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

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1.0 Problem Statement

Lake Victoria, a source of livelihood for 35 million people who live along its shores[1], is a vital resource in East Africa. For good reason it is also colloquially known as the world's most dangerous lake. With an estimated 5,000 deaths per year due to drowning[2], the National Lake Rescue Institute reports Lake Victoria is the most dangerous stretch of water in the world in terms of the number of deaths per square kilometer. This is but the most dramatic example of climate risks in Uganda, some of which are acute, and some building invisibly for months or years.

The problem stems from the fact that National Meteorological and Hydrological Services (NMHS) in the Horn of Africa lack the resources to deliver timely warnings to the estimated 200,000 active fisherman on the lake[3]. According to a recent report[4], Uganda's meteorological system does not adequately meet the needs of its citizens for simple access to past weather and climate data, present conditions and hazards, or detailed and accurate forecasts of future weather. Weather observing equipment is in a state of disrepair with many sensors nonfunctional, thereby limiting its utility. There is no operational lightning detection network or weather radar, which are essential means of identifying and predicting thunderstorm activity. Communication between weather station locations and the National Meteorological Center in Entebbe is inadequate; many communications can only be initiated from Entebbe. Without lighting detection, weather radar or an adequate communications system, it is impossible to provide timely hazardous weather warnings. Essential and preventive maintenance of weather sensors and other equipment is lacking. Spare parts and supplies are often unavailable. The result is that many observing systems do not function, and those that do suffer compromised accuracy and reduced measurement frequency.

An earlier Ericsson Lake Victoria Early warning system (see Figure 1) failed to impact the losses because its warnings are average 24 hour 100 km x 100 km (10,000 km^2 pixel) "predictions" without the specificity to be actionable by fisherman. On the other hand, by making use of knowledge of the location of fisherman's cell phones, and with the Earth Networks triangulating lightning detection system, our team can give to-the-minute updates on current threats at kilometer-scale precision. Finally, the Ericsson effort had no sustainable financial model, and so has foundered as donor support has dried up. In fact, our preliminary survey results show that fishermen are willing to pay for high-quality, timely information.

[1] http://www.wmo.int/pages/prog/wcp/cop16/documents/VCP_factsheets_3_Victoria_EN.pdf

[2] Mary Ak, Gomes C. Lightning safety of under-privileged communities around Lake Victoria. Geomatics, Natural Hazards and Risk 2014; (ahead-of-print): 1-17.

[3] http://netfam.fmi.fi/Lake12/Onvlee_pres.pdf

[4] Heitkemper, L. Kirk-Davidoff, D and Haynes, C.S. MDA Information Systems LLC. (Draft-2013). A Modernization Plan for Uganda's Meteorological Services. Gaitherburg, US.

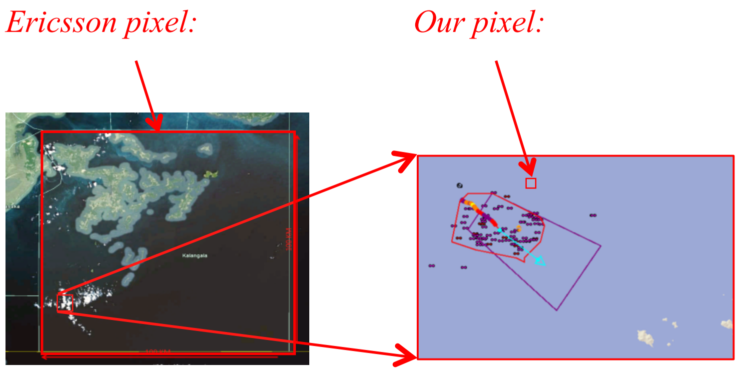

Figure 1. Comparison of scale of current system (100 km x 100 km pixel provided every 24 hrs) and required system (100 m x100 m pixel provided each minute) for timely warning of hazards.

An effective early warning system in the Horn of Africa, beginning in Uganda, could significantly mitigate the effects of acute climate-induced shocks and build resilience to the ever-changing climate, which promises to exacerbate regional crises such as drought. Based on robust climate observations, such a system would leverage high rates of cell phone adoption to deliver timely alerts to those who are most vulnerable. Providing timely and critical information to fisherman and smallholders will increase their capacity to adapt in real-time to severe weather events.

