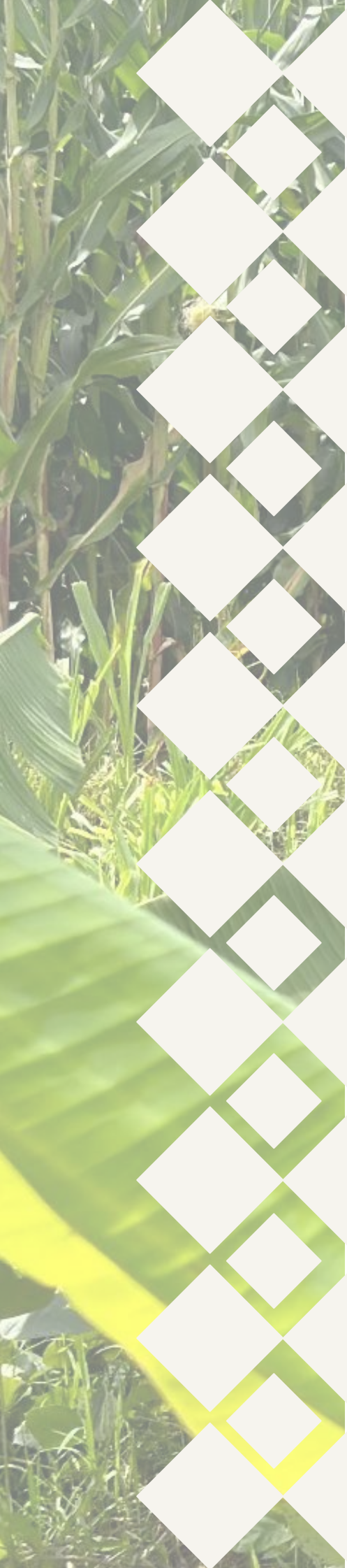

tomorrownow.org

# OSIRIS

# SYNTHESIS

# REPORT

**NOVEMBER 2023**

BILL & MELINDA GATES *foundation*

tomorrow.io

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EXECUTIVE

# Executive Summary

The OSIRIS project was an ambitious 18-month undertaking to demonstrate the power of next generation weather data, tools and analytics to revolutionize small-scale agriculture on a data-sparse African continent. By enabling close partnerships with key weather intelligence, seed breeding, and crop modeling ecosystem stakeholders, including CGIAR, Regrow, and Tomorrow.io, the project assessed the transformative potential of weather and climate technologies for enhanced seed breeding outcomes.

Concentrating on closing the weather data gap and transforming forecasts into practical insights, the project has significantly advanced understanding of the requirements of trial managers and data scientists. This progress has led to the development of a new high resolution historical reanalysis data set for East Africa that has been made available through multiple open platforms. These efforts are crucial in facilitating informed decision-making, optimizing crop yields, and strengthening food security.

OSIRIS was oriented around the ***hypothesis*** that ***innovative weather data and tools can improve smallholder economics and food security in our changing climate***.

The ***hypothesis was tested*** through the ***focused application of breeding trials to develop advanced crop varieties in East Africa.*** Data/tools were developed to enable and assess the usefulness of advanced weather technologies through the lens of specific users at different value chain points, including the crop modeling community and on-site farm managers, especially women.

In conclusion, the OSIRIS project's results offer encouraging evidence supporting the hypothesis that innovative weather data and tools can significantly enhance the smallholder ecosystem, and bolster food security in the face of climate change. Validation studies conducted with key partners, including CGIAR and Regrow, have affirmed the substantial benefits and impact of utilizing higher resolution historical reanalysis data on breeding outcomes, underscoring the vital role of data accessibility in these efforts.

# Executive Summary

The **key learnings** from the project:

1. Six key factors currently influence the adoption of weather data & tools across the seed breeding ecosystem:

- Data accessibility
- Data quality
- Data relevance
- Timely delivery of data
- Data presentation
- Affordability

2. Data accessibility remains the single biggest factor influencing the uptake of weather data & tools in East Africa.

3. Validation is critical for de-risking and iterating/improving weather technologies for local adoption/uptake. Validations require infrastructure and expertise external to the companies engaged for food system-specific applications.

4. Next-generation weather innovations have the potential to provide critical value to food systems severely impacted by limitations in the quality and accessibility of weather & climate data. The potential of the data being generated goes well beyond the three use cases tested in Osiris phase one. Several different models could enable maximum reach, adoption, impact and sustainability of data.

5. New commercial weather assets such as Tomorrow.io's CBAM can dramatically improve the usability and usefulness of data for R&D and small-scale producer (SSP) applications. There is also a massive opportunity for future space-radar capabilities identified within the seed breeding ecosystem and broader SSP applications. Efficient and effective access to data is as important to breeding scientists as the quality and accuracy of weather and climate data.

6. The role of trial managers differs greatly between trial management programs across East Africa with different personas, each with specific weather intelligence needs.

7. The temperature measurements derived from the CBAM reanalysis outperformed all existing climate data sets and enhanced crop variety modeling outcomes by more than 40%.

8. The rainfall and solar radiation measurements derived from CBAM requires significant bias adjustments to ensure future adoption.

SUMMARY

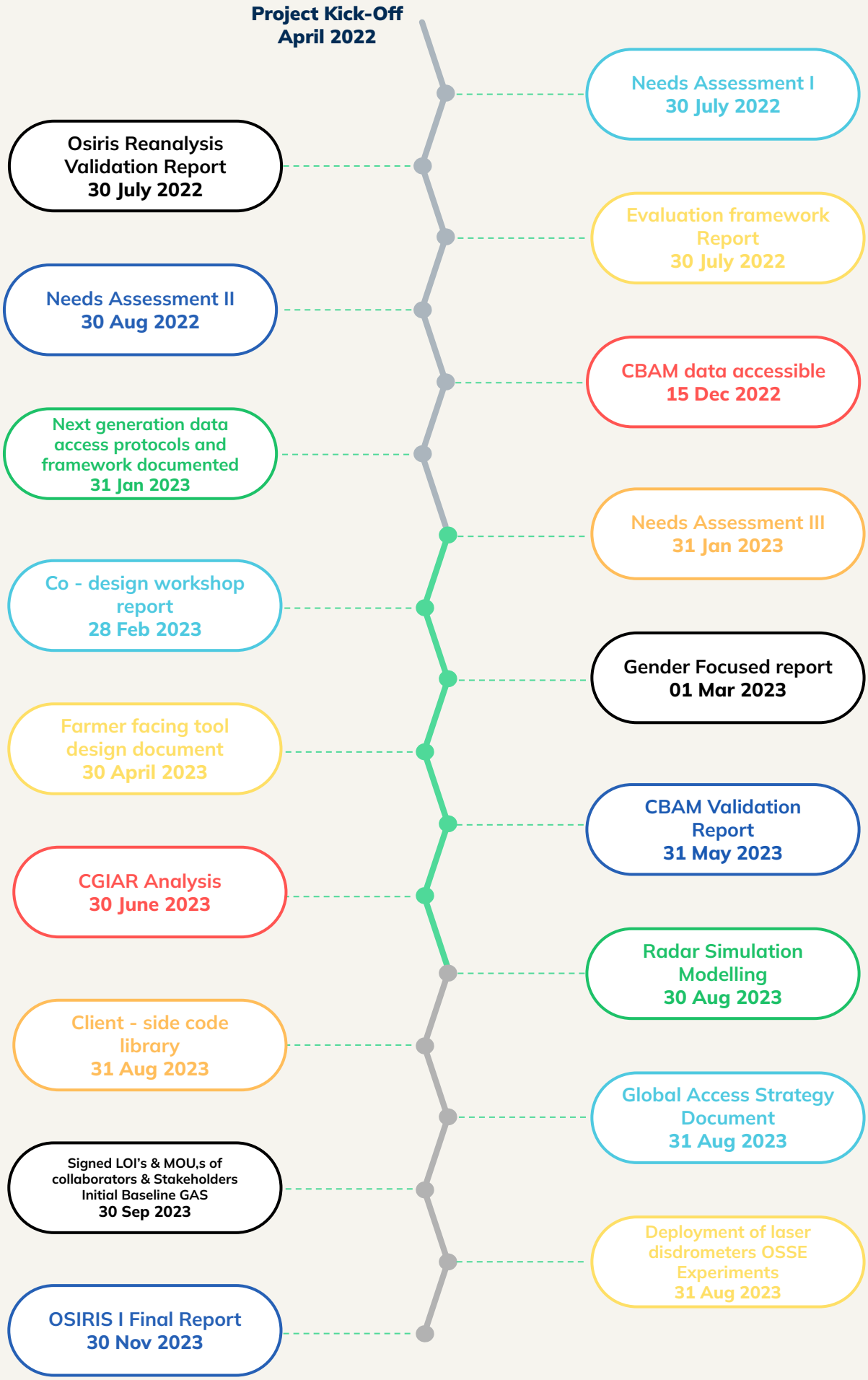



**Figure 1: OSIRIS Project Timeline**

# Project Progress Reporting per Outcome

## Outcome 1: Tools to interpret breeding outcomes at sites as a function of spatially and seasonally varying agro-climatic weather drivers

