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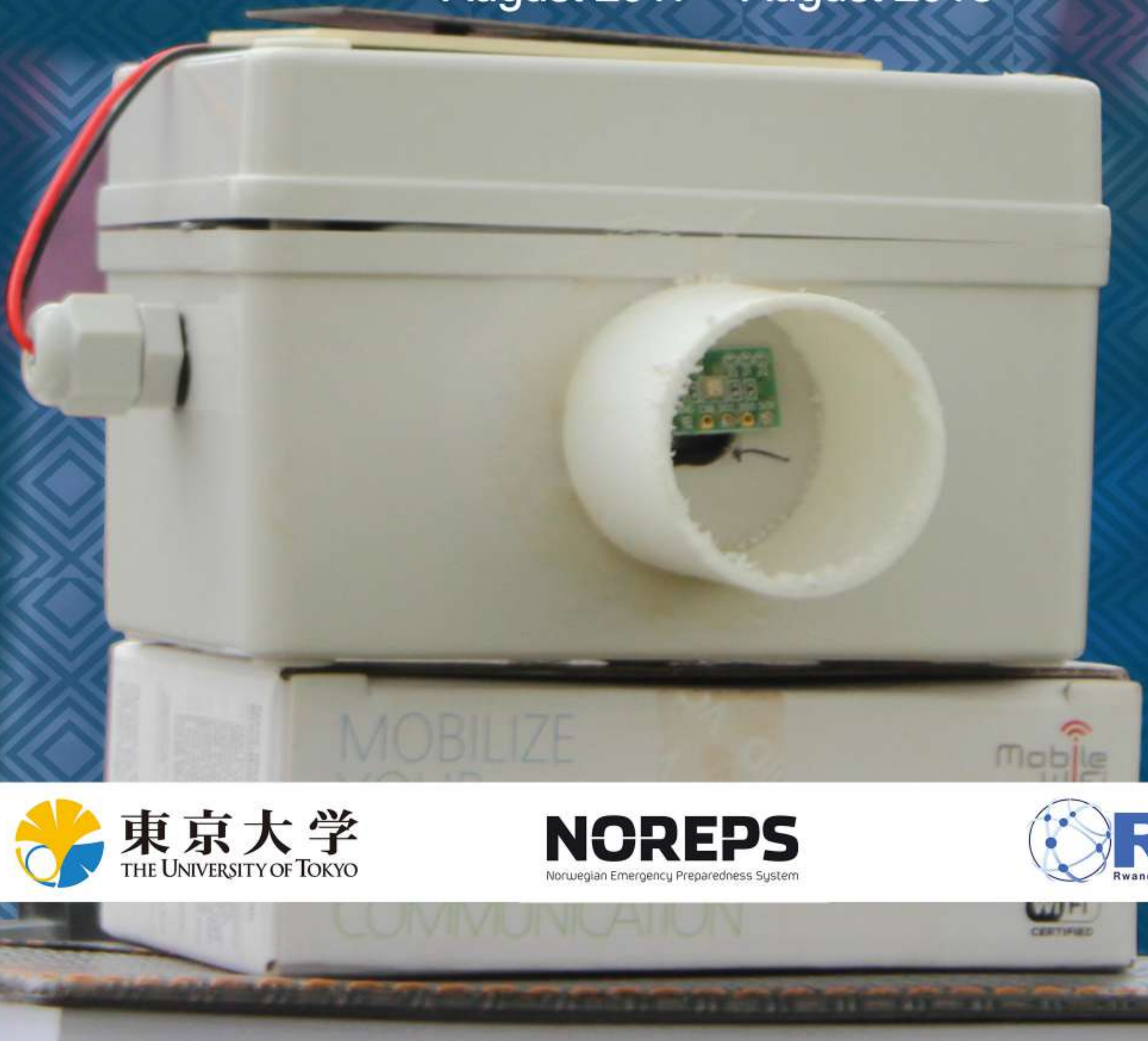
Rwanda Meteorology Agency

