Overview first set Proof-of-Concept

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SAFE4ALL AFRICA

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1. Background

Tools overview

The project consortium brings an extensive collection of tools, focusing on different time and spatial scales, as well as different climate change impacts. The selection of tools appropriate for the case studies depends to a large extent on the end-users' needs and the prioritization of the stakeholders at the LivingLabs (co-creation case studies).

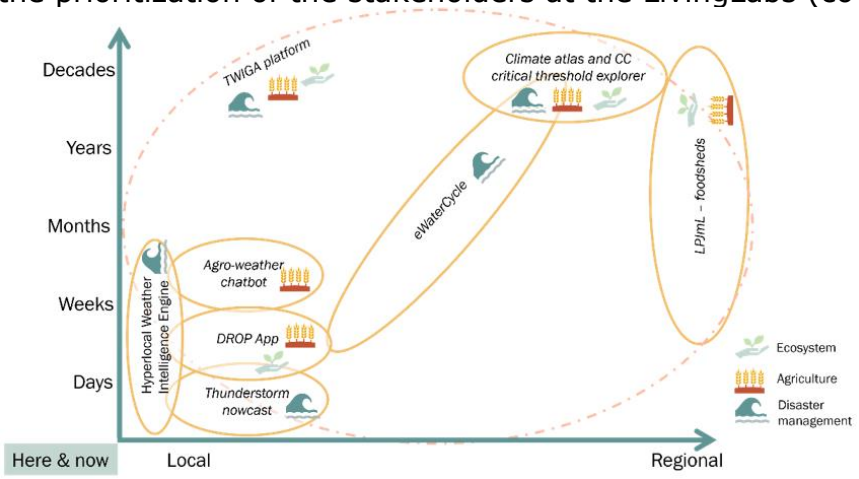


Figure: SAFE4ALL Tools

Foodshed Information Service (FIS)
This model uses historical climate data (continuously updated up to the latest month), seasonal forecasts and long-term climate scenarios from the climate data store to generate projections of water availability and crop production for the near and far future. The model combines simulations of climate impacts on water resources and crop production with socio-economic data, such as changing food and water demand, to provide integrated assessments of the current and future risks for the regional food system in our case studies In the co-creation sessions, we will decide which specific indicators will be delivered to the developed Foodshed Information Service (FIS). This service will assist policy makers, extension officers and other associated stakeholders in the agri-food chain to improve land use and water management planning at the regional to country scale.

Climate Atlas and critical threshold explorer
What is the effect of climate change on a specific crop? The climate atlas combines maps of impacts and hazards for specific crops, and it contains an application to analyse the exceedance of critical thresholds. This C3S based application generates user defined indicators and allows users to set temperature and precipitation thresholds. Users can generate crop specific graphs and maps, which allows them to explore the vulnerability of crops to climate change. The tool was developed as a demo case for Copernicus (https://climate.copernicus.eu/climateservices-smallholder-farmers-kenya). SAFE4ALL will utilize the explorer to bring climate data that cover the globe to a farm level in the co-creation case studies and the cities that the project will cover. The tool will translate the most critical signals from climate projections and seasonal forecasts and will be tailored to specific crops and critical agro-climatic conditions in the co-creation cases. Through easy-to-understand interactive maps and graphs, it will help farmers directly see what the future impacts of climate change are likely to be, to enable climate-smart adaptive decision-making.

Agro-weather and -season decision support chatbot Uliza-WI

This tool is a tailored chatbot that gives operational farming advice based on forecasts ranging from medium range weather forecast to seasonal forecasts. The innovative character of this product is both in the back-end and in the front-end. A blended product from medium-range weather, to sub-seasonal, to seasonal forecasts will be developed to give farmers and other users an accurate outlook for the coming days, weeks and months to make climate-smart decisions on a farm level. The blended product will also entail a ML trained algorithm that monitors and predicts the onset of the rainy season. A rainy season onset alert is coupled with advice for the most suitable planting date which is crucial for a high-yielding growing season. The decision-making support also contains advice for other operational activities, e.g. the timing of fertilizing, pest & disease control, weeding, based on current weather conditions, crop, growth phase, and locally employed farming practices. The user can request information in different languages and specifically for their location to obtain the most accurate forecast and advice. Furthermore, the platform allows for using various output formats such as visualizations, text format, and voice message for illiterate users to fit a range of target groups. Input information and feedback can be directly collected from the user and used to calibrate and improve the underlying forecasting algorithms.

