surveying and EWS design feedback.	$65,000	CHAI, ACLE											
4. Benefit-Cost Analysis and financial tracking system 4.1 Evaluation of benefits and costs of program implementation utilizing project metrics.	$30,000	CHAI		*									
5. Observation network for weather and severe event sensors set-up 5.1 Create installation plan (sensor delivery, siting, coordinate with national partners, local partners for oversight, i.e. schools). 5.2 Phased installations by region.	$200,000	TAHMO											
6. System operation and maintenance 6.1 Write station operation and maintenance plan. 6.2 Execute ongoing network maintenance. 6.3 Training workshops on system O&M with local technicians.	$40,000	TAHMO											
7. Data integration 7.1 Create data integration plan. 7.2 Execute data integration and automatic harvesting.	$120,000	EN, TAHMO, HNI											
8. Weather modeling and severe event forecasting 8.1 Training workshops for national agencies on severe event forecasting. 8.2 Ongoing modeling and data analysis.	$100,000	EN,											
9. Assimilation of weather/alert information by 321 service 9.1 Deliver information to voice recorder for message creation. 9.2 Communication plan for static and dynamic messages linked to weather for the 321 Service. 9.3 Use IVR to create voice messages for 321 call-in service and other preparedness messages. 9.4 Programming to automate 321 Service and weather information for automatically updated text messages. 9.5 Programming to automate 321 Service with extreme weather alerts for users who have 'opted-in' to SMS.	$20,000	HNI											
10. Outreach on 321 and other EWS messages to stakeholders 10.1 Airtel Uganda will promote the 321 Service, ex. bulk SMS announcing the new service and a launch event. 10.2 Communications plan to broadcast alerts via mobile and traditional communication channels.	$50,000	HNI, CHAI											
11. Delivery of weather information to end-users and Sustainability Partners (clients) 11.1 Coordination of Sustainability Partner needs and data delivery methods. 11.2 Cross-promotion of data services on 321 platform.	$65,000	EN, HNI											
12. Sustainable financing model assessment and implementation 12.1 Market weather/alert information to data clients. 12.2 Business model analysis. 12.3 Set-up business contracts.	$60,000	EN, CHAI, ACLE			**	**							
13. Assist in creation of value-added information portals 13.1 Design free and for-pay app for target audiences. 13.2 Design internet based platform for target audiences.	$100,000	EN, CHAI, ACLE											
14. Project monitoring 14.1 Feedback sessions with stakeholder groups on EWS information type, delivery methods, access, use. 14.2 Feedback sessions with government, NGO.	$35,000	CHAI											
15. Evaluation 15.1 Repeat 'baseline surveying' to measure impacts. 15.2 Evaluate observation network function, maintenance and long-term sustainability. 15.3 Evaluate sustainable financing progress.	$50,000	CHAI											

*Indicates BCA research plan development. **Indicates presentations and marketing outreach events to recruit Sustainability Partners.

2.9 MEASURING PROGRESS TOWARDS OUTCOMES

2.9.1 Indicators

The primary project indicators are progress towards (1) a functional EWS delivering useful information to target end-users, (2) increased local institutional capacity to maintain and operate the EWS, and (3) framework and agreements in place for sustainable system financing. Indicators of our project's successful outputs are detailed in the logical framework on page 10, including:

- Proportion of high-quality data reported from observation network. *Target: Observations every 900 km^2 over target areas.*
- Proportion of decision-makers and the population receiving timely and actionable alerts. *Target: 50% of mobile consumers notified.*
- Amount of revenue generated through financial sustainability strategy. *Target: 100% sustainable financing for system operations and maintenance in two years.*
- Increased stakeholder adoption of safer practices in response to severe weather alerts. *Target: 50% of end-users report resilient decisions based on EWS use.*

2.9.2. Baselines

Technology baseline:

The current weather and early warning monitoring networks in Uganda were reviewed by UNMA in 2015 (Majugu 2015). Only 44 of 202 stations nationwide are reporting regularly and the poor distribution of currently operating stations emphasizes the urgent need to update the network. USD$30 million in capital costs alone would be required to upgrade the UNMA system using traditional radar technologies. UNMA cited the urgent need for resources and technical staff to conduct necessary oversight, calibration, and maintenance of existing or proposed stations (Majugu 2015). To overcome these hurdles, our team will collaborate with UNMA to install low-cost weather stations based on their optimum network plan (see Appendix 6.8). Technical hardware and software trainings with UNMA staff will improve their human capacity and support long-term improvements to weather monitoring in Uganda.

Baseline Resilience of Vulnerable Populations:

In 2013, USAID completed a vulnerability assessment to understand the impact of climate change on agricultural populations in Uganda (USAID 2013). It identified factors influencing vulnerability and key adaptation strategies to increase resilience to climate impacts. In 2012-13, surveying of farmer and pastoralist households investigated the use of mobile-based ICTs in overcoming climate-induced water challenges (Gebru et al. 2015). Results from these studies provide baseline information on the state of weather and climate knowledge, weather impacts on livelihoods, financial costs of weather hazards, and recommended adaptation measures which are critical to our implementation development and project monitoring.

In June and July of 2015, we surveyed over 100 fisherfolk and used Q-sort surveying of 120 fishermen and stakeholders. This initial work indicates that mobile phone use is prevalent among fishermen (>90%) and EWS familiarity is strong. During implementation, additional baseline surveying of agricultural communities and schools will be conducted. Findings will guide our implementation processes and procedures. Details from the Ugandan Census, expected to be available in December of 2015, will allow extrapolation of impacts outside our surveyed areas.