Outcome 1 encompassed the dynamic downscaling and reanalysis of weather data for crucial regions in Sub-Saharan Africa, utilizing Tomorrow.io's proprietary cloud-native CBAM. This process included a comparative analysis of this product with existing benchmarks such as CHIRPS, NASA POWER, and ERA5, specifically for precipitation and surface meteorology. Furthermore, the outcome involved a thorough assessment of the enhancements in these data resulting from the integration of data from precipitation radar satellites, which are scheduled for launch by Tomorrow.io.

Outcome 1 deliverables included:

- The undertaking of a needs assessment study to identify needs and opportunities for improved weather intelligence in support of seed trials
- The development of an evaluation and validation framework for Tomorrow.io's CBAM Reanalysis over East Africa
- The development of a data store with ground-based data for assimilation and/or performance benchmarking
- A summary of the results of Tomorrow.io's Comprehensive Bespoke Atmospheric Model (CBAM) reanalysis
- The development of a data portal and custom API

**Recommendation**:

To address the challenge of coarse, inaccurate, or agronomically irrelevant data, and the limitations in current tools for retrieving and summarizing time series data for trial outcomes, the project proposes the creation of an advanced benchmark dataset for East Africa.

This dataset will be complemented by the development of an online platform and tools designed for ease of access and utilization by breeders, including those at CGIAR. This initiative will be aimed at enhancing the quality and relevance of agricultural data, thereby improving trial outcomes and overall agricultural practices in the region

In the following, we will summarize each activity and synthesize the key outcomes, learnings, and recommendations.

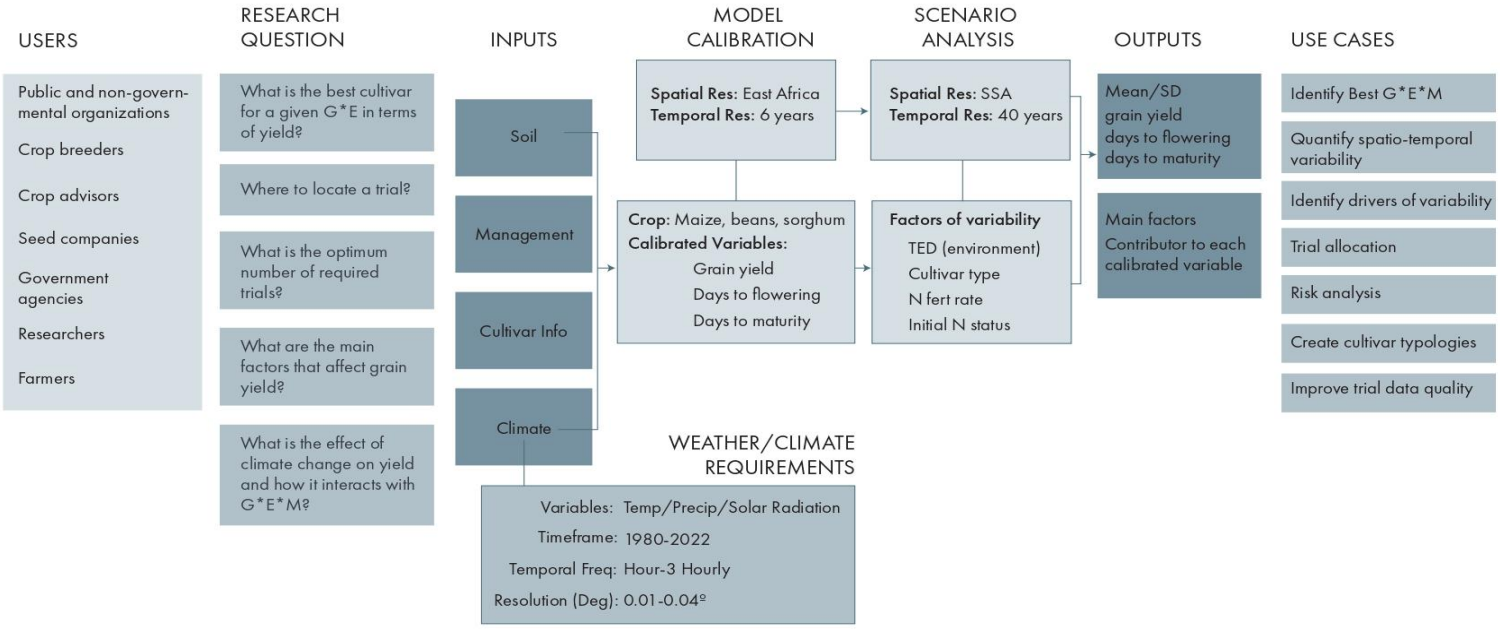



**Figure 2: Crop Modeling Value Chain**

# 1.1a - Needs Assessment 1: Weather and Climate Tools in Support of Data-Driven Seed Trial Analysis

**Hypothesis**

Next-generation weather technologies have the potential to improve breeding trial outcomes by ensuring better quality input data of higher spatial and temporal resolution in support of enhanced trial analysis.

The **goal of this needs assessment** was to identify the needs, limitations, and opportunities for improved weather innovations that have the potential to transform agriculture, help overcome climate challenges, and initiate the next plant breeding revolution.

According to CGIAR research, efficient access via API's to quality **climate data was identified to be the single most important environmental factor in crop models**. This finding suggested the need for scientists or seed breeders to access high-quality climate data to develop new crop varieties.

The study **recommends** the provision of high-resolution temperature, rainfall, and solar radiation data through efficient APIs. This data could include providing regional climate reanalysis to support trial analysis on independent local observations, improving precipitation measurements, and increasing spatial and temporal resolution.