Summary Findings of the Pilot Project Internet of Things (IoT) for Climate Early Warning

August 2017 – August 2018



東京大学
THE UNIVERSITY OF TOKYO

NOREPS
Norwegian Emergency Preparedness System

RISA
Rwanda Information Society Authority

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Background

Intense climate-related disasters have been on the rise worldwide. Between 1995 and 2015, 90% of disasters were caused by floods, storms, heatwaves and other weather-related events. While floods have accounted for the majority of weather-related disasters worldwide, droughts are also significant as they are associated with widespread agricultural failures, loss of livestock and water shortages. In total, more than one billion people have been affected by droughts in the past 20 years.[1] Droughts predominantly affect Africa putting at risk the lives and livelihoods of vulnerable populations such as smallholder farmers who account for 70 percent of Africa's population.

In Rwanda, climate related issues remain a significant impediment to the country's green growth strategy and pose direct risks for vulnerable populations, such as rain dependent smallholder farmers. According to The National Risk Atlas of Rwanda, over the last decade the frequency and severity of natural disasters, particularly caused by floods and droughts, have significantly increased. Over 157,000 people are vulnerable to drought, about 7,500 are vulnerable to landslide and over 5,000 houses are vulnerable to windstorm, while forest and landscape degradation and climate change increase the risk and severity of disaster.[2] In particular, the districts of Kayonza, Gatsibo, Kirehe, Nyagatare, Rwamagana, Ngoma and Bugesera in the Eastern province are likely to experience severe drought. Conversely, the highlands of the Congo-Nile Ridge in the Western, Southern and Northern provinces are prone to landslide.

Accurate climate and weather information is critical for managing climate related risks such as droughts and floods, early warnings and fast response; however, micro level data is very difficult to collect only with meteorological stations. African observation networks are still very sparse and unevenly distributed, and there is not enough data to inform decisions for climate change adaptation. Weather stations in Africa are spread out over large distances, mostly in northern and southern Africa, resulting in data gaps at multiple levels.

In Rwanda, climate related data is collected and analysed by Rwanda Meteorology Agency (Meteo Rwanda) under the Ministry of Environment. Meteo Rwanda's observational network platform contains automatic weather stations but also many manual weather stations. In the manual stations, one staff or volunteer observer per station writes down the record for the day and sends the data as a monthly report by phone or paper form. Thus, the process is slow and is prone to human error. This can delay early warning mechanisms, and in the face of large-scale disasters, be inefficient in providing first-hand scoping information and lead to loss of data. Meteo Rwanda and other relevant stakeholders and users of climate information have expressed the need for more targeted and speedy information, especially for disaster risk reduction and agricultural planning. The importance of weather and climate information for effective disaster risk management is also articulated in major national strategies such as the National Strategy for Transformation (NST1) and the Green Growth and Climate Resilience Strategy (GGCRS).

1 ***Guha-Sapir, D., Hoyois, P., Wallemacq, P., and Below, R. (2016). Annual Disaster Statistical Review 2016: The numbers and trends. Brussels***
2 ***MIDIMAR (2015). The National Risk Atlas of Rwanda. Kigali.***

Project objectives and scope

Considering the pressing challenge of climate-related risks in Rwanda and in the region, as well as the need for more accurate climate and weather data and information, Meteo Rwanda and UNDP piloted the project 'Internet of Things (IoT) for Climate Early Warning.' The pilot project consisted of two phases. Phase One was implemented in collaboration with University of Tokyo (UoT) and with seed funding from UNDP Innovation Facility. This Phase 'IoT for Climate Change and Water Management' focused on testing IoT technology as a real-time microclimate data collection methodology at three small-scale sites. Phase Two was implemented in collaboration with Rwanda Information Society Authority (RISA) with funding from Noreps as 'IoT for Climate Early Warning and Humanitarian Response.'