People in developing countries like Uganda want to access reliable weather forecasts and receive early warning alerts about severe weather events, but existing information services are inadequate. Local authorities take the scant information that is available and “push” it out to the general public using mass media channels such as radio and television. They decide the subject, time and place for message broadcast. However, these “push” communication strategies do not meet the informational need of the general public; people require information at a specific moment of need. Before beginning their workday, and by the minute as storms develop, fishermen on Lake Victoria need accurate current weather conditions. They need a way to access this information continuously. As such, weather-related information needs to be available on a permanent basis, not simply broadcast at the top of the hour on rural radio stations. A fisherman cannot “pull” this information out of a radio when he or she needs it most. They need access to a search engine even if they might never surf the Internet. In other words, they need the ability to choose the subject, time and place to access reliable information in their local language. Fishermen also need a simple way to opt-in to receive early warning alerts when storms are in the area.

1.1 Building Resilience

Resilience is characterized by four measures: preparedness, mitigation, response, and recovery (Carlson et al., 2012). Each phase represents a period of time in relation to an event triggering loss of life or decreased well-being for a given society. Preparedness represents the earliest period of time, during which measures are taken to understand and define risks. Mitigation occurs immediately 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 recovery (long-term efforts to restore equilibrium) occur.

An early warning system in Uganda would build resilience primarily by building capacity for preparedness and mitigation. In the absence of being able to prevent climate-induced shocks such as severe storms and floods, the best strategy is to prepare for such events and mitigate the most severe consequences (such as death and loss of property). When a fisherman is alerted to an oncoming storm, he knows not to go out on the lake. 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 thereby avoid household catastrophe.

Agriculture is the backbone of Uganda's economy, constituting 42% of GDP, over 90% of export earnings, and employing over 80% of the labor force. Uganda depends largely on rain-fed agriculture, making rural livelihoods and food security highly vulnerable to the consequences of climate change and variability. Climate change in Uganda is expected to severely influence the variability of rainfall and to cause increases in temperature and the potential for evapotranspiration. Predicted increases in aridity, and hence droughts, will in turn influence agricultural production[5]. These impacts will negatively affect food availability and supply, therefore impacting food security.

According to the World Bank (2008), agriculture is estimated to be nearly four times more effective at raising incomes among the poor than other sectors of the economy such as mining, energy or health.[3] Over time, climate change induced shocks adversely affecting the people of Uganda have been rainfall related, affecting rain-fed agriculture. They include:

1. Droughts, which impact on all aspects of life more than any other type of climatic shock
2. Floods, which increase water and sanitation-related diseases, destroy crops and infrastructure
3. Thunderstorms, which destroy crops.

So it is clear that in addition to the primary need for rapid, short-term information to protect lives and prevent death, the same robust climate observation system can also provide benefits through the provision of medium and long-term information to build resilience through response and recovery measures. For example: seasonal forecasts provided to smallholders to guide planting, harvesting, and storage of crops can help maximize yields and income in response to predicted growing season conditions. Historical and seasonal data can be used to compute insurance actuarial data to enable the provision of drought and storm insurance to smallholders, promoting a healthy recovery to one of the most debilitating problems faced by smallholders in the region. These services are essential to a resilient community, and currently absent across Uganda. This is not because people are unaware of these needs, but because a sustainable model for implementation and delivery has not been put forward. Rather, we see a series of failed one-time-donor funded pilots that did not seek to be self-sustaining.

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[5] The Republic of Uganda. 2012. Uganda National Climate Change Policy. Ministry of Water and Environment.

1.2 The Role of Gender

There is an increasing recognition of the gender disparities associated with climate shocks that leave women more adversely affected than men in rural agricultural settings[6] [7]. Gender disparity limits access to information on which women can base decisions to adjust to climate shocks not only because they are held in less regard society, but because they may be trapped in culturally defined roles of raising children and performing farm labor. Financial barriers such as the inability to pay fees or even to own a mobile phone or radio can leave them uninformed.