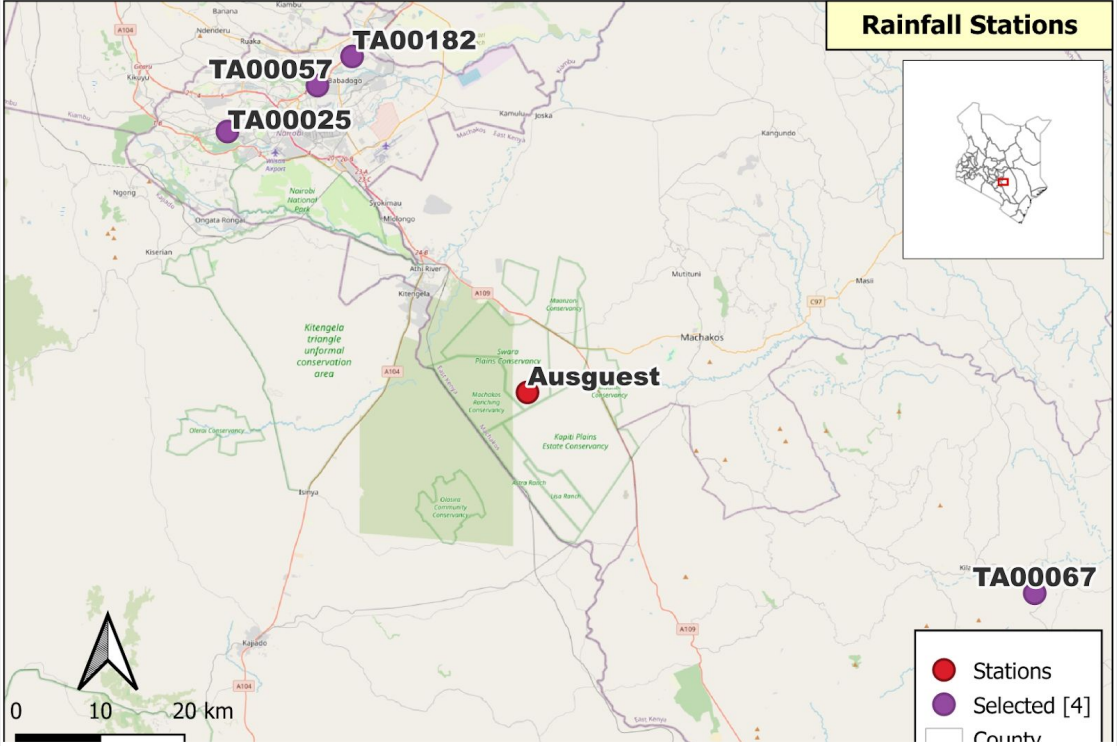



**Figure 3: Location of 5 rainfall stations used to evaluating CBAM's model performance on precipitation**

# 1.1b & 1.2: Osiris Reanalysis Framework Report

This report summarizes the proposed evaluation and validation framework of Tomorrow.io's CBAM Reanalysis over East Africa. It provides an evaluation focused on known and valuable quantities in the agricultural sector (i.e., precipitation and surface temperatures) while using familiar and relatable metrics in the sciences, particularly in atmospheric and climate science. This evaluation was critical in understanding breeding outcomes in assimilating geospatial inputs.

The key insights of this report can be summarized as follows:

1. The evaluation focused on precipitation and surface temperatures, essential factors in the agricultural sector.

2. The evaluation framework uses familiar and relatable metrics in atmospheric and climate science.

3. Independent, non-assimilated observations representative of the bioclimatic diversity and geographic uniqueness are used for validation.

4. Two observation networks, TAHMO and NCAR GLOBE, are identified for use in the reanalysis.

5. Data quality and completeness of the observation networks are assessed, including a comparison with existing meters for data quality.

6. The document discusses data quality assessment, including using median absolute deviation (MAD) as a summary statistic.

7. The report also included the establishment of definite thresholds for discrete meteorological criteria, such as precipitation occurrence and accumulation.

Overall, the report aimed to evaluate the performance of CBAM Reanalysis in terms of precipitation and surface temperatures using familiar metrics in atmospheric and climate science.

# 1.3a: Cloud-accessible Climate Reanalysis data set for East Africa

Tomorrow.io's CBAM is a customized version of the Weather Research and Forecasting (WRF) model configured with two-nested domains: a 12-km domain covering much of northeastern Africa and a 4-km domain to cover the region of interest which includes Kenya, Tanzania, Uganda, Burundi, and Rwanda (Figure 1). The CBAM reanalysis utilizes the European Center for Medium-Range Weather Forecasting Fifth Generation Atmospheric Reanalysis (ERA5) as the initial and time-dependent boundary conditions. All publicly available METAR and radiosonde data are assimilated into the reanalysis using four-dimensional data assimilation.

The CBAM reanalysis has been completed from January 1, 2012, through December 31, 2021, providing hourly analysis. Output fields include 2-m temperature, 2-m dewpoint, 2-m relative humidity, 10-m wind speed and direction, 10-m wind gust, surface pressure, mean sea level pressure, 1-hour accumulated rainfall, and global horizontal irradiance (GHI).

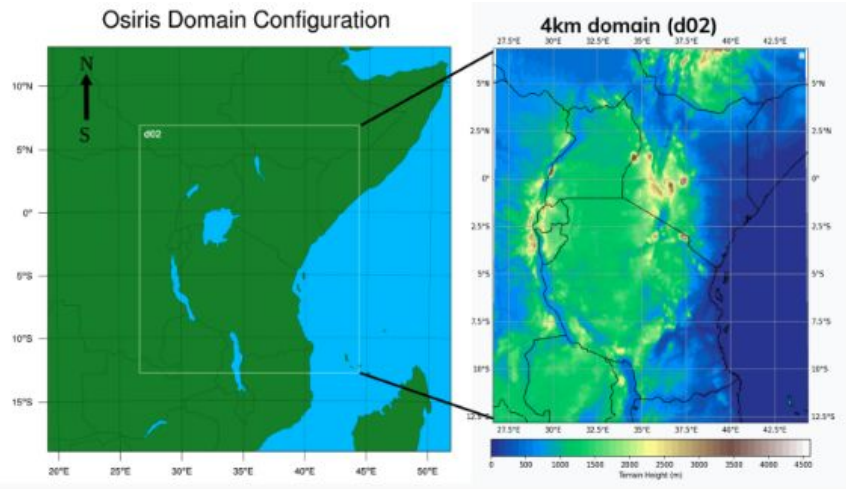



**Figure 4. Left:** CBAM nested domain configuration. **Right:** CBAM domain 2 reanalysis area with terrain (m; shading).

**Image 1:** TomorrowNow & Kenya Space Agency teams at the official partnership launch

Through partnership with Kenya Space Agency, TomorrowNow is hosting the CBAM reanalysis dataset on a data sharing platform by Source Cooperative, a neutral, non-profit data-sharing utility that allows trusted organizations to share data without purchasing a data portal SaaS subscription or managing infrastructure.

**CBAM Global Access Repository:** https://beta.source.coop/repositories/ksa/1000/description

# 1.3b: OSIRIS Reanalysis Verification Report

This report provides the results of the Comprehensive Bespoke Atmospheric Model (CBAM) reanalysis against available observations and independent reanalysis products, i.e., CHIRPS, AgERA5 NASA Powers, with attention to enhanced spatial and temporal variance for key agrometeorological variables.

The main findings and conclusions of the verification report on the Tomorrow.io Osiris Reanalysis and its comparison to other datasets are as follows:

1. Tomorrow.io's CBAM daily total precipitation skill surpassed AgERA5 and NASA Power datasets while exceeding that of the CHIRPS dataset for small precipitation thresholds but significantly overpredicted large rainfall events.

2. Accuracy of daily temperature indicators (mean, minimum, and maximum) from CBAM exhibited improvement relative to NASA POWER and similar performance to AgERA5.

3. The mean absolute error and bias in daily total solar radiation from CBAM were slightly higher compared to AgERA5, closely aligning with NASA POWER. A comprehensive evaluation was limited due to insufficient ground validation sensors, necessitating further investigation prior to extended use. CBAM data had higher spatial and temporal resolution than gridded data sets, enabling agronomic analysis and applications at finer scales.

4. Further improvements in CBAM reanalysis are being investigated to reduce bias and errors and bring the reanalysis closer to observed values.

In summary, the report presents CBAM's performance against observations and reanalysis products, i.e., CHIRPS, AgERA5 NASA Powers, with attention to enhanced spatial and temporal variance for key agrometeorological variables.

This analysis paid special attention to enhanced spatial and temporal variance for key agro-met variables as an activity under Outcome 1. The verification report highlighted Tomorrow.io's CBAM reanalysis performance as superior in precipitation skill and comparable in temperature indicators. It emphasized CBAM data's higher spatial and temporal resolution, which is suitable for fine-scale agronomic analysis.

However, ongoing efforts aim to improve accuracy and reduce bias in rainfall and solar radiation measurements.

# 1.4a: Data Access Frameworks for Next-Gen Weather Technologies

The report assesses data access protocols and recommends a framework relevant to weather intelligence platforms that will allow actors from the seed breeding ecosystem to analyze data and enable analysis-ready data (ARD) discovery, access, and distribution. The aim was to optimize data access to weather intelligence platforms cost-effectively and efficiently for seed breeders and provide recommendations for current and future data access protocols.

The report includes data storage, discovery, access, and distribution recommendations.

1. Storage

a. Data such as netCDF files and cloud-optimized geoTIFFs (CoGs) can be stored in an object store like AWS S3.

b. Structured or relational data, like weather station or laser disdrometer data, is better stored in a relational database like PostgreSQL with the PostGIS spatial extension.

2. Discovery

a. Data intended for widespread use should be well-indexed and searchable via general web search tools and search tools on specialist platforms.

b. Comprehensive metadata is crucial for successful search, citation, and trust.

c. The STAC (Spatio-Temporal Asset Catalog) specification is recommended for describing geospatial information and enabling easier indexing and discovery.