UNDP understands that innovation requires a significant upfront investment in learning. Accordingly, the pilot project focused on researching and testing of the IoT concept on all the different pieces across the entire climate information value chain, including the collection, assimilation, distribution and usage of climate data. The pilot project was designed to gain a clear understanding of the needs of the smallholder farmers, vulnerable populations, Meteo Rwanda and other stakeholders. More importantly, it allowed the team to capture key learnings that would help setting the direction for the subsequent phases to further build upon and scale up this initiative.

The project's main objective was to prototype and develop technologies and applications that can sustainably address existing and future emerging climate issues through "real time" environmental data collection, analysis, dissemination and application, including but not limited to IoT technologies. The expected long-term outcomes were as below:

Outcome 1. Vulnerability to climate change mitigated through real-time micro data provision
Real-time data collection and dissemination will support decision making at the population level (direct early warning) and the policy planning level (DRM, humanitarian response) to reduce vulnerability to climate change related issues such as drought and flood. The pilot project will test, prototype technological solutions and identify the opportunities and challenges.

Outcome 2. Capacity built from upstream to downstream on climate data collection to analysis
Technology transfer and capacity development are expected to take place from upstream assembly to downstream data application for using IoT for future climate challenges through 'learning by doing' and training opportunities. Climate data usage will be sensitized through the whole value chain of disaster risk management. Both projects will engage stakeholders to identify scale-up strategies for integrating IoT in climate service and disaster risk management.

This initiative is further linked to the government's efforts to expand Rwanda's commitment to the "Internet of Things" (IoT). It is a long-term goal that the technologies and applications developed under this initiative in Rwanda could be scaled geographically to other Sub-Saharan countries.

Project Activities

- The project piloted the IoT concept by setting up sensors and open-source data relay boxes in Kayonza District in the Eastern Province of Rwanda where drought and water shortage are persisting issues. The site was selected based on feedback from stakeholders as it is identified as one of the most vulnerable to drought in the National Risk Atlas (MIDIMAR), with 26% of the district land exposed to severe drought and agriculture at high risk.

- 12 IoT sensors were assembled, set up, and maintained in Murundi, Ndego, and Rwinkwavu sectors to collect real-time data on soil moisture, temperature and humidity. UoT staff provided training to Tumba College of Technology (TCT) graduates and Meteo technicians on the concept of IoT, assembly of the data relay box and software instalment.

- UNDP with Meteo Rwanda and the UoT conducted a Design-a-thon to convert this real time data into usable and accessible information applications through a collective designing process, bringing together national and local stakeholders, young programmers and technology experts. The Design-a-thon brought together 18 teams made of 66 participants. Participants conducted field visits to get a better understanding of their users' needs and ask for feedback on the prototypes of their applications. Six teams were selected to go to the next stage and work on developing a minimum viable product for 25 days.

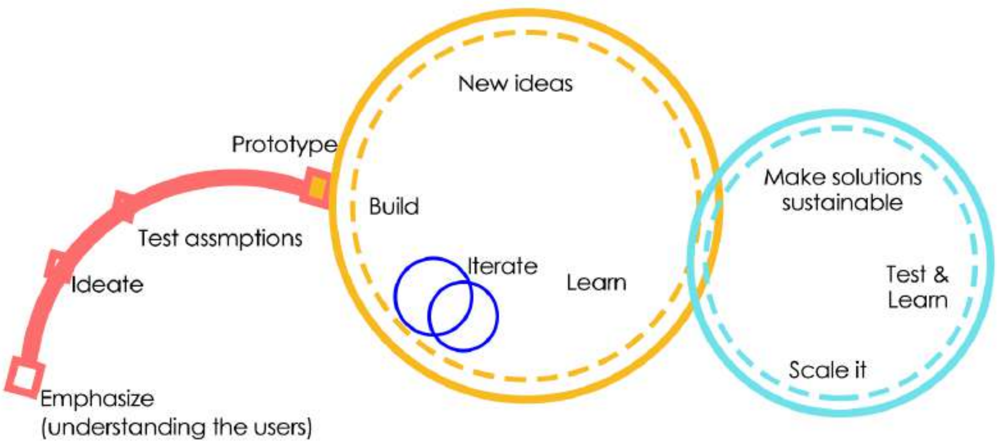
- Winning prototypes of the Design-a-thon were further developed and tested during Phase Two of the project. An application to disseminate information and advice to farmers is ready to be piloted. An API was installed in Meteo's server, improving access to climate data and allowing developers to build new applications. A volunteer observers application was developed and is ready for roll out, which will help digitize the recording of data at the manual weather stations.