In the context of our project, men and women are certainly affected differently by climate-induced shocks. Fisherman on Lake Victoria are predominantly male, and therefore an early warning system would predominantly help prevent drowning deaths among men. However, floods and severe storms tend to disproportionately affect women since they are more commonly responsible for farm labor, food security and household management. Therefore, an effective early warning system will build resilience among women to respond effectively to climate-induced shocks. These results will only be achieved if critical information reaches both men and women when it is needed. In Africa, women are 23% less likely to own a mobile phone than are men[8]. Lacking the ability to close this gap, we must find creative ways to ensure early warnings reach women, instead of relying on SMS alone. This task will be addressed in the solution statement phase of this project, during which we will collect gender-disaggregated data exploring the most effective channels to distribute timely warnings to Ugandans.

1.3 Unique Selling Point

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 10 African Countries. **Earth Networks**, operating over 10,000 operating weather stations, 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 3-2-1, which can instantly deliver messages to millions of Ugandan phones. They have reached an agreement with Airtel to bring the 3-2-1 service to Uganda, free of charge to end-users. **ACLE**'s mission is to bring early detection of and protection from lightning hazards to all corners of Uganda and Africa. Beyond direct risk of electrocution, lightning is the leading indicator of severe weather activity and a prime 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.

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[6] Steenwerth K, Hodson A, Bloom A, et al. Climate-smart agriculture global research agenda: scientific basis for action. Agriculture & Food Security 2014; 3(1): 11.