3. Access and Distribution

a. Weather intelligence companies are encouraged to open access to their data for scientific users, who often have low or no budget and require fast access to large datasets and computing resources.

b. Scientific users need access to raw data, ideally in an "analysis ready" format, along with sufficient metadata and the ability to filter or select subsets based on dimensions or metadata fields.

c. Data should be available in open, widely-used formats and protocols to serve a wider community.

Additionally, the report also gives recommendations to weather intelligence companies. Some of these recommendations include:

1. Open access to data that meets scientific computing requirements, including raw and "analysis-ready" data.

2. Provide sufficient metadata to describe and filter/select subsets of data based on dimensions or metadata fields.

3. Consider providing resources for scientific users to perform their computations.

# 1.4b: CGIAR Technical Report Enhanced Crop Variety Evaluation (Use Case 1)

**This report analyzes the impact and value of the CBAM temperature, rainfall, and solar radiation data in supporting crop variety analytics through the Plackett-Luce model compared to existing models such as NASA Power and ERA5.**

The findings of this study are summarized as follows:

1. CBAM temperature measurements indicate an enhanced ability to delineate agroecological zones in Rwanda. Precipitation estimates from CBAM, however, degraded the model results compared to the other models. Conversely, both NASA POWER and AgERA4 demonstrate improved performance in groundnut production in Tanzania.

2. CBAM shows enhanced model performance for various recommendations in complex terrains, like the case of Rwanda highlands. Conversely, NASA POWER and AgERA5 performed well in Tanzania, where data samples are limited and the landscape is homogenous.

3. CBAM is a reliable data source for ranking Rwandan potato varieties. Decision makers in Rwanda can utilize CBAM to track agroclimatic variability and recommend types, considering performance and risk mitigation. In Tanzania, CBAM is less strong than the other models. All three models identified ICGV-SM 16593 as the top groundnut variety regarding winning probability and worst regret.

A comparison of the three climate models indicated variations in accuracy and reliability among the models in predicting crop yields and climate conditions. Regarding accuracy, the CBAM model enhanced performance in delineating agroecological zones in Rwanda based on temperature measurements. However, the precipitation estimates from CBAM degraded the model results compared to the other models. On the other hand, both NASA POWER and AgERA5 demonstrated improved performance in groundnut production in Tanzania.

Regarding reliability, CBAM demonstrated enhanced model performance for various recommendations in complex terrains like the Rwanda highlands. This suggests that CBAM is better suited for areas with diverse topography. In contrast, NASA POWER and AgERA5 performed well in Tanzania, where data samples are limited, and the terrain is more homogenous.

The benchmarking results highlighted the importance of selecting the appropriate climate model based on the target region's specific agro-ecological conditions and terrain characteristics. The accuracy and reliability of each model can vary depending on the location and the specific crop being evaluated.

# 1.5a&c: Satellite Constellation for Rainfall Monitoring in East Africa

The report covers the development of radar simulation and rain retrieval methods by Tomorrow.io for the East Africa region, using training data from NASA/JAXA's GPM mission observations. These algorithms are undergoing validation with data from Tomorrow.io's Pathfinder R1 and R2 satellites. The launch of the full TRAKR constellation, including the Rain-mapping, Adaptive Ka-band Radar (TRAKR) satellites, is anticipated by late 2025. Furthermore, Tomorrow.io intends to deploy a series of microwave sounders capable of estimating precipitation profiles. While these instruments offer more frequent revisits, they have a lower resolution than the TRAKR satellites.

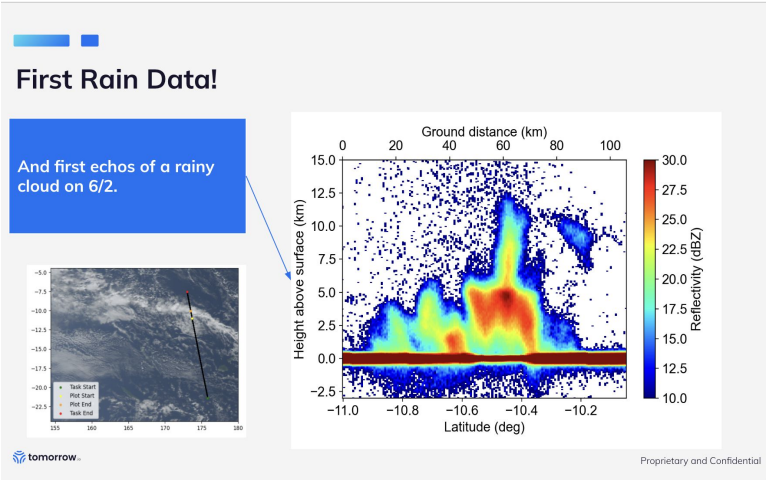



**Figure 5: First science data collected by the Tomorrow-R1 Pathfinder on June 24, 2023** **Left:** Satellite ground track overlaidon GOES-18 true-color composite satellite image. **Right:** Profiles of measured reflectivity, retrieved precipitation particle size, water content, and precipitation rate

The key insights and takeaways from the report include:

1. Tomorrow.io is implementing a novel two-step retrieval algorithm for accurate precipitation rates using Ka-band radar measurements. The algorithm uses a data-driven neural network technique that provides statistics of the probability distribution of precipitation profiles. The training data for the algorithm is sourced from the dual-frequency retrievals from the NASA/JAXA GPM mission.

2. The Tomorrow.io Radar Constellation is expected to improve spatiotemporal coverage compared to ground-based measurements. The sounder constellation will provide more frequent observations and critical inputs for weather forecasts.

3. The TRAKR and TMS constellations could improve nowcast lead time by nearly an hour. The typical lead times for warnings driven by real-time precipitation data and nowcasts are 15-30 minutes.

4. The NWS Warn-on-Forecast project aims to improve warning lead times by 10 to 20 minutes. The accuracy of the nowcast and precipitation retrievals varies over time, with radar observations losing value relative to geostationary observations after 1-2 hours.

**This report successfully demonstrated the new rainfall retrieval algorithm based on satellite inputs and the performance of simulated radar data. The outcomes provide insight into understanding precipitation as an agro-climatic weather driver.**

# 1.5b: Deployment of five laser disdrometers to enhance evaluation of Pathfinder satellite in East Africa

The project initiated the deployment of a set of state-of-the-art laser disdrometers at five locations across Kenya and Rwanda in convectively active areas of the continent. These sensors will accurately measure the true surface rainfall rate and provide detailed information on the size distribution of individual precipitation particles, a technical detail crucial for transforming radar observations to rain rate.

Successful deployment of two disdrometers has already been achieved. The inaugural sensor found its home at Maseno University in Kisumu, Kenya, while the second was set up in Kayonza, Rwanda, through a collaboration with One Acre Fund. Plans are in place to install the remaining three sensors by February 2024. These will be under the management of the Kenya Meteorological Department, with locations set for Nairobi, Mombasa, and Moi University

| Locations | Reliable Partner |
|---|---|
| Nairobi, Kenya | KMD |
| Eldoret, Kenya | Moi Univ |
| Kisumu, Kenya | Maseno Univ |
| Mombassa, Kenya | KMD |
| Kayonza, Rwanda | OAF |

**Image 2:** A laser disdrometer deployed in Maseno University (Kisumu, Kenya)

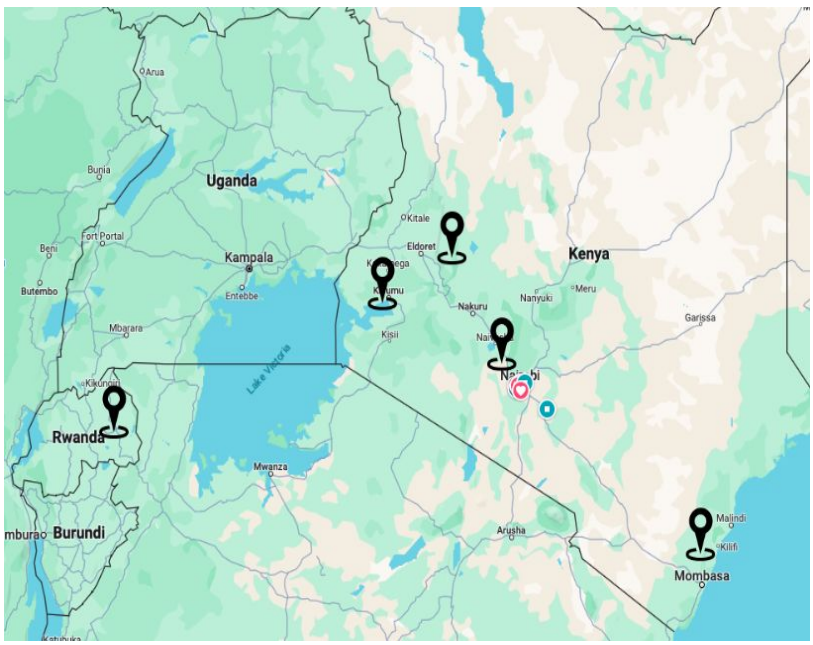



**Figure 6:** Location of sites for 5 deployed laser disdrometers in East Africa

# 1.6b: Global Access Strategy

The document describes TomorrowNow.org and Tomorrow.io's commitment to ensuring global accessibility of developments from the OSIRIS Project. Their mission is to make new technologies and ideas available, accessible, and affordable for users in Africa, particularly in East Africa.

