DECENTRALISED COMMUNITY-POWERED WEATHER NETWORKS FOR HYPER-LOCALISED WEATHER AND CLIMATE INFORMATION SERVICES IN KENYA

African Technology Policy Studies Network (ATPS)
TECHNOPOLICY BRIEF NO. 85

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The African Technology Policy Studies Network (ATPS) is a transdisciplinarynetwork of researchers, policymakers, private sector actors and the civil society promoting the generation, dissemination, use and mastery of Science, Technology and Innovations (STI) for African development, environmental sustainability and global inclusion. In collaboration with like-minded institutions, ATPS provides platforms for regional and international research and knowledge sharing in order to build Africa’s capabilities in STI policy research, policymaking and implementation for sustainable development.

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About the Project

Africa's rapidly growing population, projected to reach 2.6 billion by 2050, posed significant challenges for agricultural and food systems. To meet the increased demand for food, production needed to rise by up to 70%. However, resource scarcity, climate change, the impact of the COVID-19 pandemic, and socioeconomic hardships made this a daunting task. Recognizing these challenges, the initiative focused on leveraging emerging technologies, particularly artificial intelligence (AI), to transform Africa's agricultural and food systems.

The project successfully advanced the responsible development, deployment, and scaling of AI research and innovations tailored to address Africa's agricultural challenges. A key achievement of the initiative was the establishment and management of the AI for Agriculture and Food Systems (AI4AFS) research network, which comprised ten innovation research projects. These projects focused on creating and implementing homegrown AI solutions that were tested, deployed, and scaled to meet Africa's specific agricultural needs.

The initiative deepened the understanding of how AI can be responsibly developed and scaled for sustainable agriculture in Africa. By building the capacity of African researchers and innovators, the project equipped them to create and apply AI solutions that had a tangible impact on agriculture and food systems. Moreover, the project contributed to shaping both African and international AI policy and practice by sharing valuable insights gained through research and innovation.

Throughout the project, several key activities were carried out, including issuing calls for Expressions of Interest (EOI), conducting training workshops for preselected consortia, and engaging with selected grantees. The project was overseen by the Hub Management Committee (HMC), which worked closely with a Hub Advisory Team (HAT) of experts to ensure strategic guidance and support. A robust Monitoring, Evaluation, and Learning (MEL) framework was implemented to track progress and ensure that the project remained on course. The initiative also fostered networking and collaboration through platforms for knowledge exchange, with quality assurance mechanisms in place to ensure transparency and credibility at every stage.

As a result of the project, African researchers and innovators were empowered with enhanced research infrastructure and a conducive environment to lead in AI for

Agriculture and Food Systems (AI4AFS). The research network was strengthened, generating new AI research and innovations that tackled pressing agricultural challenges in Africa. Additionally, the project contributed to the development of more inclusive policies and strategies that supported transformative change in AI for agriculture and food systems, based on the needs of African societies.

This initiative was part of the larger Artificial Intelligence for Development Africa (AI4D Africa) program, which was co-funded by Canada's International Development Research Centre (IDRC) and the Swedish International Development Agency (Sida). AI4D Africa aimed to create a future where Africans across all regions use AI to lead healthier, happier, and greener lives. Through this completed project, the mission to promote responsible AI innovation, improve quality of life, and drive sustainable development in Africa was successfully realized.

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Acknowledgement

We extend our gratitude to the smallholder farmers of Wesakulile Women, Bulwani Imagine, Mali Shambani and Abatimanga self-help groups, whose invaluable insights and participation have been fundamental to the success of this project. We also thank our partners Centre for Enterprising Communities, Kenya Agricultural and Livestock Research Organisation (KARLO) and Benjamin Makai @ Technology for Development and Safaricom for their ongoing support and collaboration. Special acknowledgment goes to our funding partner, the African Technology Studies Network (ATPS), whose commitment and support have made this important work possible. Their dedication to fostering innovation and sustainability in agriculture continues to inspire and drive our efforts to enhance climate resilience among communities most in need.

Key Messages:

- Smallholder farmers in Kenya often struggle to access localised weather information due to the high costs and complexities associated with advanced meteorological tools. To address this, we recommend scaling decentralised community-powered weather monitoring systems that utilise cost-effective Internet of Things (IoT) and Artificial Intelligence (AI) technologies. These systems provide hyper-localised weather forecasts and data-driven agronomic advice, enhancing agricultural productivity and resilience.

- Government agencies should support the expansion of this technology to new regions through funding and partnership development, as well as policy support that will integrate these solutions into national agricultural strategies and ensure that all smallholder farmers can benefit from these innovations.

- There is need to amend the Meteorological Bill 2024 in Kenya to remove punitive fines on third party weather information dissemination and formally recognise decentralised community-powered weather monitoring systems within the Kenya Meteorological Department's (KMD) mandate.