[7] Shackleton S, Ziervogel G, Sallu S, Gill T, Tschakert P. Why is socially-just climate change adaptation in sub-Saharan Africa so challenging? A review of barriers identified from empirical cases. Wiley Interdisciplinary Reviews: Climate Change 2015; 6(3): 321-44.

[8] http://www.gsma.com/connectedwomen/wp-content/uploads/2013/01/GSMA_Women_and_Mobile-A_Global_Opportunity.pdf

CHAI has built a wealth of experience and achieved impressive results in providing life-saving information to Ugandan communities.

Leveraging this unique partnership, we will create a sustainable climate observation network by delivering accurate products across large geographic areas. In Africa, this requires a trans-national approach (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, 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 track record in this domain is a game-changing advantage for our team of local and international partners.

2.0 Theory of Change

Under this project, farmers and fishermen will build resilience, improve productivity, and better protect their lives and assets along three impact pathways:

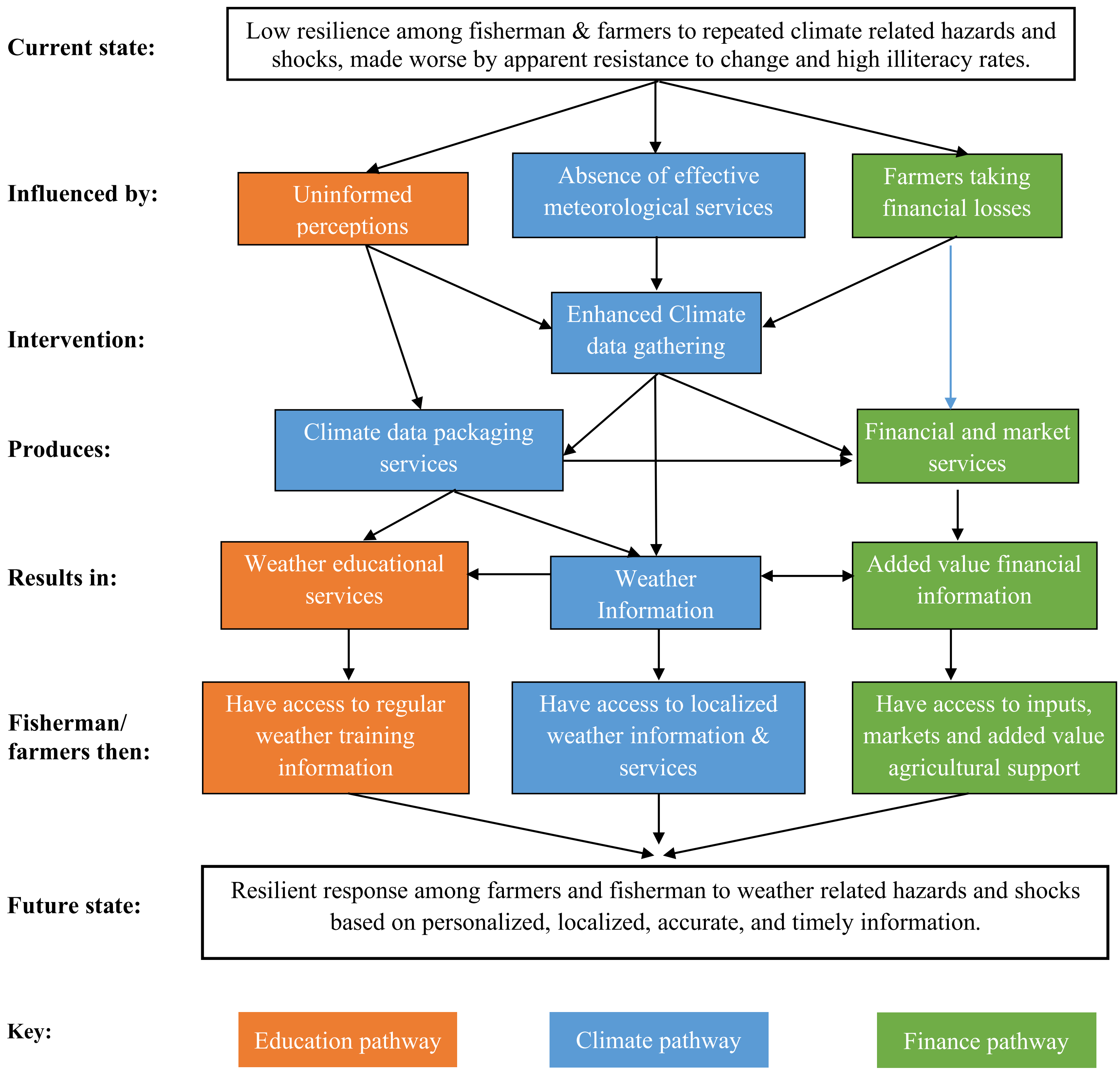
1. Improved Technology: We will design and implement an end-to-end meteorological monitoring and prediction infrastructure based on an innovative, cost-effective, durable, and real-time early warning system network that will enable collection and transmission of timely, accurate, and local data to users. We will package and disseminate the information to fit local contexts and local languages using multiple technology options including mobile phones, multimedia, and radio. The end result is to provide localized information to the general public that will help mitigate the effects of floods, severe storms, and other climate-induced shocks.