2.9.3 Value for Money Plan

Core approaches of our project are innovative because they employ new technologies and partnerships to create great value for money. Our state-of-the-art total lightning detectors and low-cost robust automatic weather stations will create a high-quality meteorological observation network at 10% the cost of radar and traditional sensing equipment (Heitkemper 2012). Automated mass communications via the 321 service will make early warning information accessible to 8 million Airtel mobile users at a fraction of the cost of TV, print, and radio messages. We will focus our publicity and sensitization of the EWS to targeted outreach venues, such as markets and health centers, to actively reach women end-users. Leveraging partnerships and interests within our team and collaborating with Ugandan national agencies will create an effective and efficient EWS. For example, technicians visiting sites to install weather stations will also be trained to give informal lessons to students and community members and complete preliminary assessments to determine lightning arrester placement on school buildings. Our project will ensure the efficiency of our work by conducting comprehensive training for technical staff about the various implementation activities. We will monitor three indicators to ensure the efficiency, equity, economy, and effectiveness of our project:

- **Economic indicator:** The capital and ongoing costs of the technology deployed compared to historic and traditional observation network costs in the region.
- **Equity indicator:** The differential access to EWS information by women and men.
- **Efficiency indicator:** Capacity of technical staff to implement activities and sensitize users on various project components.

2.9.4 Monitoring and Evaluation Plan (M&E)

Throughout the implementation phase, our team will monitor users of the 321 mobile service and other value-added products to quantify the number of direct beneficiaries of our weather information services as well as their usage rate. Callers can also provide immediate feedback ("Was this information helpful? Please press 1 for yes, press 2 for no") and call a toll free line to provide suggestions to a live operator. Quarterly feedback sessions with various stakeholders, end-users, and project collaborators will be conducted to solicit qualitative feedback. In Year Two of our project, our team will survey target communities on the role of weather-related impacts, estimated loss to life and livelihood, and perceptions on the EWS to compare to baseline measurements. This 'endline' surveying will allow us to quantitatively measure the change in resilience of vulnerable populations to weather-induced shocks as well as modify and improve the system.

3 ACHIEVING THE RESILIENCE CHALLENGE

3.1 GENDER AND EQUITY

There is an increasing recognition of the gender disparities associated with climate shocks that leave women more adversely affected and less prepared to respond than men in rural agricultural settings. Floods, drought, and severe storms tend to disproportionately affect women since they are more commonly responsible for farm labor, food security and household management. The majority of farmers in Uganda are women, yet gender disparities limit their access to information on which to base decisions and adjust to climate shocks (CIGAR 2011). This is caused by women's restricted access to technology and communication channels, lower education levels, and culturally defined roles in household chores such as raising children and cooking. In Africa, women are 23% less likely to own a mobile phone than

are men (GSMA 2013). Financial barriers such as the inability to pay fees or even to own a mobile phone or radio can leave them uninformed of weather-related impacts.

Agriculture is the main occupation of women in Uganda; 72% of all employed women and 90% of rural women work in agriculture, compared to 53% of rural men (Elson and Evers 1996). Recent estimates show women contribute a 56% share of crop labor (O'Sullivan 2014). Additionally, fisherfolk on Lake Victoria are predominantly male and women in fishing communities are poorly represented in community organizations that provide information and support, such as Beach Management Units (Lwenya et al. 2009). Nevertheless, many women and children live in the Lake Victoria basin where they are subject to severe weather hazards and simultaneously are dependent on the fishing industry for economic solvency. By educating men and women about safety, lightning, and other hazards, women who may be dependent on the income-generating activities of their male partners, are benefited by mitigation of their partner's risks of injury or death.

Improving the resiliency of women will only be achieved if critical information reaches both men and women when it is needed. Lacking the ability to close the socio-economic gap between men and women, we must find creative ways to ensure early warnings reach women. Instead of relying on traditional communication channels alone, our project will conduct dissemination through known effective channels of communication, such as radio, while also employing the new 321 service. This service allows Ugandan women to call-in and 'pull' information when they need it, instead of simply broadcasting the information once-a-day on radios and TVs that may be inaccessible or inapplicable to their area. Additionally, targeted education and sensitization activities, such as the use of colored alert flags at markets and beaches, will specifically focus on educating women on actionable responses to help them improve their livelihoods and that of their children.

3.2 RESILIENCE

Resilience is characterized by four phases: preparedness, mitigation, response, and recovery (Carlson et al. 2012). Each phase represents a period of time in relation to an event that triggers loss of life or decreased well-being. Preparedness represents the earliest period of time, during which measures are taken before an event to understand and define risks that may impact life or livelihood. Mitigation also occurs preceding an event in order to decrease the severity of the consequences of the event. Following the event, response (immediate action taken to address the hazard and its impacts) and recovery (long-term efforts to restore equilibrium) occur. Both preparedness and mitigation are impacted by EWSs and response is a result of education and choices.