High impact thunderstorm nowcast

This tool has the intention to move beyond the state of the art of the nowcasting of thunderstorms, to significantly increase its accuracy and availability, which will help farmers and all citizens to better adapt to climate change, because studies prove that climate change will make thunderstorms extreme. Standard State of the art thunderstorm nowcasting is based on extrapolation of radar data. This tool is also based on satellite data and using AI techniques. The advantages of satellite data (ESA, EUMETSAT) compared to radars are that they are available for all areas (including the case study countries) and the advantage of AI techniques is that they can better grasp complex non-linear features of natural processes. Better accuracy of thunderstorm nowcast is achieved by use of the complex AI method called ensemble stacking, where the predictors would be the output of several standard extrapolation models based on radar data as well as the output of the model on satellite data stated above and even current measurements from the stations (TAHMO, National Met. networks). Usage of large-scale data (radar/satellite) and precise local point measurement provide both unparalleled preciseness (inherited from point stations) and spatial coverage. In SAFE4ALL, the tool will be used to issue severe weather warnings a) for farmers, b) for urban citizens. Additionally, a pipeline can be constructed to forward the precipitation nowcast to flood models provided by other partners such as TAHMO and KMD in this project, to generate flash flood warnings.

eWaterCycle

Hydrological modelling platform that can be run through a simple Notebook and is FAIR by design. The platform allows the rapid delineation of the area of interest, the choice of any of (presently) six hydrological models, and different climatological inputs, to assess the hydrological outcomes in terms of river flow, groundwater, and evaporation. The platform follows a "three clicks to a model run" philosophy. It allows adoption of processes within different models through user-friendly Python scripts. Currently the following models and model suites are available through eWaterCycle: PCR-GLOBWB 2.0, wflow, Hype, LISFLOOD, MARRMoT, and WALRUS. While these models are written in different programming languages they can all be run and interacted with from the Jupyter notebook environment within eWaterCycle. The pre-processing of input data for these models has been streamlined by making use of ESMValTool. Forcing for the models available in eWaterCycle from well-known datasets such as ERA5 can be generated with a single line of code.

DROP app

The DROP app is a research-based, tailor-made hydro-climate information service that is co-produced with and for farmers in Ghana together with UDS (*Sutanto et al. 2025*). The co-production process involved scientists, app developers, and farmers to identify their information needs and requirements. The co-production processes actively engaged farmers to harness their knowledge and experience to develop a service that is tailored to smallholder context-specific needs and in the end increase trust and chances of information uptake. Monitoring and evaluation of the app were conducted after it was used by the farmers for a minimum of one month. Farmers also provided feedback for future improvements of the app.