2. Innovative Financing Solutions: The same meteorological infrastructure that enables an effective early warning system will enable new and innovative financing options for smallholders. Over 300,000 farmers in East Africa are already insured against drought through index insurance products enabled by robust meteorological data collection in Kenya and Rwanda. Insured farmers are significantly more likely to access credit markets and use high-yield seeds and fertilizer, leading to 16% higher incomes[9]. Smallholders in Uganda will benefit from the same access to financial services.

3. Education: The project will bring out the inherent resilience and adaptability of farmers and fishermen by sensitizing them to the benefits of accessing and using weather and climate information as the missing link in the equation of managing and improving their productivity. They will learn to protect assets by providing many messages about these benefits with the end result of making the users knowledgeable and able to effectively demand for these services

[9] https://cgspace.cgiar.org/bitstream/handle/10568/53101/CCAFS_Report14.pdf

2.1 Impact Pathway



2.2 Logical Framework

Narrative summary	Objective verifiable indicators	Means of verification	Assumptions
Primary Goal: 1. Improved and sustainable climate resilience across targeted geographical areas, sectors of economy, and segments of society	Measures of Goal Achievement: 1. Enhanced capacity of targeted audiences to monitor extreme weather and climate change 2. Early warnings issued and decision making enhanced with quality, timely information	1. Regulated by funder's Monitoring and Evaluation Framework	Assumptions for Achieving Goal Targets: 1. External socio-economic factors remain stable 2. Conducive stakeholder agreements
Purposes: 1. Provide EWS infrastructure to at-risk areas 2. Provide capacity building to local organizations 3. Provide timely, relevant content to communities Provide path to sustainability	Measures of Purpose Achievement: 1. Functional EWS with sufficient uptime and warning delivery levels 2. Increased local capacity to maintain and operate the EWS 3. Sustainability framework and agreements with funding streams in place	1. Grantee's self-reporting Information from EWS statistical portal 2. Surveys of government and targeted populations	Assumptions for Achieving Purpose: 1. Sufficient funding for full implementation 2. The EWS gets integrated into government and society 3. End-user ability to pay 4. Fee-for-service contracts are forthcoming
Outputs: 1. Early Warning System Design 2. Metadata Handling System 3. Quality Assurance / Quality Control (QA/QC) System 4. Installation of Stations in Targeted Areas 5. Ongoing Operations Plan 6. Forecasting and Data Archiving 7. Broad-Based Dissemination Platforms 8. SMS/IVR Message Delivery 9. Sustainability Component	Magnitude of Outputs: 1. Observation networks reporting a high proportion of data Proportion of decision-makers and the population receiving quality, timely EWS alerts 2. Successful technology introduction with accompanied training and professional development 3. Amounts of revenue generated through sustainability program	1. Grantee's self-reporting 2. Information from EWS statistical portal 3. Surveys of government and general public Periodic knowledge assessments	Assumptions for Providing Outputs: 1. Availability of secure locations with power and communications for observation network elements 2. Adequate in-country telecommunications infrastructure 3. Availability of trainable staff at community-based institutions 4. Full reapplication of generated revenues toward program needs
Inputs: 1. Funding approval and project initiation Co-financing and support of national government 2. Sufficient absorptive capacity of the grantee 3. Partnerships with paying industries 4. Technical and programmatic subcontractors	Implementation Target: 1. 90% of observational data per every 10,000km^2 of country 2. 50% of mobile consumers notified of extreme weather events 3. Series of initial Train the Trainer workshops per Output followed by refresher trainings 4. 100% self-financing operation in 3 years	1. Information from EWS statistical portal 2. Surveys of government and general public 3. Periodic knowledge assessments 4. Financial audits	Assumptions for Obtaining Inputs: 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

3.0 Environmental and Social Safeguards

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.

4.0 Risk Matrix and Mitigation

Risk	**Impact**	**Probability**	**Mitigation**
Dysfunctional administration of funds due to high number of partners	High	Medium	Clear assignment of roles among partners, strong leadership from TAHMO. Clear system for tracking responsibilities and outputs for each partners
Change of institutional priorities & leadership	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
Failure to reach agreements with political stakeholders	High	Low	Continue negotiations with UNMA and other key stakeholders to ensure agreements are reached before implementation
Poor reception of project by the public	High	Low	Phased rollout of product that incorporates feedback from end-users. Ongoing survey efforts will ensure continuous interface with end-users to determine preferences
Failure of stations leading to missing data	High	Medium	Selecting secure installation sites and having a local technician in the field ready to promptly replace or repair stations

5.0 Measuring Resilience

Understanding the drivers of a community's vulnerability and knowing the strength of that community is a good starting point in measuring resilience and improving it. According to Fran Norris, et al. (2008), information and communication is one of the four adaptive capacities most essential for a resilient community. As discussed in section 1.1, the intervention we are providing is information leading up to a potential climate shock, providing mitigation capacity. The weather and climate information services embedded in the Early Warning System shall provide an opportunity for continuous interaction between end-users and solution providers to measure and increase the resilience of vulnerable communities. Unpublished data so far gathered by the school of public health indicates that a majority of fishermen (more than 90%) use mobile phones as their main tool of communication. For the fishing sector, we will measure the adoption and self-reported weather-based decision making (change of boat course, decision not to fish) based on our text alerts. Based on baseline survey data collected during Stage II, we will establish a baseline measurement of resilience which can be used for comparison during Stage III. Ultimately, we hope to be the driving force behind a drastic reduction in the estimated 5,000 lives that are lost on Lake Victoria every year.

5.1 Value for money

An effective early warning system in Uganda would be highly scalable. HNI's 3-2-1 service will soon be made available free of charge to all 7.5 million Airtel subscribers in the country. (Ultimately HNI plans to make the service available to all mobile phone users, regardless of carrier.) Once TAHMO and Earth Networks have established an effective climate monitoring system, climate information will be made available to all 3-2-1 users on-demand. This established path to scale will therefore provide a high value for money to the GRP.

All goods and services procured for the implementation of this project will represent the best value for money possible. For example, TAHMO has worked with Decagon Devices, Inc. to develop a state of the art weather station that is solid-state, solar-powered, and uploads data over the local cell phone network. Based on the high volume of stations needed, Decagon has agreed to provide these stations at a fraction of the cost that would be paid to procure a weather station of similar specifications today.