In the absence of being able to prevent climate-induced shocks such as severe storms and floods, the best strategy is to educate vulnerable groups on proactive, rather than reactive, behavior. Preparing for weather impacts will mitigate the most severe consequences such as death and loss of assets. When fisherfolk are alerted to an oncoming storm, they can respond by choosing not to go out that day and fixing their nets or other income-producing tasks. When a farmer is alerted to an oncoming flood, she can take measures to move her family and valuable property (such as livestock) to safer areas. When an insurance agency is alerted to a critical period of drought, they can pay out to farmers, who can buy food and supplies to withstand hard times while diversifying agricultural practices for the future. Our project will specifically research the benefits of using ICTs in disseminating information that equips end-users with the knowledge to prepare, mitigate, and respond to severe weather-related hazards.

In addition to the primary need for rapid, short-term information to protect lives and prevent death of fisherfolk on Lake Victoria, the same robust climate observation system can also provide benefits to farmers with medium-term weather forecasts. Of over 600 households surveyed throughout the cattle corridor of Uganda, 87% had experienced a climate crisis in the past 12 months. However, only 17% of

these said they had ever received any assistance to overcome these crises. Gebru et al. has shown that providing locally relevant weather forecasts and adaptation information can reduce crop loss and damage by 40% to 65%. For example: 10-day forecasts provided to smallholders to guide schedules for planting, harvesting, and storage of crops which helps maximize yields and incomes. Additionally, historical and seasonal data can be used to compute insurance actuarial statistics and enable the provision of drought and storm insurance to smallholders, promoting a healthy recovery to one of the most debilitating impacts faced by smallholders in the region. These services, currently absent across Uganda, are essential to a resilient community. This is not because people are unaware of these needs, but because a sustainable model for implementation and delivery has not been put forward. Past attempts to address these threats were often failed one-time donor-funded pilots that did not seek to be self-sustaining (e.g. Snow 2013).

3.3 SUSTAINABILITY

In June and July 2015 our team conducted a series of workshops with key national government agencies and stakeholders to engage them in the EWS design and implementation plan, including:

- Uganda National Meteorological Authority
- Ministry of Water and Environment
- Office of the Prime Minister, Department of Relief, Disaster Preparedness and Management
- Ministry of Health
- State House Uganda
- Climate Action Network Uganda (NGO)
- UBC Radio/TV
- Makerere University
- District Environmental Officers

Our team intends to call upon these collaborators and local district gatekeepers regularly to aid in the dissemination of EWS services and provide qualitative on-the-ground feedback for its improvement.

At the community level, sustainability will be achieved by integrating our project activities within schools and community groups. During initial surveying and outreach sessions, end-users were asked to identify their preferences for an EWS. Users demonstrated that the most important EWS components were, in order of most to least important: simple color coding, no false alarms, hourly updates, high spatial accuracy, and no costs. Our EWS design will cater to these preferences. Repeated interventions in stakeholder communities will engage end-users to provide feedback and improve prototype EWS services. Additionally, working with end-users to determine resilient strategies that are within the capacity of low-income groups will ensure that their safety is improved, but not at the cost of negatively impacting their income-generating activities.

Automatic weather stations will be installed at sites located in collaboration with UNMA, with preference primarily to schools and health centers. Community groups will assign a local caretaker. Technical field staff will also conduct short hands-on teaching sessions to local community members and schoolchildren during technology deployment. These activities will promote project ownership by our target audience.

4 RISK MANAGEMENT

4.1 SOCIAL AND ENVIRONMENTAL IMPACT ASSESSMENT

The only physical intervention planned in our project is the installation of weather and lightning detection stations in the country of Uganda. At scale, hundreds of weather stations would be needed for effective

climate monitoring. Each would be installed at a secure site (such as a school, commercial farm, or government building). Each station requires an installation pole to attach the sensors that is either mounted in the ground with concrete or attached to an existing building. Installation sites would be selected based on individual characteristics of the site (e.g. security and suitability) as well as strategic factors (e.g. distance to the next weather station in the network and desirability of data from the site). For ground-mounted stations, primary security of the stations will be provided by the host of the weather station (i.e. the school or farm where it is installed). Secondary security enclosures will also be constructed to protect the stations. These enclosures will consist of a barbed wire fence and gate to prevent tampering or theft of the sensors. Therefore, given the nature of our proposed intervention we do not expect any significant risk of negative environmental or social impacts. We plan to apply for Categorical Exclusion, per 22 CFR 216, during stage three implementation.

4.2 RISK MATRIX

Risk	Impact	Probability	Mitigation and management
Programmatic: Dysfunctional administration of funds and group governance due to high number of partners	High	Medium	Clear assignment of roles among partners, strong leadership from TAHMO. Rigorous system for tracking responsibilities and outputs for each partner.
Political: Change of institutional priorities and leadership within Uganda	Medium	Low	Uganda will have elections in 2016. It is not possible for us to mitigate this risk aside from making all arrangements as clear on paper as possible, rather than “handshake” agreements.
Political: Failure to reach agreements with political stakeholders, i.e. national meteorological service	High	Low	Continue negotiations with UNMA and other key stakeholders to ensure agreements are reached before implementation. Engage supportively through active programmatic collaboration and public-private partnership.
Reputational: Poor reception of project by the public	High	Low	Ongoing survey efforts to ensure continuous interface with end-users to determine preferences. Phased rollout of alert products that incorporates feedback from end-users. Workshops with district officials to garner input and support.
Financial: Failure of station equipment leading to missing data and higher operational costs than expected	High	Medium	Selecting secure installation sites and having a local technician in the field ready to promptly replace or repair stations. Installations completed in phases to allow for improvement in installation methods.
Financial: Inability to identify sufficient Sustainability Partners for revenue generation for long-term system sustainability	High	Medium	Aggressive outreach and marketing to potential financial partners in a wide range of sectors, including data clients and end-users. Demand has been demonstrated in other regions and potential partners have already been identified to begin building this business model.
Political: Competitive relationships with at-risk private sector industries	Medium	Medium	Intensive outreach and communication with potential at-risk groups to define shared opportunities.
Social: Maladaptation risks such as when end-user expectations are not met and future adaptation incentives are impacted or when external dependencies develop	High	Medium	Maladaptation risk assessment will be conducted at project onset. No regret actions will be emphasized for end-users. Monitoring of end-user investments in project and rigorous dissemination of locally appropriate adaption strategies for long-term beneficial outcomes.