- Decentralised, community-powered weather stations have proven successful in providing hyper-localised, accurate weather data. Incorporating these systems into KMD's mandate would expand reliable meteorological services to underserved regions, enhancing agricultural productivity, improving disaster preparedness, and fostering resilience among farming communities.

1. Introduction

Climate change has led to more frequent and severe weather events, including droughts and heavy rains. This unpredictability hampers farmers' ability to plan and manage their agricultural activities effectively. The damage from climate change on agricultural productivity will be severely felt in Africa with an estimated decline in agricultural output of up to 17% by 2080 (Cline, 2007). Smallholder farmers are among the most vulnerable to climate shocks due to their limited resources and reliance on rain-fed agriculture. In Kenya, the agricultural sector is heavily dependent on smallholder farmers, classified as farmers who farmland smaller than 2 hectares, who account for 80% of the country’s total agricultural output (Food to Market Alliance, 2022).

Climate smart agriculture (CSA) aims to transform agricultural systems to support food in the face of climate change. The main objectives of CSA are to increase agricultural productivity and build climate resilience through mitigation and adaptation. This has been emphasized through several strategies aimed at attaining these objectives; an example is the use of technology and innovation to deliver timely and accurate weather and climate information to farmers as highlighted in the Kenya Climate Smart Agriculture Strategy 2017-2026 (GoK, 2017). WCIS refers to the systems and tools that avail to the farmer or users’ weather and climate data appropriate, timely, and relevant enough for making informed agricultural decisions. These services range from forecasts, current weather conditions, warnings of weather extremes, and climate trends. The integration of WCIS into farming will, therefore, enable smallholder farmers to make informed decisions on the appropriate planting, irrigation, application of pesticides, and diseases, and harvest time. This will help mitigate most of the risks that emanate from variability in climate conditions, thereby improving productivity and the sustainability of the agricultural activities.

However, access to climate information technologies is one of the key challenges in adopting CSA technologies (Autio et al, 2021). Only about 40% of smallholder farmers in Kenya, access and use WCIS to make decisions on adopting CSA technologies (Ngigi et al, 2022). One of the barriers to access and use of WCIS is the lack of accurate and timely information. This is because farmers make decisions at the level of their fields, whereas climate model outputs are at a very coarse scale, downscaled at best to the country, state or provincial levels. This is further aggravated by decline in the number of connected weather stations, disrepair, and low reporting from existing stations. 50% of the radar stations in Africa do not produce accurate data to predict hourly or even daily weather. A 7-day forecast in a high-income country can be more accurate than a one-day forecast in some low-income ones (Linsenmeier and Shrader, 2023). Another challenge is the digital divide preventing scaling of WCIS provided through mobile-based technologies despite their benefits (Ngigi et al, 2022).

The purpose of this policy brief is to highlight the challenges, opportunities, and recommendations for the use of IoT and AI technologies to offer cost-effective solutions for real-time weather monitoring and data-driven agricultural practices. This brief aims to inform policymakers about the potential of these technologies in enhancing the resilience of smallholder farmers to climate variability by providing accurate and timely weather information. It also seeks to advocate for the integration of decentralised weather monitoring systems within the national framework to ensure comprehensive coverage and accessibility for all farmers, particularly those in remote and underserved regions. By addressing these key areas, the policy brief underscores the critical need for supportive policies, funding, and infrastructure to facilitate the widespread adoption of these innovative solutions.