- Gaps along the climate information for early warning were clearly identified and documented and solutions were prototyped through the Phase Two Hackathon event. Meteo Rwanda and UNDP organized a five-day Hackathon for Climate Early Warning in Kayonza District, bringing together 10 teams made up of 33 participants and mentors from stakeholder institutions.

- Teams worked on prototyping the following solutions which will be scaled in Phase Three:
  - Low-cost sensors to collect soil moisture data and a dashboard to monitor sensors data
  - Platform using machine learning algorithm to help MIDIMAR identify at risk areas,
  - visualize the areas on the map and communicate the information to concerned officers
  - Platform to visualize disaster risk areas by contextualizing Meteo Rwanda weather forecasts with MIDIMAR disaster risk profiles
  - Platform to automate the flow of communication between Meteo Rwanda and MIDIMAR, and between MIDIMAR and the vulnerable population (end users)
  - Android, SMS and USSD applications as well as sirens to disseminate early warning information to the population

Innovation approach

The project focused on a strong user-centered approach; on understanding the needs of the "users," (as opposed to the traditional term "beneficiary") it was trying to serve. The project also used a collective approach by engaging a wide range of stakeholders from the beginning and designing the project in a collective manner. The project further used a lean startup approach, a process through which ideas are prototyped and tested continuously. From selecting the site all the way to developing the applications for the end users, there was always a process of testing and learning. Lastly, the project made sure to look at the scalability and sustainability of the initiative. As part of the pilot project, partnership workshops were designed to bring together key stakeholders and discuss the next steps IoT for Climate Initiative.



Innovation approach used for the IoT for Climate Initiative

Key project achievements

Strong stakeholder buy-in as foundation for future scale up

A strong understanding of the needs of vulnerable populations and key stakeholders was attained through extensive stakeholder engagement, user interviews and field visits to Murundi, Ndego and Rwinkwavu Sectors in Kayonza District. Key stakeholders, including Rwanda Agriculture Board (RAB), Rwanda Water and Forestry Authority (RWFA), Ministry of Disaster Management and Refugee Affairs (MIDIMAR), Rwanda Environment Management Authority (REMA), agronomists, farmers and Kayonza District officials were engaged in the design and implementation of the pilot project and are supportive of the initiative and its future scale up. Strategies for scale up were identified with strong stakeholder engagement.

Technical capacity built on the use of IoT along the Climate Information value chain

Capacity was built through "learning by doing" – The process involved trainings, stakeholder workshops and field work, which built the capacity of engineers and practitioners across different stakeholder institutions. UoT staff trained Meteo Rwanda staff and TCT graduates on IoT sensors assembly, set up and maintenance. In addition to the core technical stakeholder team, 38 participants from different institutions were trained during the Hackathon side event sessions on IoT technologies, IoT weather stations and IoT for Early Warning. 66 young local programmers and scientists came together to design IoT applications for climate change adaptation during the Phase One Design-a-thon for Climate, and 33 came together for Phase Two Hackathon to test and strengthen their technical skills on real-world development problems. As a result, a loose ecosystem of engineers, entrepreneurs and government practitioners were built. Technical and institutional capacity gaps along the climate information related to early warning were clearly identified and documented for future programmes and projects.

Participants of the IoT Design-a-thon listening to a farmer in Rwinkwavu sector to be able to propose a solution

Graduates from Tumba College of Technology being trained to use IoT for Climate change.