6 APPENDICES

6.1 TEAM COMPOSITION / LIST OF FULL TEAM

Primary lead

Trans-African Hydro-Meteorological Observatory (TAHMO), www.TAHMO.org
Contact: Nick van de Giesen, TAHMO Co-Director
Stevinweg 1, 2628 CN, Delft, The Netherlands
n.c.vandegiesen@tudelft.nl +31 6 28713477
John Selker, TAHMO Co-Director
210 Gilmore Hall, Corvallis, OR 97331
j.selker@TAHMO.org +1 541 737 6304

Alternative lead

Earth Networks, www.EarthNetworks.com
Contact: Christopher Sloop, CTO
12410 Milestone Center Dr, Suite 300 Germantown, MD 20876, USA
csloop@earthnetworks.com +1 800 544 4429
Stan Heckman, Senior Lightning Scientist

Team members

***Please note, the Uganda Chartered Healthnet (UCH) listed as an original team member has changed its name to Climate Change Adaptation Innovation (CHAI), as reflected in their attached Letter of Commitment.*

African Centres for Lightning and Electromagnetics (ACLE) www.ACLENet.org
Contact: Richard Tushemereirwe, Relationships Manager
Makerere University Business School, Kampala, Uganda
acle@mubs.ac.ug, +256 414 338120

Climate Change Adaptation Innovation (CHAI)**, www.CHAI.ug
Contact: Kibaya Patrick, Chief Executive Officer
Ivory Building, Makerere University College of Natural Resources
P.O. Box 3267, Kampala, Uganda
pkibaya@gmail.com, +256 752 222 821

Human Network International (HNI), www.HNI.org
Contact: David McAfee, CEO
1120 19th Street N.W. Suite 480, Washington, DC 20036
dmcafee@hni.org +261 32 07 452 70

6.2 SUMMARY OF TEAM'S STRENGTHS AND RELEVANT EXPERIENCE

Our team is made up of a consortium of organizations with complementary sets of experience and knowledge. **TAHMO**'s mission is to get reliable, high quality surface observations out of the most challenging places by using uniquely adapted weather station technologies - now deployed in ten African Countries.

Earth Networks, operating over 10,000 active weather stations worldwide, has pioneered and proven operability and application of total lightning detection based on compact sensors and cloud computing as a cost-effective, scalable alternative to weather radar systems that produces advanced early warning and precision forecasts of the most common and damaging weather extremes.

HNI has developed a proven mobile phone platform, known as 321, which can instantly deliver messages to millions of Ugandan phones. They have reached an agreement with Airtel to bring the 321 service to Uganda, free of charge to end-users (see Appendix).

ACLE's mission is to bring early detection of and protection from lightning hazards to all corners of Uganda and Africa. Not only does lightning cause property damage, it can also cause death and disability. Although deaths are tragic and to be avoided, studies show that as many as 90% of those injured by lightning survive but may have lifelong disability from brain injury and chronic pain from nervous system injury which can have profound effects on the survivor's family (Cherington et al. 1999, Cooper 2001). Lightning can be used as a leading indicator of severe weather activity and a proxy for heavy rains, high winds, hail, and ground lightning strikes.

CHAI addresses the last mile problem: if technology delivers the necessary information to communities in danger of impending climate hazards, it doesn't mean appropriate decisions will be made and actions taken – education and behavior change only come with repeated intensive interventions. CHAI has built a wealth of experience and achieved impressive results in providing life-saving information to Ugandan communities. Recently, CHAI conducted a project aimed at enhancing the adaptive capacity of communities to climate induced water challenges in the four districts of Nakasongola, Soroti, Sembabule and Rakai using ICTs. The project was co-implemented by Uganda Chartered Healthnet (UCH), the grant recipient, and FHI 360, with partners from Makerere University and Ministry of Water and Environment. Funding is from the International Development Research Centre of Canada (IDRC), worth USD$590,000 over two years.

TEAM - Leveraging this unique partnership, we will create a sustainable climate observation network by delivering reliable products across large geographic areas. In Africa, this requires a trans-national approach since weather does not respect national boundaries. Furthermore, no one industry (e.g., agriculture) can support the needed dense station network, so the data must be packaged and marketed to multiple sectors. Earlier, these organizations worked together in the installation of stations in the five countries near Lake Victoria (Rwanda, Burundi, Tanzania, Kenya, and Uganda). We have built out organizations on precisely the business premise of delivering weather-related information to end-users in different sectors. As such, we are positioned ideally to address this critical need in a sustainable manner. Our organizations are dedicated to the free dissemination of basic climate observations, while marketing valuable derived products (e.g., forecasts, cell-phone alerts, drought maps, weather alerts) to support the enterprise. The combination of a cutting-edge business model with decades of success in many other counties is a game-changing advantage for our team of local and international partners.