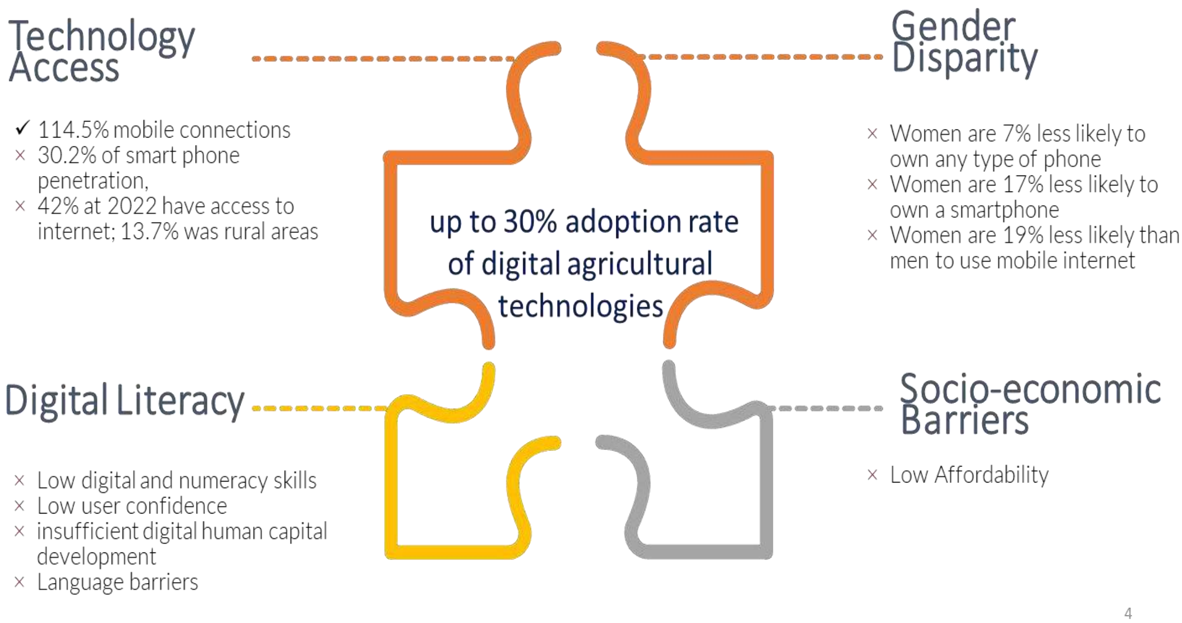

Figure 1: Barriers to adoption of digital agricultures technologies summarised from Kajilwa (2024), Kyalo (2023), Namara (2022) and Jeffrie (2024)

2. Rationale for the development and adoption of IoT and AI enabled mini- weather stations

IoT and AI technologies provide affordable solutions for real-time weather monitoring and data-driven agricultural practices through deploying mini weather stations that can collect localized weather data, important for informed decision-making at the farm level. These technologies address the challenge of traditional centralized weather monitoring systems, which often provide generalized weather data not representative of microclimates experienced by the smallholder farmer. Mini weather stations can provide hyper-localized real-time weather data, thus allowing farmers to make timely and informed planting, irrigation, and harvesting decisions. Designed to be low-cost and solar-powered, these mini weather stations become financially accessible and sustainable for smallholder farmers. This is paramount, especially in areas where resources are limited.

AI algorithms can analyse this data for accurate and timely weather forecasts and agricultural advisories at the local level. AI-powered systems can offer customized alerts and recommendations to farmers according to their particular needs and conditions. For instance, warnings about impending drought conditions can trigger farmers to adjust their irrigation schedule accordingly. Besides, AI algorithms can also transcend language barriers by providing weather forecasts and agricultural advisories in local languages, ensuring that even the illiterate farmer will be able to access the information.

This decentralised community-powered approach ensures that even remote and marginalised communities receive precise weather information, empowering smallholder farmers to adopt CSA technologies effectively. Many smallholder farmers are women, who often have less access to weather information and technology. WCIS technology related training programs can help bridge this gap, empowering women farmers with the information they need to succeed.

3. Methodology

Focus group discussions were held with key stakeholders in Busia County to align the project with existing climate-smart initiatives. Two sub-counties, Butula and Nambale, were selected for the pilot project, with specific farmer groups identified by local agricultural officers. A formative study using questionnaires was conducted with these groups to identify gaps in access and use of weather information. Participants were chosen through a purposive sampling technique to ensure diversity in age, gender, education, income, and location.

A community-powered weather network was developed consisting of three components: on-farm weather stations, a data processing centre, and AI-enabled user applications.

a) In-farm Weather Monitoring Devices: These devices include sensors for temperature, humidity, pressure, and UV index, transmitting data via mobile networks to a central database. The system is solar-powered for consistent operation.
b) Agro-climatic Data Processing Centre: This centre manages real-time data from the weather stations using a web application and APIs developed with React Native and Flask frameworks, facilitating centralised monitoring and data sharing.
c) Web and Mobile Applications: The data from the weather stations is used to provide 7-day weather forecasts and localised agricultural advice through a mobile app. The app includes a chatbot that delivers weather-based agricultural recommendations in *Swahili*, using a translation model and a knowledge base developed from the FAO Crop Calendar and KALRO data.

The usability of the mobile application was evaluated using the System Usability Scale (SUS), which assesses factors like ease of use and training requirements. The results provide insights into the application's effectiveness and user-friendliness.