The document emphasizes the dissemination of knowledge and the availability of products and services resulting from the project at a reasonable cost to those in need. It also highlights the importance of managing intellectual property assets for global access.

A detailed technical document is being developed to provide more information on data sets, background technology, IP rights, platforms for dissemination, and the development and post-project plan for OSIRIS.

The **key insights and takeaways** from the strategy are as follows:

1. Contracts have been signed with sub awardees and relevant partners such as Tomorrow.io and TAHMO

2. Contracts have been drawn up with relevant parties such as OAF,  Kenya Space Agency and KMD

3. TAHMO network has deployed three disdrometers and with remaining two to be installed in January 2024. All data is available via API

4. Open access to OSIRIS CBAM reanalysis data  for East Africa is provided through platforms such as Kenya Space Agency and Radient Earth Source Cooperative global platforms

https://beta.source.coop/repositories/ksa/1000

# Project Progress Reporting per Outcome

## Outcome 2: Tools to apply insights from trial sites to farm fields

Validating tools to extend knowledge from trial farm sites to user farm sites.

Outcome 2 extended crop simulation of the 1000Farms and One Acre Fund Fund trial data across Kenya and Rwanda based on the APSIM model with inputs from CBAM and other climate models. The project aimed to demonstrate the impact and value of better quality climate data on APSIM model outputs for specific crops such as beans and maize.

Main deliverables included:

- The undertaking of a needs assessment with Regrow (Niche project) to better understand the needs within Crop Simulation modeling
- Preparation of a validation report for CBAM data through APSIM crop simulation
- Development and customization of the Bestiapop Python package to automatically generate and visualize CBAM gridded climate data for crop model applications within the APSIM software

**Recommendation**:

To overcome data quality and access limitations associated with gridded data in existing models and the lack of tools for applying these models to large, gridded datasets, the project proposes the development of user-friendly tools that simplify access to validated and localized data for multi-site trial locations.

Additionally, we propose the development of design methods for effectively applying predictive models to these gridded datasets, thereby enhancing the utility and accuracy of model outputs for practical agricultural applications.

# 2.1: Needs Assessment 2: Importance of Weather and Climate Tools in Supporting Crop Modeling for Improved Breeding Outcomes.

**Hypothesis**

Innovative new weather technologies have the potential to improve crop modeling efforts currently limited by the quality of available gridded climate data.

The **goal of this needs assessment** was to understand further the role of improved weather innovations that can transform agriculture, specifically focusing on the needs, limitations, and opportunities for improved weather innovations within crop simulation modeling and its potential to enhance seed breeding outcomes.

**High-quality weather data was essential for accurate yield situation modeling**, which helps understand crop responses to climate variability and change. Weather data also supports risk analysis and helps improve trial data quality. Furthermore, it supports the classification of cultivars based on environmental factors.

Developing countries in Africa face challenges in obtaining quality weather data due to the scarcity and poor quality of observation data in many agricultural areas. A need was identified for weather data with higher spatial resolution (<5km) to capture the variability in climatic conditions across different regions. This will enable more accurate and localized crop modeling and seed breeding.

As a **recommendation**, efforts should encourage enhanced collaboration between stakeholders, weather data providers, and breeding programs to ensure better data collection and sharing. Data standardization is also necessary to make datasets efficiently usable. Finally, there is a need to enhance the quality of climate models and data outputs. This includes producing model performance results, clearly defining model uncertainties and limitations, and incorporating innovative weather technologies to improve the accuracy of climate data.

# 2.2a: Use Case 2 - Analysis of APSIM crop simulation outcomes using CBAM vs NASA to assess ROI in Rwanda

This report assesses the accuracy of three global climate datasets for maize yield simulations using Rwanda's APSIM crop production model. The objectives were:

1. Assess similarities/differences between weather station data (WS), NASA POWER (NP), and Custom Bespoke Atmospheric Model (CBAM) datasets. The variables under scrutiny encompass minimum and maximum temperature, rain, and radiation.

2. Assess the accuracy of simulated maize yield using weather stations, NASA POWER, and CBAM weather data relative to observed maize yields from maize trials in Rwanda.

CBAM temperature data has shown evidence of improving crop simulation model outcomes and improving yield estimates at trial sites. However, CBAM rainfall and solar radiation measurements negatively impacted model trial outcomes and required further investigation. It is recommended that future research delve into the sensitivity analysis of these variables to enhance the understanding of their impact further.

The main findings and conclusions can be summarized as follows:

- The gridded data from CBAM for maximum temperature showed a stronger overall agreement and better predictive performance than NP. In contrast, the minimum temperature data from CBAM and NP showed similar predictive accuracy.
- Both NP and CBAM raw weather data displayed unbiased precipitation, but CBAM radiation produced questionable results, negatively impacting model outcomes. The higher radiation elevates soil evaporation, which can contribute to water stress in crops, resulting in lower simulated yield during modeling. Thus, CBAM weather data tends to limit simulated crop yield due to significantly higher radiation values than weather stations and NASA POWER data.
- There was an acknowledged need for gap-filling to flesh out the full set of required inputs for APSIM simulations; as such, it was impossible to compare either NASA POWER or CBAM against the weather station data across all variables for all crop trials. The variable distances between the weather station and the crop trial locations and elevation differences were also expected to impact the yield estimations and bias comparisons. Finally, for trials in which the exact trial location was not known, we estimated the location based on the nearest distribution center, which can create challenges in directly comparing data sources.

# Project Progress Reporting per Outcome

## Outcome 3: Tools for managers in farm fields to use weather data

Outcome 3 involved the engagement of trial managers to better understand the value of farmer/user-facing tools in the context of weather intelligence and seed trials. A tight feedback loop between the technical teams and users will ensure that the voice of users, especially women, are represented in the tools' design and outputs from the outset. Studies have shown that while women only own 20% of the land, they account for roughly half the smallholder farmers and, in Africa, are responsible for producing 70% of the food.

Outcome 3 deliverables included:

- The undertaking of a needs assessment with trial management organizations
- A gender-focused report to assess the role of women in two trial programs
- Capacity building workshop for using decision support tool

**Recommendation**:

To bridge the gap between research and operational aspects of trial sites, address the limitations of agroclimatic weather forecasts, and enhance the usability of weather intelligence for operational staff, we recommend developing decision support tools tailored to the specific needs and information access patterns of 1000Farms sites, considering gender-specific roles and responsibilities.

# 3.1a: Needs Assessment 3: Assessing the Trial Management Ecosystem, the Personas Involved and their Needs for Weather Intelligence in Support of Improved Breeding Outcomes

**Hypothesis**
Improved Weather Intelligence supported by well-designed decision support tools has the potential to improve trial management outcomes through focused interventions aligned with the different personas and roles within trial management.

The **goal of this needs assessment** was to understand how the seed breeding ecosystem interacts with each other and the value generated from this interaction.

The Seed Breeding Ecosystem comprises numerous role players historically centered around governments and the private sector. sector. The potential value and importance of community participatory breeding programs - such as the CGIAR 1000Farms program - is currently being demonstrated across East Africa with the participation of thousands of small-scale farmers.

They play an important role in meeting food systems' multiple challenges by supporting food security and nutrition, livelihoods, sustainable resource use, and climate change mitigation. This can lead to improved planning and management of trials, ultimately enhancing the success and productivity of breeding outcomes.