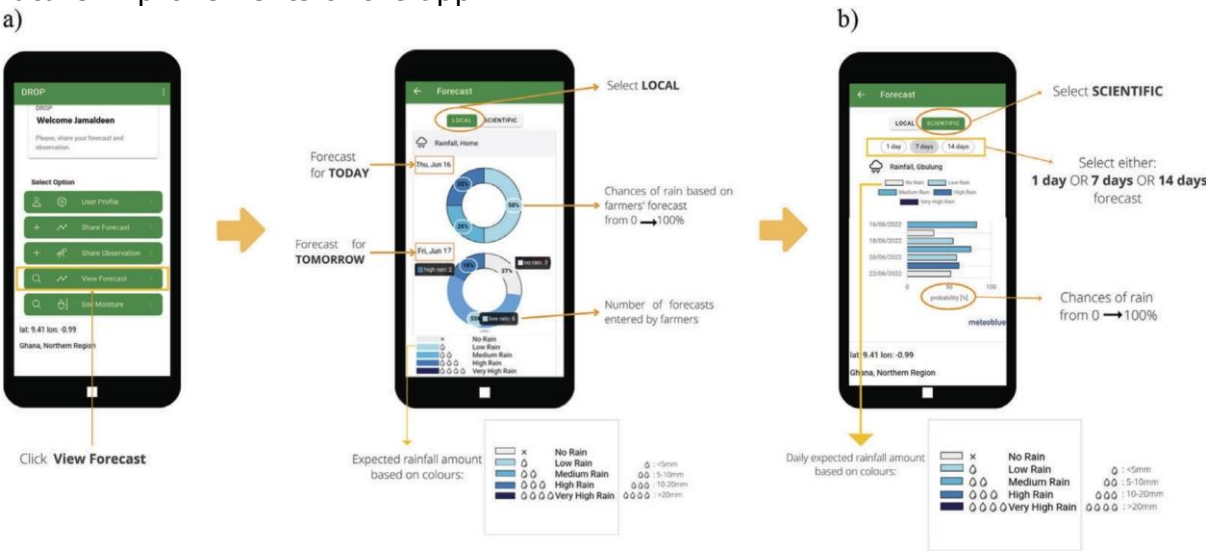


Figure: a) Example of the local precipitation forecast provided by the farmer and b) scientific weather forecasts for 1-day, 7-day, and 14-day retrieved from the meteoblue API:URL by the DROP app.

TWIGA Platform

The TWIGA platform developed through the H2020 funded TWIGA project is a central platform through which many data sources and services can flow. Users can access the data through a comprehensive API or via the TWIGA portal. The portal is a web-based interface through which registered users can see and interact with the data. Experienced users can create their own custom dashboards completely tailored to their own needs. However, in many cases, dashboards can be prepared and shared to new users, such that new users can directly interact with the data without needing detailed knowledge. The TWIGA platform was built on top of the HydroNet platform developed by HydroLogic BV (HR) now known as the Water Platform Company BV (WPC) based in Delft in the Netherlands to ensure long-term sustainability. The platform is operational at TRL 9. A set of micro-services has been developed that link data sources to the platform which could be bundled with the new SAFE4ALL services. Data and metadata formats have been implemented that support GEOSS integration and could be the pipeline to provide data from the project to GEOSS. New sensors and, especially, citizen science data, demand special quality control and calibration for which a framework has been put in place and being implemented so TAHMO can support with the addition of any new data sets collected during this project. The network of 650 TAHMO stations can be accessed via this portal as well.

Hyperlocal Weather Intelligence Engine

The Neuralio AI - Hyperlocal Weather Intelligence Engine, is an in-house suite of routines that generates and handles weather and climate data. This engine comprises a Numerical Weather prediction model (WRF) that operates at high spatial resolutions at targeted areas and provides short to medium-range weather forecasts and sub-seasonal to seasonal forecasts. The team also applies Data Assimilation to improve the initial conditions of the modelling framework, using a 3D-Var assimilation technique and incorporating satellite and weather station data into the model's background state. This allows a highly accurate representation of the atmospheric state. Moreover, the engine provides suites for accessing, downloading and processing climate data from Copernicus Data Store (CDS), giving access to both multi-model seasonal and decadal predictions as well as to climate change projection scenarios. The climate and weather information are further assessed by applying a Model Evaluation Tools framework that provides metrics for assessing the weather and climate data statistical scores. The climate data that are usually delivered as an ensemble of climate realizations, are further processed through data analytics that provide an overview of the realizations in terms of graphical display, time series at location for ensemble mean, standard deviation, quantiles, anomalies. To downscale at finer spatial resolution at a field level, the Hyperlocal Weather Engine utilizes AI techniques (Generative Adversarial Networks (GANs)), trained with reanalysis data and extracts from a low resolution, high spatial resolution features.

Multi-agent Reinforcement Learning Framework

This framework offers the necessary tools to create a simulated interactive environment that displays the spatial representation of land suitability based on collected climatic, Earth Observation (EO), and socioeconomic data. The spatial representation consists of a population of agents with distinct attributes such as age, social network, land size, and economic resources. Land suitability parameters, including crop growth, meteorology, soil, water, and social indicators from the FAO, are assigned weights through a Reinforcement Learning module, resulting in a clustering of suitable criteria that maximizes crop yield. This multi-agent-based approach allows for: 1) the observation of emerging phenomena; 2) a natural setting to study the system; and 3) enhanced flexibility, especially concerning the development of geospatial models.

Countries introduction

Ghana
The study area in Ghana is in the North, where out migration is common and related to the climatic variations. Like most of West Africa, the northern part of Ghana has only one rainy season, which lasts up to six months. This makes people in the rural areas move to the towns where more work opportunities exist, outside agriculture, or towards southern and more urbanized locations in search of employment and livelihood opportunities, during the long hot dry season. Some irrigation dams provide opportunities to work, but these are not sufficient to stem the flow of migration.