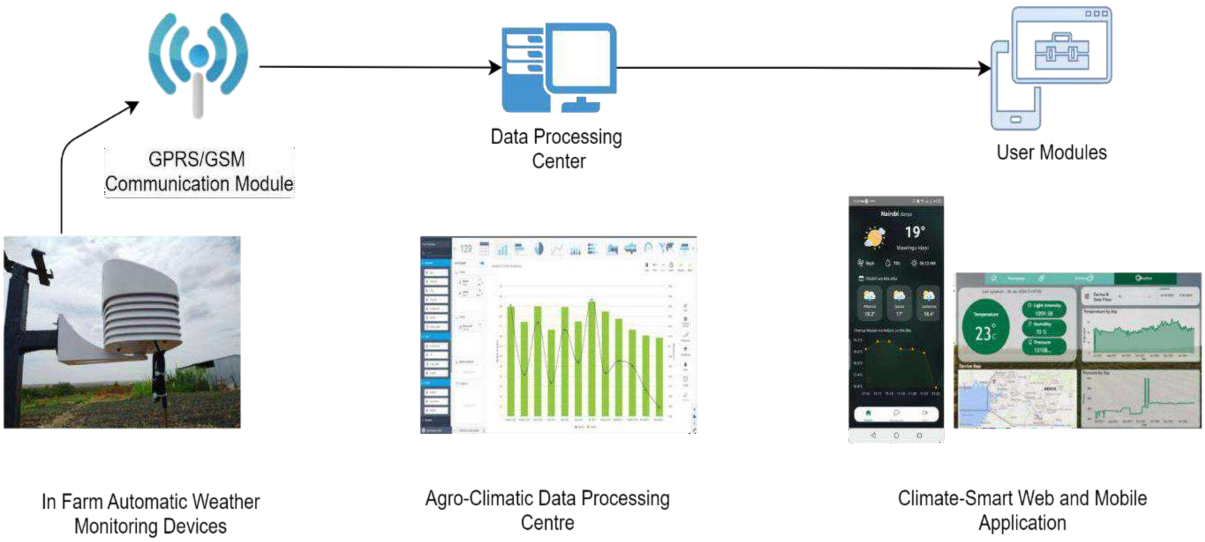

Figure 2: Mini-Weather Monitoring System Diagram

4. Major Findings

4.1 Understanding Farmers' Key Wants and Needs

Weather advisory services facilitate the access of farmers to knowledge, information, financial services, and technologies necessary for improving farm performance. However, it still remains a critical issue in rural settings due to insufficient funds for supporting public extension services, a lack of appropriate strategies for effective research on how to provide useful information on climate, and the limited coverage of extension services. In our analysis, we identified two main categories of challenges faced by smallholder farmers in accessing weather and climate information.

a) ***Access-related barriers,*** which include no access channels, poor network coverage, lack of access to devices, infrequent use, and challenges with the internet.
b) ***Use-related barriers***, which include low literacy levels, language barriers, poor quality information, lack of trustworthiness, irrelevance, and incomprehensibility.

Our analysis found that smallholder farmers face significant access related challenges when trying to obtain WCIS. The most prominent barriers identified are poor network coverage, a lack of access channels, no access to climate information and infrequent use of available channels. These obstacles limit smallholder farmers' ability to obtain information they need to make informed decisions leading to reduced yields and income.

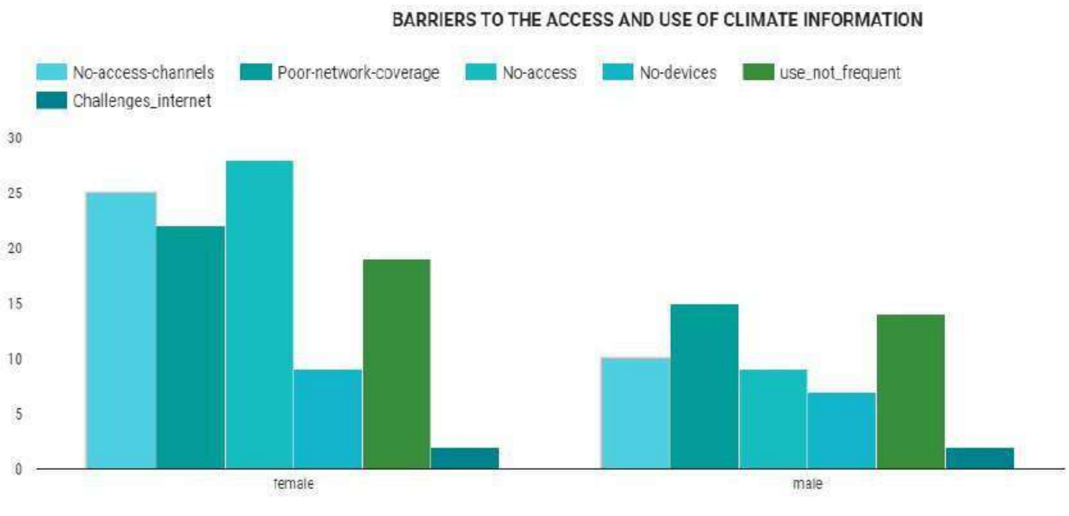

Figure 3 Reported barriers to access of weather and climate information from the formative study (n=65)

In terms of barriers to use WCIS for those who had access, the farmers surveyed reported that the weather and climate information provided is often not relevant to their specific needs, making it difficult to apply in their farming practices. Also, lack of comprehension was cited as a significant barrier to the adoption of digital climate advisory services. Low literacy levels make it difficult for farmers to comprehend the climate information provided particularly among women farmers. Furthermore, the quality and trustworthiness of the information provided were another concern shared among smallholder farmers. They often perceive the **information as not being of good quality and not trustworthy**, which can lead to a lack of confidence in using the information in their decision-making processes.