6.3 LETTERS OF SUPPORT, COMMITMENT OF TEAM MEMBERS, AND CVS

6.3.1 Letter of Support – Airtel

Airtel Uganda Ltd,
Airtel House,
Plot 40 Jinja Road,
P. O. Box 6771

Kampala. Uganda.
Tel: +256 752 230 110
Fax: +256 752 234 933
www.airtel.com

Thursday, April 09, 2015

Mr. David McAfee
President and CEO
Human Network International
1120 19th Street, NW, Suite 480
Washington, DC 20036
United States of America

Dear Sir,

RE: 321 SERVICE IN UGANDA

We would like to thank you for sharing the details of the "321" information service that your organization launched in collaboration with Airtel Madagascar and Airtel Malawi.

We are committed to replicating this successful initiative here in Uganda. We agree with the basic outline of the arrangement you have with Airtel in Madagascar and Malawi where your organization provides development content of interest to Airtel subscribers free of charge.

In return, Airtel Madagascar and Malawi makes the content available to their clients free of charge as outlined in the contract between Human Network International and Airtel Madagascar and Malawi.

Please let us know how we can partner with Human Network International to launch a similar "321" service here in Uganda.

Yours Sincerely,

Tom Gutjahr
MANAGING DIRECTOR

6.3.2 Letter of Introduction for Experimental Installations – UNMA

Head Office:
Plot 67 - 75
Clement Hill Road
KAMPALA
E-mail: ed.unma.go.ug

Tel: +256 414 251798
Fax: +256 414 251797
P.O. Box 7025
KAMPALA
Website: www.unma.go.ug

UGANDA NATIONAL METEOROLOGICAL AUTHORITY

Ref:

July 3, 2015

To: .....

.....

.....

.....

Re: Installation of experimental automatic weather stations for Meteorological Early Warning Systems to Build Resilience to Acute Climate-Induced Shocks

The Global Resilience Partnership (GRP) will be installing six experimental automatic weather stations in different parts of the country under the above project. The stations are solar powered and will therefore not need an external power source.

Your school / organization is one of those that have been selected to be visited and talked to by the project team about the installation and running of the stations. It will also be important if you indicate to the team the main issues concerning weather and climate of your interest for discussion.

Please confirm acceptance to the visit and indicate the willingness of your institution to run the station. Your positive response will be highly appreciated.

I assure you of our continued cooperation

Magezi-Akiiki
For: Ag. EXECUTIVE DIRECTOR - UNMA

6.3.3 Letter of Invitation for Stakeholder Collaboration – UNMA

Head Office:
Plot 67 – 75
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KAMPALA
E-mail: ed.unma.go.ug

Tel: +256 414 251798
Fax: +256 414 251797
P.O. Box 7025
KAMPALA
Website: www.unma.go.ug

UGANDA NATIONAL METEOROLOGICAL AUTHORITY

Ref:

July 1, 2015

To: .....

.....

.....

RE: STAKEHOLDERS MEETING.

The Uganda National Meteorology Authority (UNMA) together with the Climate Change Adaption Innovation (CHAI) invites you to a half-day stakeholders' meeting which will take place on Friday, 03rd July, 2015 at Kolping Hotel.

The Global Resilience Partnership (GRP) is funded by the Rockefeller foundation, USAID and SIDA. The GRP aims to build resilience to acute shocks and chronic stress in the Sahel, Horn of Africa, South and South East Asia. The GRP is a three stage competitive grant process which invited applications from teams of experts with ideas for combating acute shocks and chronic stresses in the priority regions.

A team of five organizations, led by the Trans-African Hydro-Meteorological Observatory (TAHMO), with the African Centres for Lightning and Electromagnetics (ACLE-Uganda), Climate Change Adaptation Innovation (CHAI), Earth Networks (EN-USA) and Human Networks International (HNI) submitted a proposal for an Early Warning System (EWS) development and validation project in Uganda.

The team was one of seventeen successful teams worldwide to proceed to the next two rounds. The second round was to articulate a problem statement, which was submitted on May the 15th 2015. The current round is to submit a solution statement by July 15th 2015.

The purpose of the meeting is to inform you of this proposal which is being developed by a team of the five organizations for the Global Resilience Partnership, get your views on the proposal and identify your potential collaboration in the project. Please find attached the workshop Agenda.

We look forward to your participation in this very important event as we work towards improving weather monitoring, forecasting and Early warning systems in Uganda. As a conference participant, you will be provided with a transport refund.

Yours sincerely

Paul Isabirye
Ag. EXECUTIVE DIRECTOR – UNMA

6.3.4 Letter of Commitment – ACLE

ACLENet
Lightning and Electromagnetics Network

November 29, 2014

Dear Dr. Nick van de Giesen,

Re: Letter of Commitment

African Centers for Lightning and Electromagnetics (ACLE) is a Pan African network of centers dedicated to reducing deaths, injuries and property damage from lightning. It is headquartered at Makerere University Business School in Kampala, Uganda. On behalf of ACLE, I express our commitment to support Trans-African Hydro-Meteorological Observatory's 'Global Resilience Challenge for Building Resilience to Acute Shocks and Chronic Stresses in the Horn of Africa' grant proposal, entitled 'Meteorological Early Warning Systems to Build Resilience to Acute Climate-Induced Shocks'.