Kenya
The case-study in Kenya covers three counties: Kisumu County, Narok county and Nairobi County. Narok county is the largest of the three and has some arid and semi-arid areas that experience low rains, reaching up to the highest altitude of 3100 m above sea level. Both Kisumu County and Nairobi County are significantly smaller in area compared to Narok county and they are at an altitude between 1100 m and 1800 m above sea level. Whereas Narok county experiences one long rainy season, both Kisumu and Nairobi County experience both a long and a short rainy season every year. Nairobi county, being the smallest in land area, has the largest population, up to 5 million people, of which approximately half are female. Kisumu county and Narok county both have a population of around 1.1 to 1.2 million people, of which also approximately half is female.

Zimbabwe
The Zimbabwe case study is in the Secondary City of Marondera with the Primary City being Harare, the capital city of the country. Marondera is 70km from Harare along the Harare-Mutare highway. According the ZIMSTAT 2022 population census, the total population of Marondera District is 136,173 comprising 68,180 males and 67,993 females The Primary City Harare has a total population of 2,427,231 comprising 1,159,350 males and 1,267,881 females. 15 wards have been selected to participate in the SAFE4ALL Case Study.

2. Proof-of-concept and next steps

The table below presents the development status of the SAFE4ALL Tools by Month 18.

Tool	Ghana	Kenya	Zimbabwe
Foodsheds Information Service (FIS)	Under development	Under development	Under development
Climate Atlas and critical threshold explorer	Under development	Under implementation	Under development
Agro-weather and -season decision support chatbot	Operational	Operational	Operational
High impact thunderstorm nowcast	Under development	Under development	Under development
eWaterCycle	Under development	Under development	Under development
DROP app	Under implementation	Under implementation	Under implementation
TWIGA Platform	Under development	Under development	Under development
Hyperlocal Weather Intelligence Engine	Under implementation	Under implementation	Under implementation
Multi-agent Reinforcement Learning Framework	Under development	Under development	Under development

Foodsheds Information Service (FIS)

Current (valid for all three countries)
The status of the FIS is the same for all three countries, as specific data from each country does not condition its development much.
The FIS has two main parts: a Seasonal Crop Yield Forecasting (SCYF) tool and a Foodshed Scenarios tool. The overall framework and concept of the FIS are under current development, and we are still researching and co-developing with stakeholders to find the most useful and actionable indicators and data to include in the FIS. We are also validating and processing all the input data for the SCYF.

Future (valid for all three countries)
The focus of 2025 is on the SCYF to get a prototype to continue co-designing the tool with stakeholders in the next SAFE4ALL sessions. At the end of the year, we will move to finalising the methodological framework of the FIS to then develop a prototype of the Foodshed Scenarios tool in 2026 and present it at the end of the year.
After initial discussions with local stakeholders and tool owners, we do not see the need to develop another independent digital platform for the FIS but rather embed and integrate it in the Climate Impact Atlas digital platforms we are developing for each country. In 2028, most of the work will be on iteratively improving the tool with feedback from co-developing sessions and evaluating the capacity of the FIS to provide actionable information to decision-makers in the three countries.

Activities

Climate critical moments and foodshed indicators workshops in Ghana and Zimabwe

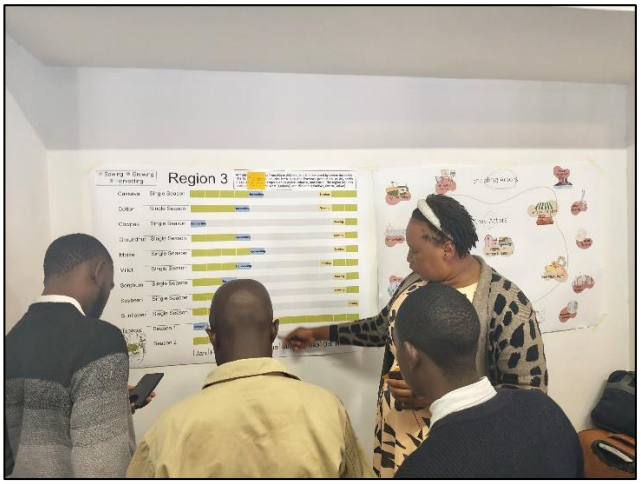
At the SAFE4ALL General Assembly in Ghana (March 2025) and at the Zimbabwe workshops (June 2025), sessions were held to support the co-design of the Foodshed Information Service (FIS). The sessions included two workshops focused on translating local knowledge into useful indicators and tools.