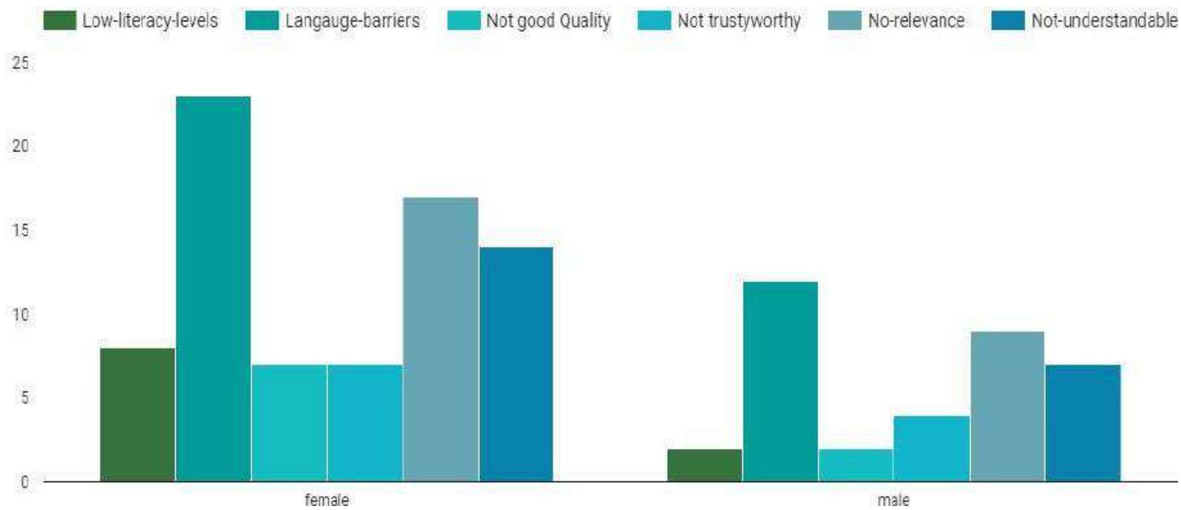

Figure 4 Reported barriers to use of weather and climate information from the formative study (n=65)

Our analysis of the survey revealed that both men and women farmers need regular weather forecasts, climate forecasts and the information of the start of the rainy season. However, women farmers were more likely than men to prioritise this information, perhaps due to their greater responsibility for household food security. Women also expressed a greater need for information on drought, pest outbreaks, wind direction and other extreme climate related risks that affect their agricultural activities. In contrast, men expressed less interest in wind direction, disease and pest outbreak and extreme weather conditions.