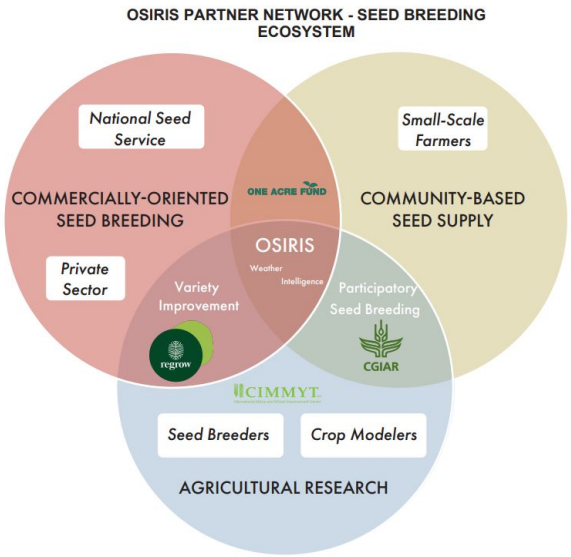



**Figure 7:** Weather intelligence and the seed breeding ecosystem in East Africa

This assessment **recommended** that by addressing the challenges of accessing quality weather information and decision support tools, these advancements can contribute to more efficient and effective trial management practices.

Additionally, customized weather and climate data products and tools can cater to the specific needs of different personas involved in trial management, such as analysts and crop advisors.

# 3.1b: Gender Roles in Seed Trial Programs and the Impact of Weather Intelligence

The **goal of this study** was to highlight the need to deliver gender-based insights to enhance the usability and operationalization of weather data through developing weather intelligence-enabled decision support tools that take into account gender perspectives in the context of seed trial programs.

The study **outcomes** indicate that women tend to adopt weather information faster than men. However, the uptake of this information is subject to many factors, such as cultural, economic, and educational. Female farmers are also keen on getting short-term forecasts compared to their male counterparts. This was attributed to their farming practices. Male farmers were more likely to be cash-crop farmers, while female farmers were more likely to need weather information for activities like harvesting.

**Hypothesis**

Improved Weather Intelligence supported by well-designed decision-support tools has the potential to improve trial management outcomes through focused interventions aligned with the different personas, especially women and roles within trial management.

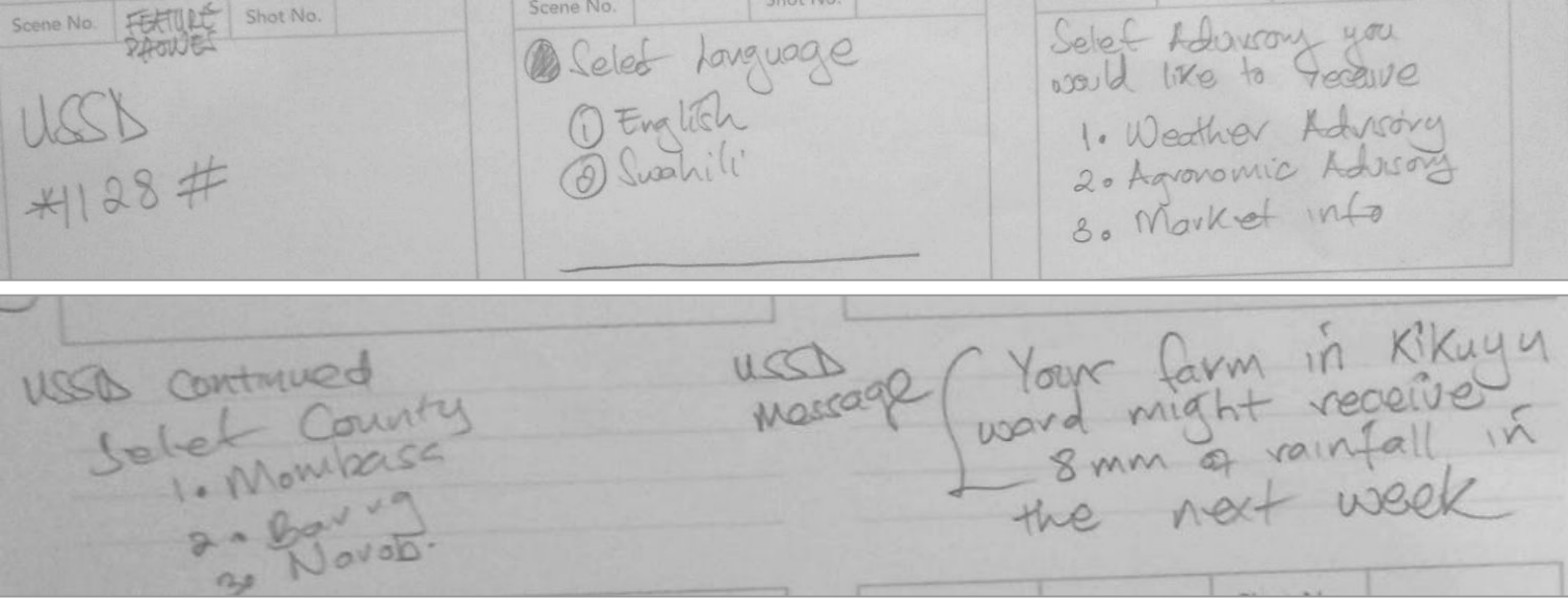



**Image 3:** USSD Platform visualization

# 3.2b: Capacity building workshop for using decision support tool

The co-creation workshop brought together key stakeholders from the weather forecasting and trial management ecosystem to co-create and design support tools to improve weather intelligence adoption by trial managers.

**The following are key takeaways from the workshop:**

Participants acknowledged that weather information is a vital resource that helps individuals and organizations make informed decisions about safety, transportation, agriculture, and more.

However, using and sharing weather information has challenges, including technology and language barriers, lack of actionable information, insufficient or inaccurate data, lack of trust, and insufficient partnerships. The workshop emphasized the crucial role of weather information in decision-making across various sectors. The consensus was that more efforts are needed to ensure communities and stakeholders utilize weather information effectively.

Key recommendations included providing weather forecasts packaged and presented to intended users with a consideration of the following factors:

1. Access to accurate weather information and actionable insights

2. Appropriate communication of weather information

3. Timeliness

4. Integration of weather information into existing platforms such as SMS, WhatsApp, mobile and web apps, and radio or TV broadcasts

5. Weather visualization tools and information should be designed to consider the differentiated gender roles at the household level.

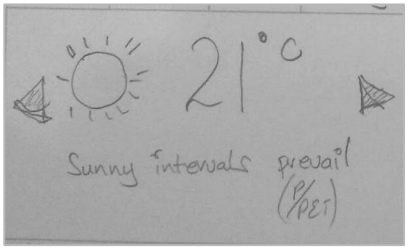



**Image 4:** Short-term forecasts visualization

# Project Progress Reporting per Outcome

## Outcome 4

External weather and climate data and tool evaluation and analysis by industry partners.

Outcome 4 was included in the project to extend weather and climate data and tool evaluations and to develop protocols to better support the seed breeding ecosystem. This outcome included project activities such as:

- External rainfall data analysis
- Assessment of the IRI Climate Data Tool's (CDT) functionality to enhance TAHMO station observations as well as the CBAM gridded reanalysis temperature data