In the first workshop, participants shared their roles in the food system and discussed major risks affecting their foodsheds. They proposed actionable indicators to monitor these risks and took part in a prioritisation exercise to identify the most pressing challenges for the FIS.

The second workshop focused on cropping calendars and critical moments in the growing season. Stakeholders grouped by agroecological zones to outline crop timelines, verify seasonal patterns, and highlight local variations. They identified critical periods when crops are most vulnerable to climate impacts, with input from both field-based and technical experts. The sessions enabled open dialogue and grounded the FIS design in real-world needs.



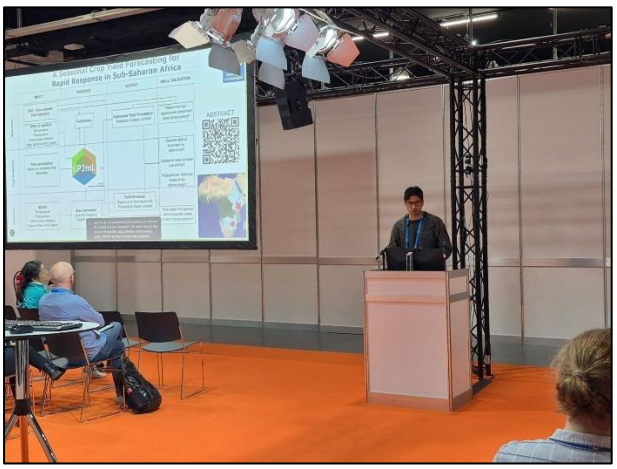
Figures: Crop calendar and critical climate moments workshops in Accra and Savelugu in March 2025.

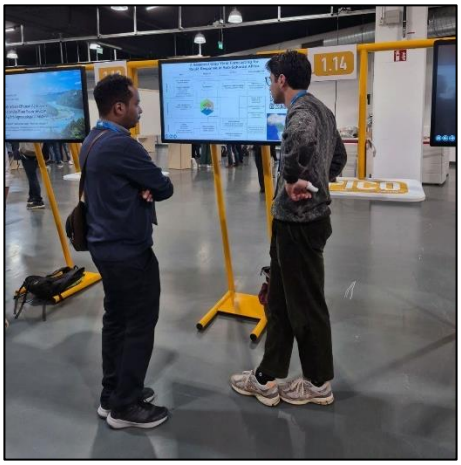



Figures: Crop calendar and critical climate moments workshops in Zimbabwe in June 2025.

Presentation of the Seasonal Crop Yield Forecasting methodology at the EGU conference, May 2025.

Representing SAFE4ALL, Ignacio Saldivia Gonzatti presented his research on Seasonal Crop Yield Forecasting at the EGU conference to share progress on integrating seasonal forecasts into crop yield modelling for short-term adaptation planning. Ignacio introduced the use of the LPJmL process-based crop and hydrology model combined with SEAS5 seasonal forecasts to assess yield prediction skill. The session contributed to broader discussions on the practical use of seasonal forecasts for food security and highlighted how process-based models can inform more responsive and context-specific adaptation strategies.





Figures: Ignacio Saldivia Gonzatti presenting the Seasonal Crop Yield Forecasting methodology idea at the EGU general assembly and discussing with academics.

Climate Atlas and critical threshold explorer

Ghana

Current

GMet is currently developing a climate atlas in collaboration with the Danish MET office. This atlas includes projections for climate and socio-economic data. To avoid duplication of efforts, we are aligning our work and place emphasis on the downstream use of climate data, impacts, and adaptation strategies and measures. As part of this focus, we are developing climate stories that illustrate the real-world value and impact of the data.

Future

The future direction of the Climate Atlas will depend on key decisions made during the project. We are currently considering two main options:

- All climate stories and other atlas components could be hosted directly on the GMet and SAFE4ALL websites.
- Alternatively, GMet could maintain the climate data, while the impact-related content would be hosted on a separate Climate Impact Atlas. This platform could later be transferred to another institution, possibly the Environmental Protection Agency.

Kenya

Current

The first version of the Climate Atlas is now available at https://kenya.safe4allafrica.eu/. The atlas provides valuable information on climate change in Kenya, climate data, an adaptation measures database, useful tools, and learning modules. CAS and JKUAT are currently exploring the establishment of a CAS-like foundation in the region, which will take over hosting and further development of the atlas after the conclusion of the project.