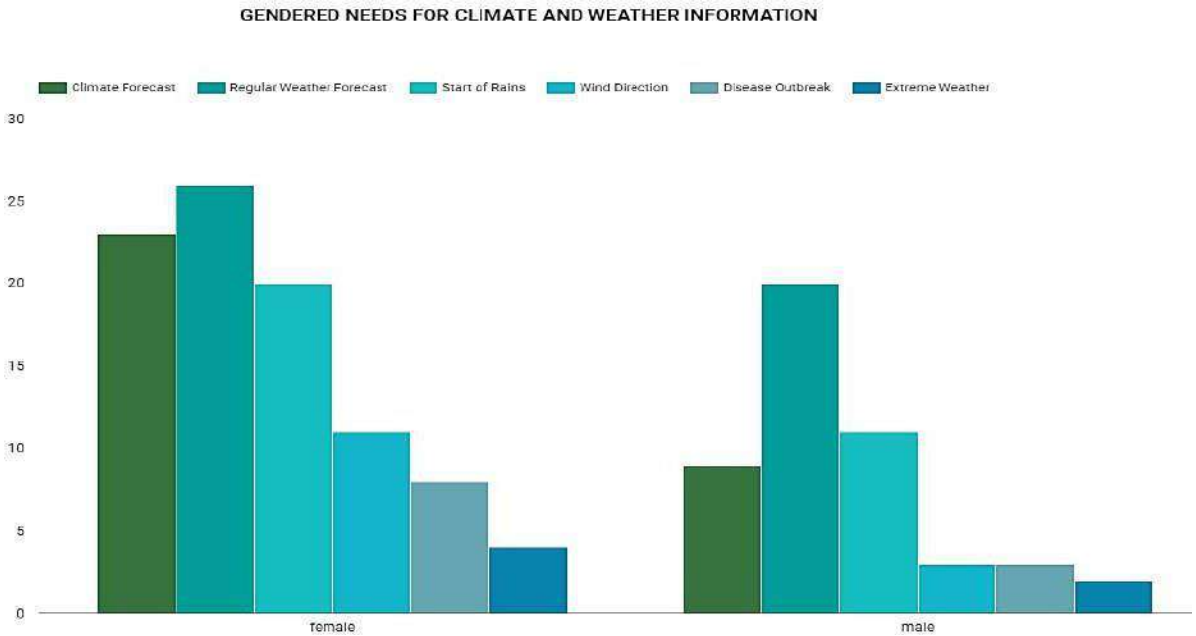

Figure 5: Smallholder farmer information needs disaggregated by gender based on the formative study (n=65)

4.2 Effective Development and Deployment of a Community-Powered Weather Network

We deployed 19 mini weather stations in selected areas, involving local farmer groups in the process to ensure community ownership and engagement. The mini weather stations were successfully designed to be low-cost, through local assembly of the components sourced from various suppliers and the use of solar-powered batteries to reduce reliance on grid electricity that can be prohibitive in rural areas. The use of durable components ensured that the stations could withstand environmental conditions and function reliably over time.

Figure 6: Deployed prototype of the mini-weather station

We validated the data collected by comparing the temperature and humidity data points with data provided by KARLO from their weather stations in the area and a weather API as ground truth. The validation showed good performance in terms of the selected error term in this case the root mean square error (RMSE) that shows the deviation from the mini weather station data and the ground truth datasets and correlation coefficient for temperature data. However, humidity data had a higher error rate when validated against KARLO weather stations compared to the Weather API.

Table 1: Validation of temperature and humidity data points from the mini weather stations (average)

Ground Truth Dataset	Temperature		Humidity	
	RMSE	Corr. Coefficient	RMSE	Corr. Coefficient
KALRO	1.9	0.70	25.92	0.41
Weather API	2.49	0.40	7.38	0.40

4.3 Insights on the Weather Champions Model: Engagement and Feedback from Smallholder Farmers

The development and deployment processes actively involved the local farmer groups, enhancing community ownership and ensuring that the stations were placed in optimal locations for data collection. Farmers participated in the co-design and decision-making process, determining where to install the stations and how to maintain them. Farmers provided guidance on the best practices for deployment such as installing in the house compound rather than the farm for enhanced security and also fencing to manage animal-tech conflict after seeing some devices knocked down by cattle.

Figure 7: Fencing of the mini-weather stations done by the farmers to counter theft and animal-tech conflict

To bridge the digital divide, 25 weather champions (11 men and 13 women), selected from within the farmer groups based on their existing leadership roles and ability to disseminate information within their communities, were trained on the installation and use of the mobile application. They were the intermediaries between the technology and the broader farming community. By relaying the weather forecasts and advisory, they helped other farmers, especially those who lacked access to smartphones, utilise the information to make informed agricultural decisions. Comprehensive training sessions were conducted to educate these champions and all farmers in the groups on how to apply the information to their farming practices. Special efforts were made to include female farmers in the training programs, helping to address gender disparities in access to agricultural information and technology.

Feedback was largely positive. The user facing mobile device got a System Usability Scale (SUS) scores of 68.5 for women and 66.8 for men suggesting a generally positive user experience. The farmers in the pilot reported using the daily weather forecasts to plan for daily activities such as during post-harvest drying of maize, farmers would check if rain was forecasted in the horizon to determine whether to leave their harvest out before they left the compound.

4.4 Challenges Posed by Regulatory Impediments

Decentralised community-powered weather data democratises access to reliable WCIS. The Kenya Meteorological department has attempted to decentralise its provision to county level but at a considerable cost. One study cites 15.6 million Kenya shillings to decentralise service provision to Kitui county level (Barrett, 2021). The mini-weather stations are small and inexpensive compared to the cost of deploying centralised weather data collection infrastructure. Co-design and development of AI/IoT solutions with smallholder farmer groups is a sure way of developing relevant AI tools that address the needs of the end users. Accurate, localised weather information provided by IoT and AI-enabled mini weather stations enhances farmers' resilience to climate variability and extreme weather events, promoting climate-smart agricultural practices. Additionally, the weather champion model bridges the digital divide by empowering community leaders with tools and knowledge who then disseminate these to the wider community. Moreover, working with women farmer groups, brings women to the table and ensures their active participation.