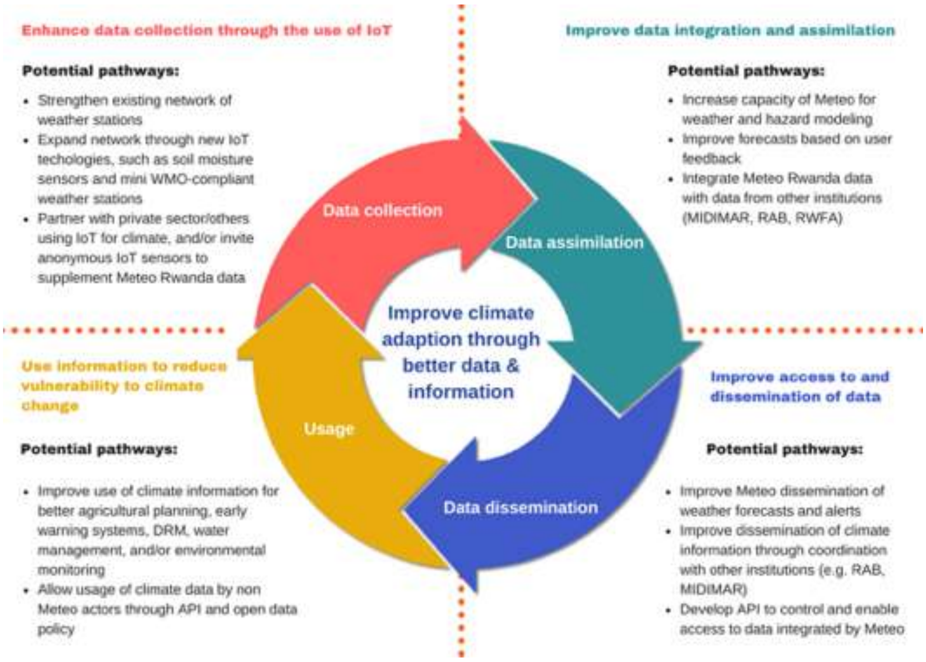
Solution for real time climate early warning designed and tested

12 IoT sensor kits were assembled, set up and maintained in Kayonza District to collect real-time data such as soil moisture, temperature and humidity. A data collection server was established: data from IoT sensors was collected and sent to the Meteo Rwanda server for 4 months and analysed, which is valuable data for designing future generation IoT networks. A mobile phone application to disseminate information and advice to farmers was fully developed and ready for institutionalization. An API was installed in Meteo Rwanda's server, improving access to climate data and allowing developers to build new applications. A volunteer observers application was developed and is ready for roll out, which will help digitize the recording of data at the manual weather stations. In addition, total 10 IT systems were prototyped through a Hackathon. Solutions include a low-cost yet robust sensors network to collect soil moisture data, platforms to help MIDIMAR quickly identify and visualize at risk areas, platforms to automate the flow of communication between Meteo Rwanda and MIDIMAR, and applications to disseminate early warning information to the population.

Key Findings from the pilot phase

1. What is the IoT for Climate Value Chain?

To improve the climate information flow for better climate adaptation, there is a need to work along the entire value chain, from data collection to data analysis, dissemination and usage. The below graph shows the pathways that were identified on each area of the chain.