Future

The Climate Atlas will be expanded with new data and insights from the SAFE4ALL Africa project. Its long-term maintenance will be secured by a CAS-like foundation, with a dedicated team equipped to maintain, update, and further develop the website. The database of climate adaptation measures will be updated, the map viewer will be fully functional, and the learning modules created through the SAFE4ALL project will be integrated.

In addition, the atlas will feature climate stories and demonstrate practical applications of the climate data. Designed as a user-friendly resource, the atlas will support decision-making processes and serve as a one-stop shop for climate-related data and information in Kenya.

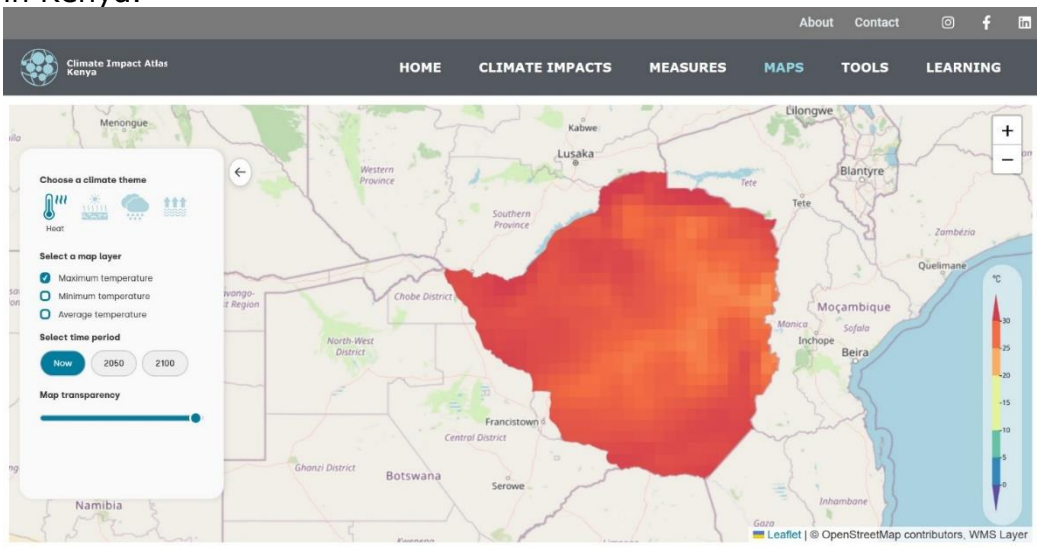


Figure: Climate Impact Atlas for Zimbabwe (under development)

Zimbabwe

Current

We are in the early stages of developing a Climate Atlas and are currently exploring the most sustainable format for its implementation with CAS, the Meteorological Services Department of Zimbabwe (MSD), and the Zimbabwe Farmers Union (ZFU). MSD has expressed a preference not to create a separate website, due to limited capacity to maintain additional digital platforms.

Future

The long-term sustainability of the Climate Atlas will depend on the needs and capacity of our local partners. A suitable solution will be identified to ensure the atlas remains accessible and actively maintained after the project concludes. In addition to our partnership with MSD and ZFU, we are exploring opportunities with other organizations to host and integrate components of the atlas within their existing websites or platforms.

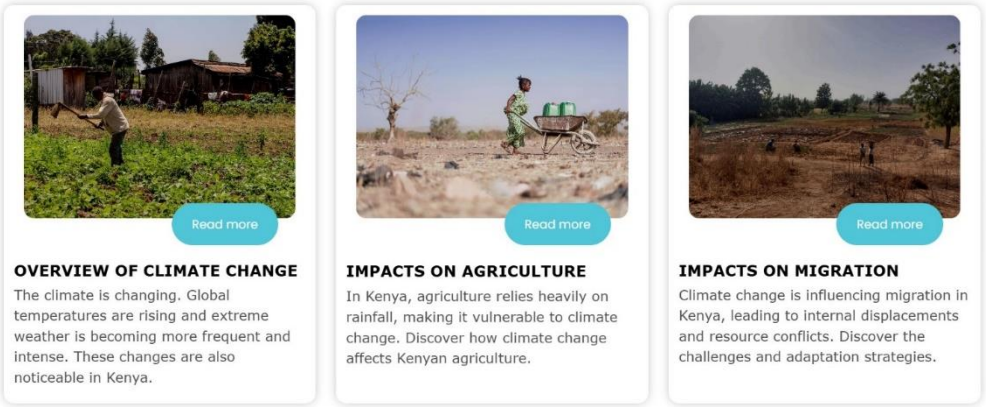


Figure: Examples of adaptation measures on the Climate Impact Atlas of Kenya

Activities

In October 2024, the inception workshop for the Climate Impact Atlas for Kenya was held in Nairobi with various stakeholders from the Met-services, municipality, agricultural extension officers and researchers from the Counties that the SAFE4ALL targets.