However, for widespread adoption, the network reliability especially in rural areas needs to be addressed. Areas in rural Kenya still lack reliable 2G and 3G network coverage, which limits the effectiveness of real-time data transmission from mini weather stations. This also limits smallholder farmers to access information using both analogue and digital means. As the country is looking to expand internet connectivity, we need to ensure that basic 2G and 3G networks are available and stable in all areas, especially remote areas. Additionally, regulations such as the proposed Meteorology Bill, 2023 could hinder the effective implementation of the decentralised community-powered model and weather champions as communication channels, potentially limiting farmers' access to crucial weather insights and undermining efforts to bridge the digital divide in underserved communities. Furthermore, the punishment for sharing such weather data without consent from the Meteorological Authority is extremely punitive and would disenfranchise those without access to data or information from authorised parties. The punishment includes a fine and/or prison time of up to two (2) years. The same is the case for using equipment which is yet to be approved by the Authority.

5. Conclusion

The deployment of IoT and AI-enabled mini weather stations offers a promising solution to enhance the resilience of smallholder farmers by providing accurate, localised, and timely weather information. These technologies empower farmers to make informed decisions on key agricultural practices, fostering climate-smart agriculture. The involvement of local communities, particularly through the Weather Champions model, ensures both engagement and widespread dissemination of critical weather data. However, challenges such as limited network coverage in rural areas and regulatory impediments threaten the scalability and effectiveness of these solutions. Addressing these issues through supportive policies, infrastructure investment, and regulatory reform is essential for the widespread adoption of innovative weather monitoring systems and the success of climate-smart agriculture initiatives.

6. Policy Recommendations

Recommendation 1: Incorporate community-powered weather monitoring systems within the mandate of the Kenya Meteorological Department authority under the Meteorological Bill 2024 to ensure regulatory compliance and nationwide scalability: The Meteorological Bill 2024 should be amended to formally discuss implementation of decentralised community-powered weather monitoring systems as part of the Kenya Meteorological Department's (KMD) mandate. This would ensure that these systems are recognized and regulated within the national meteorological framework. The licensing costs are yet to be implemented but if exorbitant would stifle innovation in this area and ownership by smallholder farmers. The bill should also be amended to recognise channels of communication within farmer groups and communities often done by intermediaries with access to information and technology. The critical actors to enable this are the Ministry of Environment and Forestry, Kenya Meteorological Department, legislators, and relevant parliamentary committees. Engagement with civil society organisations and farmer groups will also be critical to advocate for this amendment. The success of decentralised weather monitoring systems, such as the mini-weather stations, in providing hyper-localised, accurate weather data demonstrates their potential to enhance weather service delivery in remote areas. Various studies, have shown that localised weather information significantly benefits smallholder farmers by improving their ability to make informed agricultural decisions. Incorporating decentralised community-powered systems into the KMD's mandate would enable a more extensive and reliable weather monitoring network across Kenya, particularly in underserved regions. This could lead to improved agricultural productivity, better disaster preparedness, and more resilient farming communities.

Recommendation 2: Provide financial incentives, subsidies, and technical support to smallholder farmers and community groups for the purchase, installation, and maintenance of mini weather stations: The financial barrier to adopting new technology is significant for smallholder farmers. Ngigi et al. (2022) indicates that only 40% of Kenyan smallholder farmers access weather and climate information services due to high costs and lack of technical expertise. The Ministry of Agriculture, Livestock, Fisheries, and Cooperatives, financial institutions, and development partners such as NGOs and international organisations should develop and implement financial schemes such as subsidies, grants, and low-interest loans to make decentralised weather monitoring systems affordable for smallholder farmers. Smart contracts and tokens can be used as a means of coordinating and incentivising uptake by communities whereby they can receive rewards when the data is accessed and used by 3rd party users. Additionally, provide technical support for the installation and maintenance of these systems. Collaboration with county governments will be essential to implement these incentives at the local level. Providing financial and technical assistance could boost adoption rates and ensure the long-term sustainability of these systems. Increased adoption of decentralised weather monitoring systems will lead to more comprehensive data collection, enhancing the accuracy of weather forecasts and agricultural advisories. This will empower farmers to make better decisions, ultimately improving crop yields and livelihoods.

Recommendation 3: Implement ongoing training programs for farmers, focusing on the use of localised weather data for agricultural decision-making, with a particular emphasis on reaching women and marginalised groups: Training and capacity-building initiatives are critical for the effective utilisation of weather and climate information services. The analysis from the formative study shows that lack of comprehension and low literacy levels are significant barriers to using these services. Tailored training programs can address these challenges, making weather information more accessible and actionable for all farmers. We found that empowering farmers with the knowledge to use localised weather data effectively will enhance their ability to adopt climate-smart agricultural practices. This can lead to better resource management, reduced crop losses, and increased resilience to climate variability. The Ministry of Agriculture, local extension services, agricultural training institutions, and NGOs working in rural development should establish and sustain training programs focused on educating farmers about the benefits and practical uses of localised weather data for agricultural decision-making. Special emphasis should be placed on reaching women and marginalised groups through tailored programs. From the research we found collaborating with community-based organisations and farmer cooperatives can help deliver these programs at the grassroots level.