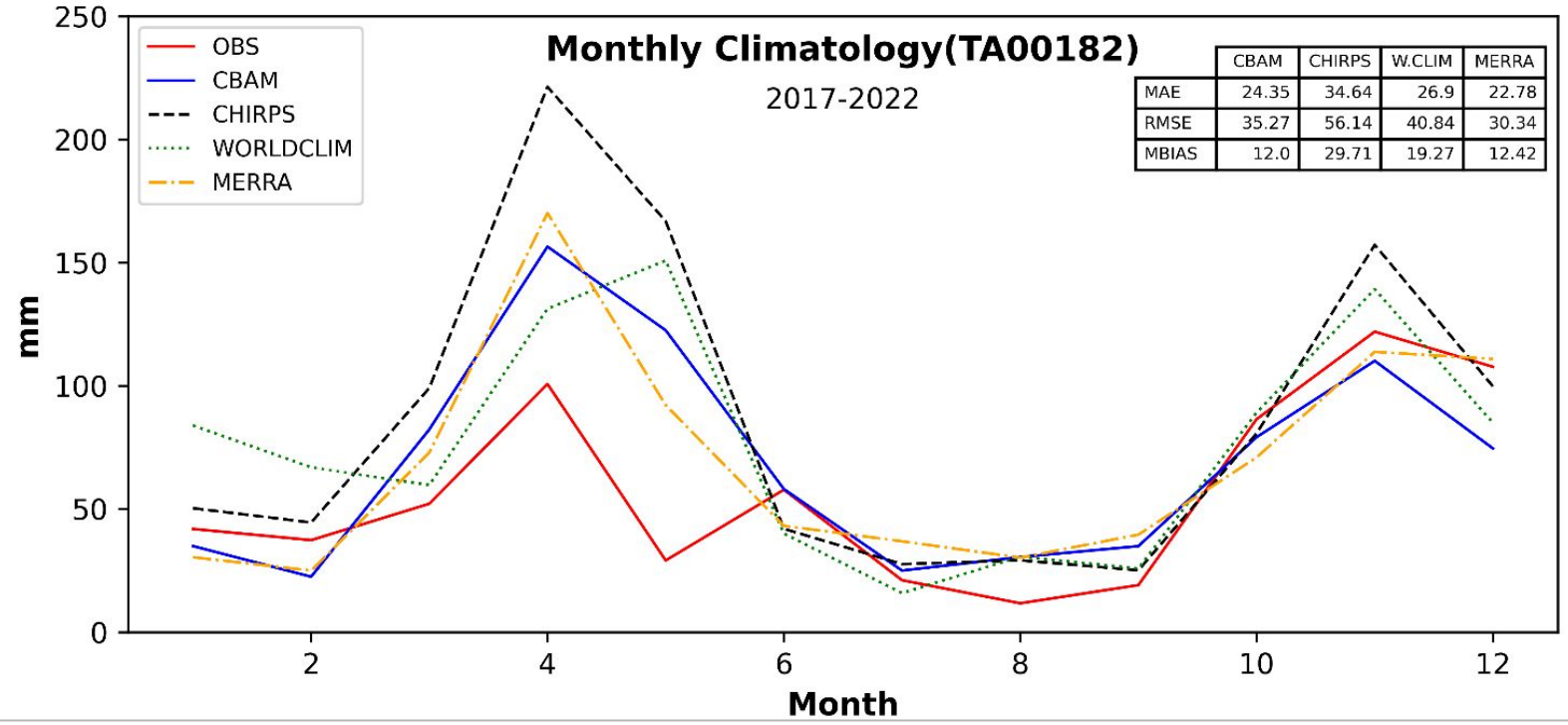



**Figure 8:** Monthly Climatology of CHIRPS2, CBAM, and MERRA2 and TAHMO in-situ observations at TA00067 (top) and TA000182 (bottom). All the products have clearly captured the bi-modal nature of rainfall (MAM and OND).

# 4.3: Kenya Rainfall Data Analysis

An external validation study performed by the Jomo Kenyatta University of Agriculture and Technology rigorously examined CBAM's accuracy in predicting precipitation by comparing its output with calibrated rain gauges in and around the Machakos region in Kenya.

The findings indicated a consistent positive bias in CBAM's daily, monthly, and annual rainfall estimations, signifying an overestimation.

Notably, CBAM demonstrated proficiency in capturing short-duration rainfall, particularly during the short rainfall season (OND), while MERRA2 excelled in longer durations, specifically during the long rainfall season (MAM).

Despite high Probability of Detection (POD) scores for both CBAM and MERRA2, the study raised concerns about the high False Alarm Rate (FAR), suggesting the models' tendency to predict rainfall even without actual precipitation.

Furthermore, MERRA2 exhibited a higher correlation than CBAM when assessing the Machakos region on monthly and annual scales.

# 4.4: Data Science - Assessment of the IRI Climate Data Tool's (CDT) functionality to enhance TAHMO station observations as well as the CBAM gridded reanalysis temperature data

This report underscored the pivotal role of meticulous data curation, bias correction methodologies, and innovative tools like the CDT in advancing the accuracy, quality, and utility of temperature reanalysis data for Kenya.

The following are key insights from the report:

Assessment of the IRI Climate Data Tool (CDT) and its Potential Impact on Temperature Data Enhancement:

- A quality-controlled observation dataset, sourced from TAHMO and UCAR data, improved the accuracy of temperature patterns in Kenya.
- The Climate Data Tool (CDT) demonstrated user-friendly and effective handling of temperature data, contributing to enhanced reanalysis outcomes.
- Bias correction techniques applied to the CBAM temperature reanalysis dataset resulted in notable accuracy improvements for both maximum and minimum temperature variables.

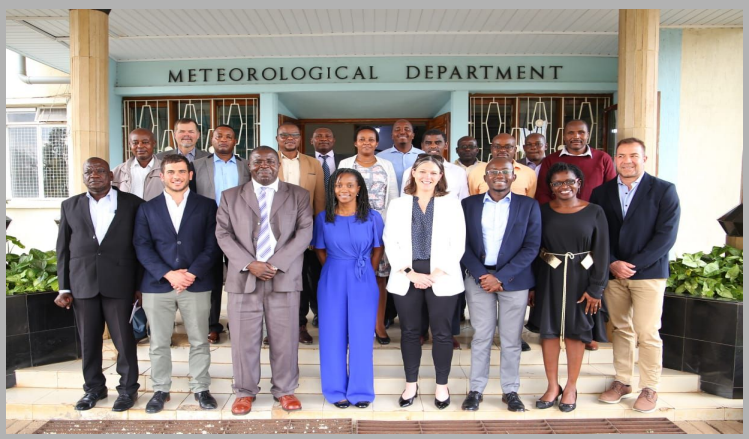
Development of Quality-Controlled, Gap-Filled Observation and Bias-Corrected CBAM Reanalysis Datasets for Kenya:

- Additional bias correction techniques were identified as having significant potential to enhance Kenya's CBAM temperature reanalysis further.
- The Climate Data Toolkit (CDT) proved valuable in generating quality-controlled observation datasets, highlighting its role in improving data accuracy.
- The CDT emerged as an effective tool for augmenting CBAM temperature reanalysis data through efficient bias correction methods.

# Workshops and Stakeholder Events during P1

## Kenya Trip 1

**The 18th April 2022 - 29th April 2022 trip to Kenya aimed to kick-start the OSIRIS Project in East Africa. This involved engaging stakeholders and partners, holding farmer workshops, participating in a conference, and engaging in team-building activities. Some key trip highlights included farm visits in Kiambu County, a Greenshade Self Help Group workshop, and meetings with stakeholders in Kenya's agriculture and weather/climate ecosystem.**




**The trip identified Kenya as a suitable launch region for advanced weather services, with a favorable ecosystem and strong local support. Overall, this paved the way for collaboration, innovation, and sustainable solutions to address climate risks and support the resilience of the agricultural sector in Kenya.**

# Workshops and Stakeholder Events during P1

## Needs Assessment Workshop with Seed Breeders in East Africa

**TomorrowNow initiated the Osiris Needs Assessment 3 with a workshop held from 5th to 9th September 2022, coinciding with a CGIAR ClimMob training course at CIMMYT. This workshop brought together trial managers from organizations including One Acre Fund, KALRO, Bayer, CGIAR, and CIMMYT. It focused on understanding different personas in trial management and their requirements for weather information, as well as enhancing stakeholder engagement and coordinating the OSIRIS project. Participants, comprising scientists and trial officers, engaged in mapping the trial management ecosystem and explored how to effectively utilize the CGIAR CIAT ClimMob tool for managing seed breeding sites.**


# Workshops and Stakeholder Events during P1

## AGRF Rwanda 2022

**The Africa Green Revolution Forum (AGRF) convened in Kigali, Rwanda, on 7th-10th September 2022, focused on empowering youth in agriculture and advancing resilient food systems. Ronald Diang'a represented TomorrowNow as a panelist at the Youth Town Hall session, where he shared TomorrowNow's mission, milestones through various projects, and its vision for Africa.**

**Key takeaways from the forum centered around two crucial themes. Firstly, there was a strong emphasis on the necessity of a multi-stakeholder approach to better support and engage the youth in agriculture. The panel highlighted the critical role of collaboration in transforming food systems. Secondly, the event underscored the transformative potential of technology, recognizing it as a powerful tool to support and amplify youth participation in agriculture sustainably.**