Figure: Climate Impact Atlas Workshop in Kenya, October 2024

In March 2025, the inception workshop for the Climate Impact Atlas for Ghana was held in Tamale, following the week after the General Assembly and Technical Days. Various stakeholders from Tamale and Savelugu such as the Met-service extension officers, municipality, agricultural extension officers and researchers were invited to participate in the session and shape the Climate Impact Atlas of Ghana.

Figure: Climate Impact Atlas Workshop in Savelugu, northern Ghana, March 2025

In June 2025, the inception workshop for the Climate Impact Atlas for Zimbabwe was held in Harare at the Zimbabwe Meteorological Services Department (MSD). Participants from MSD, the Zimbabwe Farmer's Union, agri-techs and smallholder farmers from various Wards that the SAFE4ALL targets were present and shaped the Atlas.

Figure: Climate Impact Atlas Workshop in Harare, Zimbabwe, June 2025

Agro-weather and -season decision support chatbot Uliza-WI

Current (valid for all three countries)
Uliza-WI has currently reached a version 1 stage, marking the end of the main development phase of the tool. The services currently available in all three countries are:

1. 7-day weather forecast
2. Seasonal forecast
3. Weather-informed farming advice specific for maize, sorghum and groundnut
4. Guidelines on conservation agriculture
5. Extreme rainfall alert
6. Livestock advisories for cattle, sheep and poultry.

Uliza-WI is currently available in English and Shona, one of the local languages of Zimbabwe.
Future (valid for all three countries)
As the main development phase of the tool is closed, the focus of the coming years will be on:

1. Improving the user-friendliness and accessibility of the chatbot, in particular exploring options for voice messages. This process will use ongoing testing and feedback from local farmers to guide development.
2. Making the chatbot increasingly more relevant for the local context, including new crops and tailoring the farming advice's content and formulation to the three countries.
3. Testing the integration of data and/or services from other SAFE4ALL partners, in particular from the Met offices.

Activities
Ghana
Current
Uliza-WI has been introduced to 56 farmers and 36 extension officers of the communities around Tamale during a workshop in March 2025. In the same occasion co-design workshop were held, aiming to improve the usability and relevance of the tool. A WhatsApp group with 79 members has also been created to facilitate the communication between WI and the farmers involved in the pilot.


Figure: Moment of the workshop to introduce the Uliza-WI chatbot to extension officers and lead farmers in three communities around Tamale.

Kenya
Current
Uliza-WI was introduced in a case study meeting in November 2024 in Kenya. It has also been introduced to some farmers and extension officers by JKUAT. Currently the user testing WhatsApp group counts 22 members. Aside this initiative, no further testing was carried out.

Zimbabwe
Current
Uliza-WI has been tested by 10 farmers as part of an early user testing session, organized and hosted by ZFU in August 2024. The WhatsApp group born with that initiative counts now 12 members.

Figure: The participants of the Uliza-WI Chatbot testing farmer group, who participated in the practical coaching and tool evaluation exercise in Marondera. Dr. Prince Kuipa guided the in person session.

Next to the SAFE4ALL funded activities, WI has carried out other initiative to promote the adoption of the Uliza-WI chatbot by extension officers in Zimbabwe, in close collaboration with AGRITEX (Department of Agricultural, Technical and Extension Services in Zimbabwe). This boosted the adoption of the tool, bringing almost 400 new users and reaching about 100 active users/week in the Country. This initiative brought to the introduction of a livestock advisory service in the Uliza-WI chatbot.
Weather Impact joined the SAFE4ALL consortium visit in June 2025. A key objective of

this visit was to lay the groundwork for Uiza-WI testing during the upcoming growing season, which begins from October 2025. During the visit, we have engaged in discussions with ZFU to organize workshops, either with ZFU staff or directly with farmers, who will subsequently participate in testing the tool later in the year. During a field visit on the 26th of June 2024, Weather Impact staff trained 18 extension officers and about 20 farmers on how to access Uliza-WI and the services available.