Recommendation 4: Work with telecommunications providers to improve GSM/GPRS network coverage in rural and remote areas: This can be achieved through incentives or public-private partnerships aimed at expanding network infrastructure to underserved regions. The research found a critical lack of reliable network coverage as a major obstacle to real-time data transmission from mini weather stations and to accessing weather information via mobile applications. The digital divide in Kenya persist particularly in rural areas where network infrastructure is limited. Addressing this gap is essential for the success of decentralised weather networks. Improving network coverage will enable real-time data transmission from weather stations, ensuring that farmers receive timely and accurate weather updates. This will enhance their ability to respond to weather events and make informed decisions, contributing to improved agricultural productivity and resilience. The Ministry of ICT, Innovation and Youth Affairs, the Communications Authority of Kenya, telecom companies should work together to expand GSM/GPRS network coverage in rural and remote areas. This can be achieved through public-private partnerships (PPPs) and incentives for telecom companies to invest in underserved regions.

References

Autio, A., Johansson, T., Motaroki, L., Minoia, P., & Pellikka, P. (2021). Constraints for adopting climate-smart agricultural practices among smallholder farmers in Southeast Kenya. Agricultural Systems, 194, 103284. doi.org/10.1016/j.agsy.2021.103284.

Brooke, J. (1996). SUS-A quick and dirty usability scale. Usability evaluation in industry, 189(194), 4-7. Available at: https://www.taylorfrancis.com/chapters/edit/10.1201/9781498710411-35/sus-quick-dirty-usability-scale-john-brooke

Cline, W. R. (2007). Global warming and agriculture: Impact estimates by country. Peterson Institute. Available at https://www.piie.com/bookstore/global-warming-and-agriculture-impact-estimates-country

Food to Market Alliance. (2022). FtMA Kenya Country Brief. Available at https://ftma.org/wp-content/uploads/2022/02/FtMA_Kenya_CountryBrief_Dec-2022.pdf

Kajilwa, G. (2024, February 21). Why digital technologies are out of reach for smallholder farmers. The Standard. Available at: https://www.standardmedia.co.ke/business/enterprise/article/2001490325/why-digital-technologies-are-out-of-reach-for-smallholder-farmers

Jeffrie, N. (2024). The Mobile Gender Gap Report 2024. GSMA. Available at: https://www.gsma.com/r/wp-content/uploads/2024/05/The-Mobile-Gender-Gap-Report-2024.pdf?utm_source=website&utm_medium=button&utm_campaign=gender-gap-2024

Kyalo, C. (2023). State of Internet Penetration in Kenya. KICTANet Think Tank. Retrieved July 31, 2024, from https://www.kictanet.or.ke/state-of-internet-penetration-in-kenya/

Government of Kenya [GoK]. (2017). Kenya Climate Smart Agriculture Strategy-2017-2026. . Available at https://adaptation-undp.org/resources/plans-and-policies-relevance-naps-least-developed-countries-ldcs/kenya-climate-smart

GoK. (2023). The Meteorology Bill 2023. Available at http://www.parliament.go.ke/sites/default/files/2023-08/THE%20METEOROLOGY%20BILL%2C2023.pdf

Linsenmeier, M., & Shrader, J. G. (2023). Global inequalities in weather forecasts. SocArXiv 7e2jf, Center for Open Science. Available at https://osf.io/download/65727b2a666e10023d1a7d6f/

Namara, E. (2022). $22 Millon Investment Needed to Connect 2300 Anchor Institutions in the Most Unconnected Counties in Kenya. Alliance for Affordable Internet. Available at https://a4ai.org/news/22-millon-investment-needed-to-connect-2300-anchor-institutions-in-the-most-unconnected-counties-in-kenya

Ngigi, M. W., & Muange, E. N. (2022). Access to climate information services and climate-smart agriculture in Kenya: a gender-based analysis. Climatic Change, 174(3), 21. Doi: 10.1007/s10584-022-03445-5.

Njeri, M. (2024, July 31). Senator Aaron Cheruiyot Amends Meteorological Bill to Introduce Ksh5 Million Fine and Mandatory Permits. Kenyans.co.ke. Available at https://www.kenyans.co.ke/news/103289-senator-aaron-cheruiyot-amend-meteorological-bill-introduce-ksh5-million-fine-and

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