# Workshops and Stakeholder Events during P1

## GSMA MWC Africa Event 2022

**The GSMA MWC Africa Event in October 2022 brought together key players in telco, digital inclusion, and mobile technology to address climate resilience in Africa. TomorrowNow, represented by Kenneth Chepkwony, contributed to the panel discussion on building climate resilience through digital technologies. The panel discussions delved into TomorrowNow's projects, emphasizing the role of warning systems in enhancing community resilience.**

**Insights revealed the importance of partnerships with input providers, government extension services, and community leaders to build trust with farmers. Additionally, the event shed light on the current priority for donors and organizations- shifting mindsets from mitigation to adaptation. These key learnings underscored the potential of digital technologies to address climate challenges while emphasizing the collaborative efforts needed to bridge gaps in information access and community engagement.**



# Workshops and Stakeholder Events during P1

## Mercy Corps AgriFin 6th Annual Learning Event 2022

**The Mercy Corps AgriFin 6th Annual Learning Event on 22nd November, 2022 provided a forum where participants and organizers shared experiences of tested digital technologies and practices that work to enable smallholder farmer resilience.**

**TomorrowNow had a booth and presented the OSIRIS project to farmer-facing organizations at the conference. The discussions underscored the importance of accurate weather data for effective decision-making in the agriculture sector.**

**However, a prevailing challenge identified was the generalized nature of weather-linked extension services, causing information overload and "farmer fatigue." The event revealed a willingness among organizations to invest in data access, signaling a recognition of its potential to make a significant difference in quality compared to existing solutions.**



# Workshops and Stakeholder Events during P1

## Kenya and Rwanda Trial Management and Gender Case Studies

**In Kenya, KALRO Katumani's gender-focused exploration of seed trial operations on 29th - 30th November, 2022 revealed a comprehensive approach to address the intersection of gender dynamics and weather needs.**

**The team at TomorrowNow also conducted a workshop with farmers registered under the Greenshade Self Help Group (90% women) to understand their perspectives on the importance of weather information in addition to the gender issues that define the efficacy of their seed trial activities.**

**In Rwanda, TomorrowNow visited One Acre Fund's Karongi headquarters and explored their gender dynamics and weather information within seed trial management. Through Key Informant Interviews (KIIs) on 3rd-7th December 2022, it was identified that weather information is not perceived as critical by most farmers, prompting recommendations for targeted solutions.**

**In Rwanda and Kenya, the exploration of seed trial operations reveals a shared commitment to understanding the intersection of gender dynamics and weather needs in agriculture. One Acre Fund in Rwanda emphasized the significance of weather information in seed trial management, proposing targeted solutions such as incentives and training to enhance adoption. KALRO Katumani in Kenya, through collaborative efforts, underscored the crucial role of accurate, localized weather information for farmers and trial officers. Both organizations recognized the impact of women in their agricultural ecosystems, with gender considerations extending from seed preferences to community participation. The collective takeaway emphasized the need for tailored solutions, recognizing each context's unique challenges and opportunities.**

# Workshops and Stakeholder Events during P1

## Co-design Workshop - Next-Generation Weather Intelligence Tools for Trial Managers

TomorrowNow.org organized a participatory co-design workshop on 28th February 2023 in Nairobi, Kenya to generate ideas for a decision support tool for trial managers supported by the latest weather technologies with a focus on relevance, presentation and visualization.

Participants at the co-design workshop included seed trial managers and key climate adaptation stakeholders representing Kenya Meteorological Department, Biovision Africa Trust, One Acre Fund, ICPAC, Tomorrow.io, ESRI, International Maize and Wheat Improvement Center (CIMMYT), Kenya Agricultural & Livestock Research Organization (KALRO), Kenya Space Agency, and Mercy Corps AgriFin Sprout Open Content.

A key outcome of the co-design workshop was a set of actionable recommendations and a comprehensive framework showing possible design features for a farmer-facing user interface & seed trial managers' tool for improved weather information.

In summary, it was recommended that short-term and seasonal forecasts need to be packaged and presented to intended users with a consideration of the following key factors:

- Access to accurate weather information and actionable insights
- Appropriate communication of weather information
- Timeliness

Integration of weather information into existing platforms such as SMS, WhatsApp, mobile and web apps, and radio or TV broadcasts

# Workshops and Stakeholder Events during P1

## Partnership Launch with Kenya Space Agency for Data Dissemination

**TomorrowNow and the Kenya Space Agency launched a new partnership on 9th July, 2023 to jointly leverage the power of space data to support the Kenyan government, key stakeholders, and farmers for food security and climate adaptation. As part of the OSIRIS Global Access Strategy all historical reanalysis data produced in the project will be made freely available through the Kenya data portal.**

**Our partnership with the Kenya Space Agency will jointly provide space-derived data decision support to stakeholders in agriculture to enhance food security and build climate resilience to ensure the efficient utilization of space technology through local capacity building and partnerships for increased investment in the sector.**


# Workshops and Stakeholder Events during P1

## Exhibition at the Inaugural Africa Climate Summit & TomorrowNow Side Event focused on Transformative Weather Intelligence

**TomorrowNow shared its vision and progress at the Africa Climate Summit #ACS23 (4th -8th September 2023) as an exhibitor alongside tech partner Tomorrow.io, and hosted a side event in partnership with Tomorrow.io, Regen Organics & the Kenya Agricultural & Livestock Research Organization (KALRO).**

**Themed "Transforming Africa's Food System through Weather Intelligence and Partnership", TomorrowNow's side event crowded in the perspective of public, private and NGO leaders to highlight cutting-edge space and generative AI technology and transformative financing being embraced in Kenya to transform weather and climate information services.**

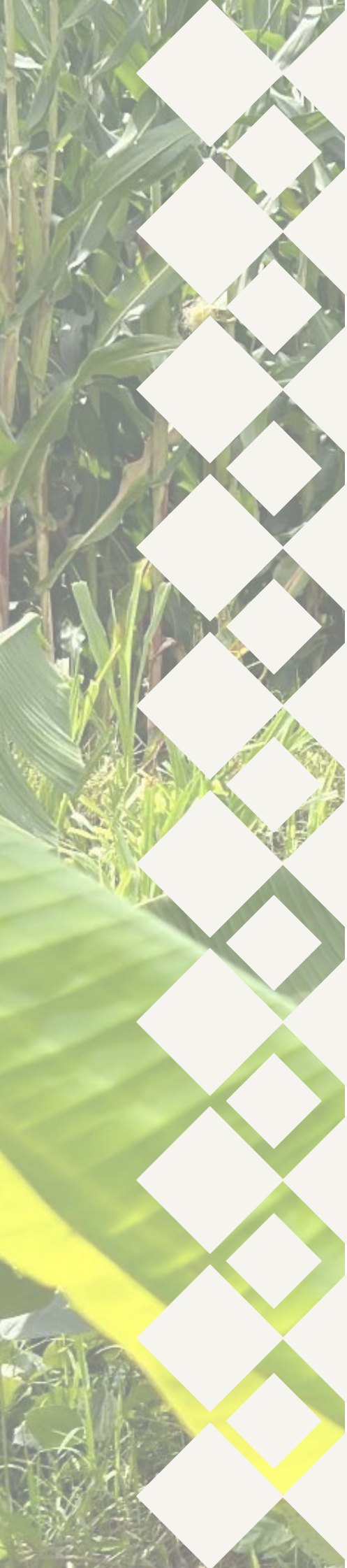

# Workshops and Stakeholder Events during P1

## Niche User Innovation, Design & Feedback Workshop Convened by Regrow Ag in Kigali and Nairobi

**TomorrowNow.org joined Regrow & partners including University of Nebraska-Lincoln, NASA Harvest & One Acre Fund in Kigali and Nairobi from 23rd - 27th October 2023 for the Niche User Innovation Design & Feedback Workshop deep dive sessions into the Niche Project led by Regrow & funded by the Bill & Melinda Gates Foundation.**

**We used the opportunity to highlight the progress that TomorrowNow.org has made through Project Osiris to understand the weather & climate data needs of seed breeding programs in East Africa, conduct data validation studies, and develop key weather/climate technologies as key inputs within seed breeding services & agro-climate modeling applications.**

**We learned from the workshop conveners and participants that high-quality weather data can make a huge difference to the outcomes of crop variety placement and ultimately contribute to inclusive local climate adaptation.**



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