We understand the partnership is designed to address the dire need for individuals, communities and nations in the broader Horn of Africa region to adapt to climate change related disasters. Lightning is the leading indicator of severe weather activity and a prime proxy for monitoring and alerting for convective weather and its effects i.e. heavy rains, high winds, hail, ground lightning strikes, etc. ACLE has in its fold world leading experts in Lightning and Electromagnetics from USA, India, and Malaysia.

ACLE shall make a contribution to the team by:

1. Serving as the central repository of lightning injury/damage data, coordinating with national institutions and sharing the data with partners in safety and rescue missions on an ongoing basis.
2. On-site investigation of many of the incidents and recommendation of appropriate technologies.
3. Building capacity of the region in applied lightning science and electromagnetics through training, research and education.
4. Raising community leadership through design of injury prevention messages for public education, training programs in public areas and Lightning Protection Systems.

ACLE promises to be an active member of the team to achieve the objectives of the grant. Prof. Udaya Kumar, our leading research advisor shall lead ACLE member's input to the overall team.

Best Regards,

Tushemereirwe R.

Richard Tushemereirwe
Relationships Manager

6.3.5 Letter of Commitment – CHAI

Climate Change Adaptation Innovation – CHAI

Makerere University College of Natural Sciences

Re: Letter of Commitment

Dear Dr.Nick van de Giesen,

On behalf of Climate Change Adaptation Innovation (CHAI), a new entity evolving from the Uganda Chartered Healthnet created to concentrate on Climate Change issues, wish to express our commitment to support Trans-Africa Hydro-Meteorological Observatory's "Global Resilience Challenge to Acute Shocks and Chronic Stresses in the horn of Africa" grant proposal, entitled "Meteorological Early Warning Systems to Build Resilience to Acute Climate-Induced Shocks". We are based at the Makerere University College of Natural Sciences.

We understand the project is designed to address the dire need for real-time severe weather information in Uganda as well as the broader Horn of Africa region by adapting innovative technologies that are saving lives and property in the United States and other developed countries. We are uniquely positioned to contribute to this project, with local and regional experience in disseminating weather information to communities in ways and languages they best understand. Our team of investigators boasts successful researchers and developers of real-world solutions, such as Prof John B Kaddu, the lead Uganda Adaptation Negotiator at the United Nations Framework Convention on Climate Change (UNFCCC), a renowned researcher and author, with a lot of interest in climate change issues. CHAI is prepared to contribute in the following ways as a Team Member;

- Provide digital data collection and transmission capability
- Provide academic, research and Uganda Government networks to the team
- Provide mobile/electronic dissemination channels for the generated weather information
- Localize early warning end user content

Please be assured that CHAI will be a proactive Team Member and will substantially contribute to the accomplishment of the objectives of the grant. I am highly supportive of your efforts as outlined in this proposal, and if there is anything more we can do to contribute to this effort, please let me know.

Best regards,

Kibaya Patrick

Chief Executive Officer

6.3.6 Letter of Commitment – EN

Earth Networks℠
Taking the Pulse of the Planet™

12410 Milestone Center Drive, Suite 300
Germantown, Maryland 20876 USA

+1-301.258.8390 • 800.544.4429
www.earthnetworks.com

November 24, 2014

Re: Letter of Commitment

Dear Dr. Nick van de Giesen,

On behalf of Earth Networks, a global company headquartered in Germantown, MD, USA, I wish to express our fullest commitment to support Trans-African Hydro-Meteorological Observatory's "Global Resilience Challenge for Building Resilience to Acute Shocks and Chronic Stresses in the Horn of Africa" grant proposal, entitled "Meteorological Early Warning Systems to Build Resilience to Acute Climate-Induced Shocks".

We understand the project is designed to address the dire need for real-time severe weather information in Uganda as well as the broader Horn of Africa region by adapting innovative technologies that are saving lives and property in the United States and other developed countries. We are uniquely positioned among technology providers contribute to this project, with our global as well as region-specific expertise of deploying early warning technology. Our team of investigators boasts successful researchers and developers of real-world applications, including one with a role as Principal Investigator for a project with National Institute of Standards and Technology.

Below I list several ways in which Earth Networks is prepared to contribute as a Team Member:

- A research license to use the real-time data from our Lake Victoria Pilot Project observations
- Deployment of additional surface observing sensor networks in the region to enable the research
- Scientific support and consulting in the area of using total lightning as an alternative to costly weather radar
- Support in the development of data quality control algorithms for in-situ weather observations
- Weather data ingest, storage, and use in nowcasting and forecasting for highly localized areas
- Technical briefings and assistance on the creation and testing of early warning end-user content
- Onsite training provided to project stakeholders including researchers and government agencies
- Administrative staff available to provide support to the researchers conducting the work

Please be assured that Earth Networks will be a proactive Team Member and will substantively help to accomplish the objectives of this grant. I am highly supportive of your efforts as outlined in this proposal, and if there is anything more I can do to assist this effort, please let me know.