2. Climate information user profiles and needs

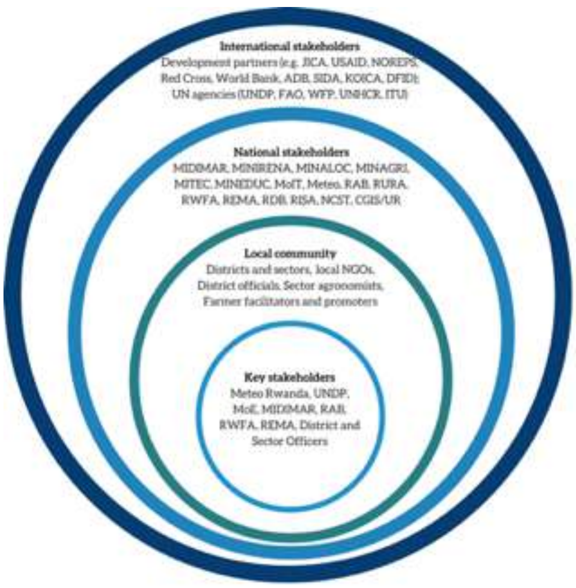
The first phase of this pilot project identified as users the rain dependant smallholder farmers in rural areas who need to utilize daily weather forecasts better in order to secure harvest and be better prepared to climate change adaptation. Phase two of the project identified as users the broader population vulnerable to disasters including flood, landslide and drought and who need early warning to evacuate or prepare. Based on a user-centered approach, the pilot project did a thorough assessment of both users and their needs through user interviews, field visits and by engaging with stakeholders and experts who provided more insights into the problem. From the initial consultations and interviews with users and stakeholders from Kayonza District what stood out as a clear finding was the need for timely and accurate climate information specific to the local (cell) level as well as the need for information that is understandable to the users. During Phase Two what stood out was the need for an Early Warning system, by which local communities could be alerted before a disaster occurs.

3. Stakeholders mapping

Engagement of key stakeholders is crucial to ensure the success and sustainability of the IoT for Climate project. A wide range of stakeholders were involved during the pilot project to ensure that the technologies and applications are relevant and meet the needs of the users. These stakeholders contributed to the pilot project by sharing expertise, providing technical advice and data, and sharing insights into the community needs.

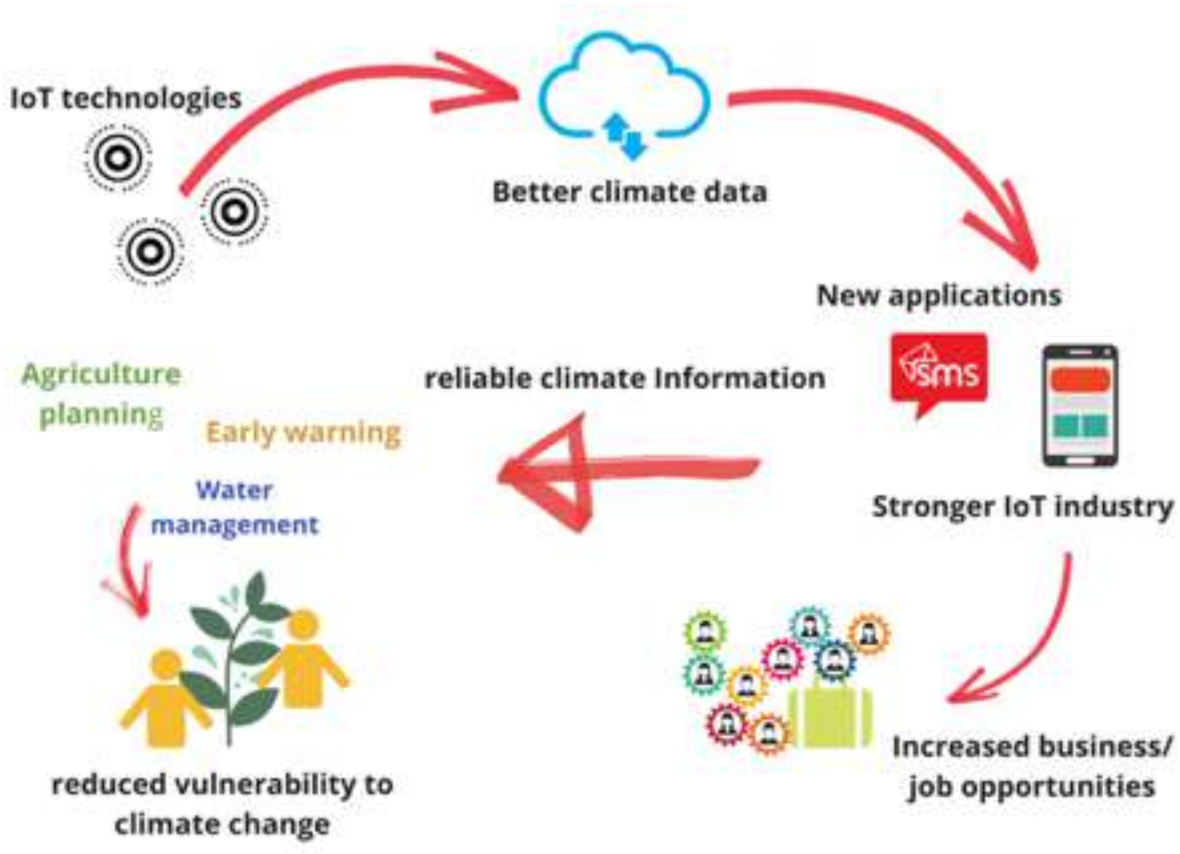
UNDP and Meteo Rwanda were the lead organizations implementing this pilot project, with the support from the University of Tokyo, NOREPS and RISA. Other key stakeholders such as MIDIMAR, RAB, RWFA and Ministry of Local Government (MINALOC) provided expertise on the current challenge of weather data collection and needs for effective disaster risk management and agricultural planning. The local community such as officers from Kayonza District, sector agronomists and smallholder farmers provided specific insights into the needs of the community at the district, sector and cell levels. For the next phases and to scale up this initiative, other key stakeholders will need to be involved in addition to those engaged during the pilot phase (as shown in the below diagram).