Best regards,

Christopher D. Sloop
Chief Technology Officer

6.3.7 Letter of Commitment – TAHMO

Date 28 November 2014

E-mail info@tahmo.org

Subject Letter of Commitment

TAHMO

Trans-African Hydro-Meteorological Observatory

TO WHOM IT MAY CONCERN

On behalf of Stichting TAHMO, I declare that, as Team Lead, we are committed to the proposed project in the framework of the Global Resilience Partnership. In addition to the tasks as Team Lead, which are described in the call, we will contribute by:

- Building a network of ground stations, measuring standard hydro-meteorological variables as well as specialized sensors for tracking heavy weather (in cooperation with Team Member Earth Networks) in Uganada
- Operate and maintain this Ugandan network
- Make available our data QA/QC system and data storage and distribution system
- Make international and regional staff available to make this project a success

In accordance with the regulations guiding the call, we will administer the project, disburse funds to other team members, and be an active member of the Global Resilience partnership.

Sincerely,

Nick van de Giesen

Co-Founder and Board Member Stichting TAHMO

6.3.8 Letter of Commitment – HNI

DataWinners powered by Human Network INTERNATIONAL

November 27, 2014

Re: Letter of Commitment

Dear Dr. Nick van de Giesen,

Human Network International, a non-profit 501c3 organization registered in the District of Columbia, is pleased to support The Trans-African Hydro-Meteorological Observatory's "Global Resilience Challenge for Building Resilience to Acute Shocks and Chronic Stresses in the Horn of Africa" grant proposal, entitled "Meteorological Early Warning Systems to Build Resilience to Acute Climate-Induced Shocks".

There is a dire need for severe weather information in Uganda as well as the broader Horn of Africa. Citizens need improved access to early warning alerts, forecasts and current conditions. Our organization is uniquely placed to help your consortium to deliver this information that "last mile". HNI's mission is to strengthen the capacity of organizations to use technology in innovative, productive and sustainable ways. In collaboration with telecommunications companies in Madagascar and Malawi, we have developed the **3-2-1 Information Service** - A free, on-demand Information Service, accessible on simple mobile phones. In 2010 Human Network International, Airtel and the Government of Madagascar launched a new way for isolated people to access "life services" information on their own simple mobile phones. Airtel subscribers call a toll-free number (3-2-1) to access important information across a broad range of development topics. In the past 5 years, 4 million people have made 50 million information requests on-demand and free of charge. In 2014, HNI won several awards for the 3-2-1 Service including grants from the GSMA's mWomen Project and Grand Challenge Canada. Airtel and HNI recently expanded the 3-2-1 Service to Malawi. We are currently in advanced negotiations to bring the Service to Uganda.

We at HNI look forward to collaborating with The Trans-African Hydro-Meteorological Observatory-led consortium on this important project.

Sincerely,

David McAfee

David G. McAfee
President and CEO
Human Network International

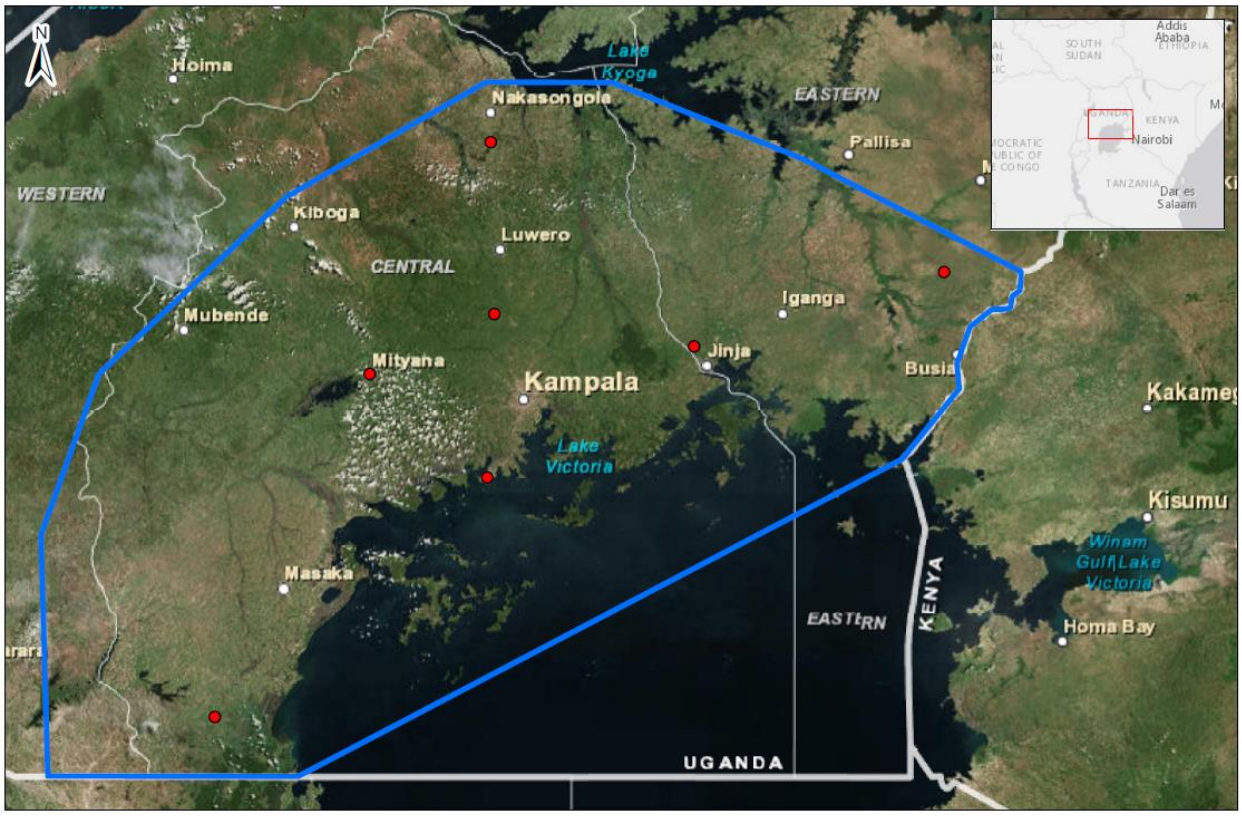
6.6 ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