A more detailed chain of communication and coordination were identified for different types of climate information.



4. Opportunities and potential of IoT for climate change adaptation

Opportunities for this initiative in Rwanda include uptake of emerging low-cost technologies, increased capabilities to process and analyse big data, increased internet penetration and mobile connectivity, commitment of the Government of Rwanda to ICTs and IoT, and strong support from stakeholders represented by Meteo Rwanda. By leveraging these opportunities, the IoT for Climate initiative can have a meaningful impact in reducing the vulnerability to climate change. Better climate data collected through IoT technologies can lead to timelier and more accurate climate information that is used for better agricultural planning, Early Warning and Disaster Risk Management, water management and to address other environmental concerns. Moreover, the initiative has the potential of strengthening the IoT industry overall, contributing to “Made in Rwanda” technology and promoting employment and business opportunities.



Potential of IoT for Climate Change Adaptation

5. Main challenges

When using IoT technologies and applications for climate change adaptation in the context of Rwanda, there are various challenges that need to be considered, which include those in relation to the collection, assimilation, distribution and usage of climate related data.

In terms of data collection, there is a trade-off between small scale low-cost IoT devices and more complex automated weather stations that meet WMO standards. Using small-scale IoT devices could potentially be deployed in more locations, helping collect more localized data in Rwanda. However, there are some drawbacks that need to be considered. The monetary cost of small-scale devices with a limited number of sensors is indeed markedly lower than that of the weather stations, yet they do not have the full array of sensors of a weather station and are not WMO compliant. Other main challenges related to IoT technologies in general include security concerns; durability, maintenance and safety of sensors; electricity stability and internet connectivity.

On the data assimilation aspect, main challenges have to do with the existing capabilities in place to actually harness granular data from IoT technologies to improve the weather forecasts. Other challenges relate to the compliance of the data collected with WMO standards as well as the complexity of using the data for drought predictions. On the data accessibility side, the main challenges relate to ensuring accessibility to Meteo Rwanda's data. The API server will need to be running and the network needs to be properly configured.

Lastly, on the usage end, the main concerns relate to making sure that climate data is turned into usable reliable climate information potentially through related stakeholder institutions. Furthermore, there needs to be the awareness and skills for users, such as smallholder farmers and vulnerable populations, to use new climate information products and services.