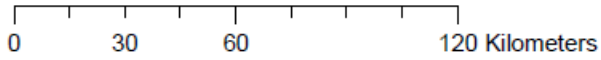
ACLE	African Centers for Lightning and Electromagnetics
BCA	Benefit-Cost Analysis
CHAI	Climate Change Adaptation Innovation
EN	Earth Networks
EWS	Early Warning System
HNI	Human Network International
ICT	Information Communications and Technology
GRP	Global Resilience Partnership
TAHMO	Trans-African Hydro-Meteorological Observatory
UNMA	Uganda National Meteorological Authority
WIFA	Weather Information For All Initiative

Horn of Africa - Easternmost extension of African and defined in this proposal to include Uganda, as well as countries of Djibouti, Eritrea, Ethiopia, and Somalia. Neighboring East African countries in the Lake Victoria Basin include Tanzania, Kenya, Rwanda, and Burundi.

Sustainability Partners – Clients for whom the project charges a fee for weather information to finance the operation and maintenance of the system.

6.7 PILOT INSTALLATIONS AND SOLUTION IMPLEMENTATION MAP





6.8 UNMA CURRENT AND PROPOSED OBSERVATION NETWORK

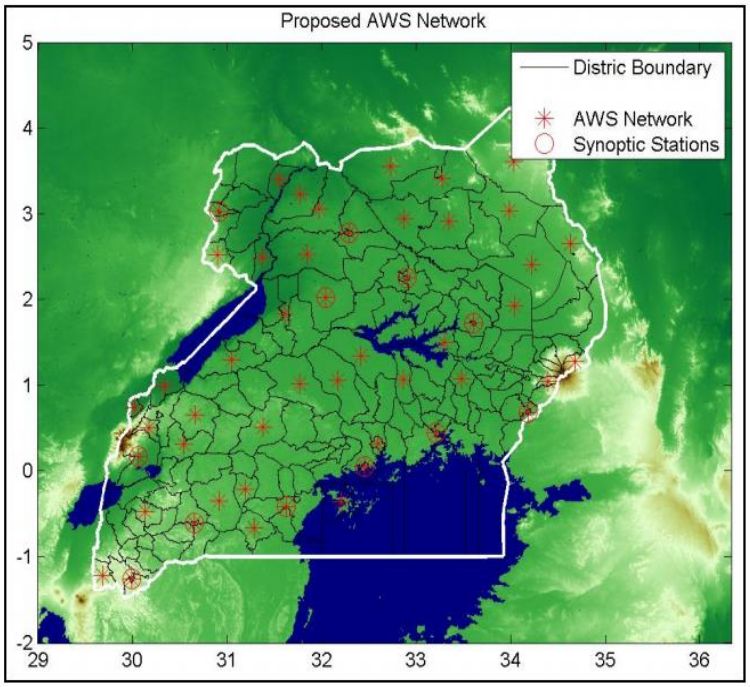


Figure. 19 Proposed AWS network (according to Heitkemper et al 2013). Locations for AWSs for synoptic purposes are identified with an asterisk in a circle)

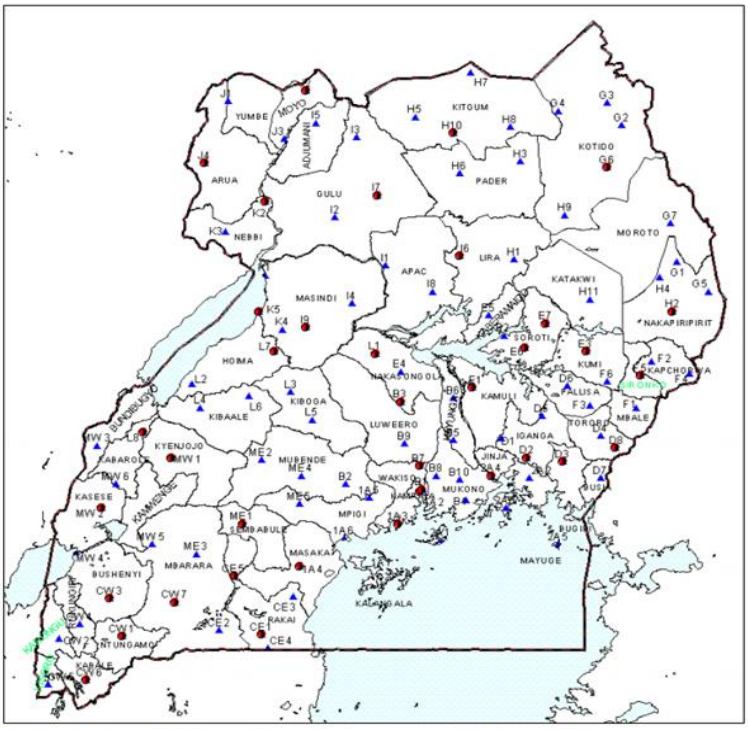


Figure. 17 Proposed Optimum Climate Monitoring Network (Majugu 2007)

KEY :

●	Current	▲	Proposed

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