Participants of the design-a-thon learning from other similar technologies in the region.

Scaling up the usage of IoT for Climate Early Warning

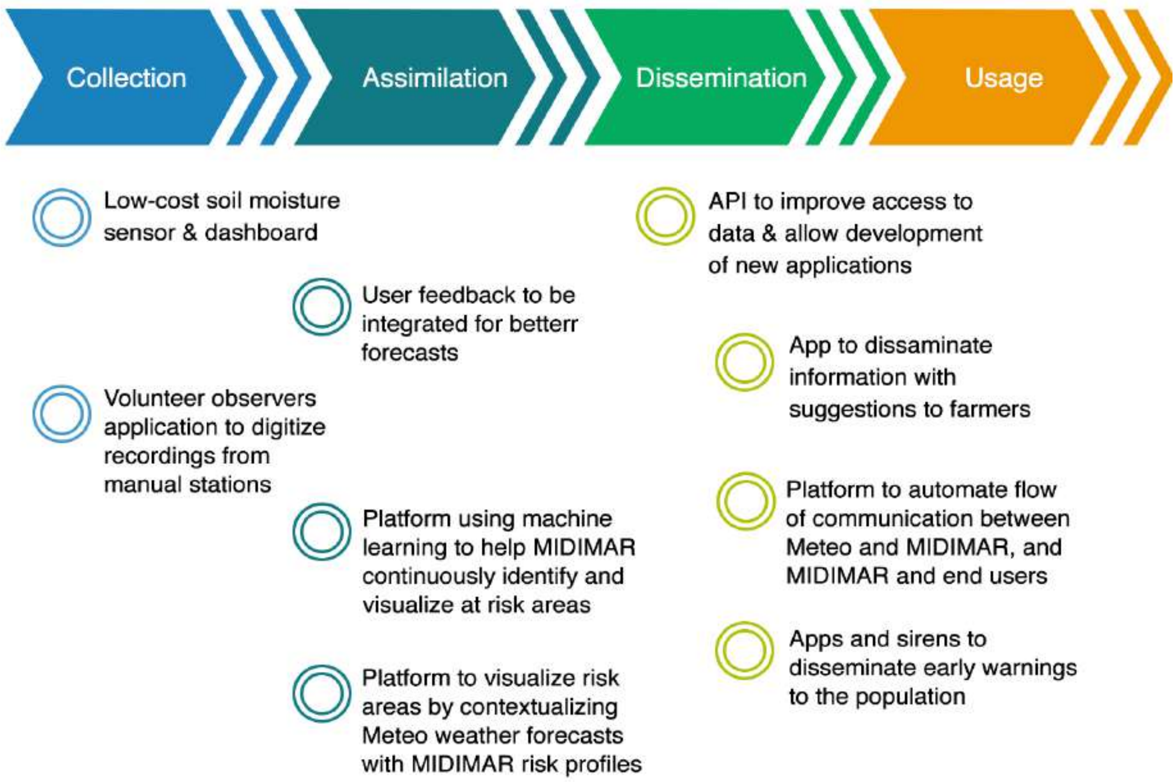
The pilot phase focused on testing different components along the IoT for climate value chain. Based on the learnings from Phase One and Two, some guidelines are suggested for the scale up of this initiative and outputs and activities are proposed for the next phase. The project will continue to engage stakeholders and seek for funding and partnerships, in order to scale up the proven seeds of solutions to smooth data collection, assimilation and dissemination as well as coordination for climate early warning in Rwanda.

Guideline #1 Scale up solutions only after piloting and testing

Guideline #2 Focus the strengthening of Meteo Rwanda in data quality control, assimilation and coordination

Guideline #3 To fully benefit from the concept of IoT, leverage on the private sector and entrepreneurs ecosystem

Guideline #4 Strengthen partnerships with other existing projects and stakeholders



‘Internet of Things for Climate Change Early Warning and Humanitarian Response Project 31st August 2018.‘