Figure: Weather Impact team introducing the chatbot to extension officers and lead farmers in Marondera district.

High impact thunderstorm nowcast

Current (valid for all three countries)
We have finished collecting and organizing long-term satellite data (tens of terabytes) relevant to the regions and their adequate pre-processing and cleaning for AI modelling.

Figure: Optimal local modeling domains for each country (from left: Ghana, Kenya and Zimbabwe)

The UNet AI architecture was chosen based on the latest research and the company's practical experience. Proof-of-concept (PoC) models were evaluated using the initial downloaded datasets. The adaptability of UNet-based models, originally trained on data from other regions, was tested under local African conditions. In the early modelling stage, hyperparameters and loss functions from the PoC models were applied to this new context to create a baseline for ongoing development.

Future (valid for all three countries)
Later in 2025, the focus is on analysing local meteorological characteristics and beginning country-specific AI modelling activities. The goal is to tailor the algorithms and logic of the tool to local conditions to ensure relevance and local usability. In 2026, improved models will be developed and validated. Then the tool will be integrated into the operational platform and handed over to users, ensuring long-term sustainability.

Activities
Workshop Ghana during GA 2025 - Local knowledge collection: Alongside data preprocessing, expert know-how from MET institutes was gathered to support future model improvements by incorporating specialist insights on daily and annual thunderstorm variability. These insights revealed the need for further data preprocessing to enhance AI model training, which was subsequently carried out.
Presentation Ghana during GA 2025 - A comprehensive technical presentation was delivered at a recent SAFE4ALL workshop in Accra, highlighting the AI methodology and key strategic direction. This fulfilled the request made by African institutions during the first General Assembly in 2024, which emphasized the need for capacity building in AI methodologies.

eWaterCycle

Current (valid for all three countries)
eWaterCycle is currently in operated by using a JupyterHub environment that runs on a supercomputer in Amsterdam, The Netherlands. Meaning that all the computations are done on that computer, making sure that the user does not need heavy computational power or high bandwidth internet. We have 8 models available:

- "leaky bucket" toy model
- wflow
- pcrglobwb
- marrmot M01
- marrmot M14
- lisflood
- hype
- HBV

They can easily be used because of containerization and the use of the basic model interface (BMI). Forcings can be generated for all the models if one presents the correct shapefiles.
The ease of use is demonstrated by the Bachelor theses of our students, using complicated models like PCRGlobWB:
eWaterCycle now has a projects teachbook that shows what it is capable of.
https://www.ewatercycle.org/projects/main/intro.html
Also we have some examples of the use of eWaterCycle here in the tutorials:
https://www.ewatercycle.org/projects/main/tutorials_examples/intro_tutorials_examples.html

Future (valid for all three countries)
We are currently working on:

- a CAMELS dataset for Ghana, Kenya and Zimbabwe.
- Use of a the spider supercomputer cluster for faster calibration and ensemble simulations.
- Lower bandwidth mode for really low internet bandwidth
- More/updating models
- Getting more forcing data for eWaterCycle
- Possible other cloud service providers like AWS etc.
- Use of machine learning

The next steps are new manuals which is needed for new users. Also setting up the ERA5 download page.

Activities
The workshop in Zimbabwe was done together with MSD, students and researchers from the universities. The workshop was designed for people that have experience with hydrological modelling. We went through the basics of how eWaterCycle works and then the participants did the HBV tutorial. Where we gathered feedback. MSD mainly wants to model flooding. The team was also approached to setup a server for easy access to the ERA5 reanalysis data. Our goal for integrating their data is not for now. MSD still needs to improve their data-integration for eWaterCycle to incorporate it. We are willing to help with that.

Figure: eWaterCycle workshop in Harare, Zimbabwe in June 2025

DROP app

The DROP app offers scientific rainfall forecasts with 1- to 14-day lead times, local rainfall with 2-day lead time, and 7-day soil moisture forecasts. Farmers can select the crop type and the planting date for their fields. Farmers can also add additional crops in the same field and edit their planting dates. The currently available crop types are Rice, Maize, Cowpea, Groundnut, and Leafy Vegetables, which are the most common crops in northern Ghana. Share forecast is an option where farmers can share their own forecast based on local indicators they observed. We equipped farmers in our study regions with simple rain gauges, as no Ghana Met Office (GMet) rain gauges are installed nearby. Farmers measure the precipitation every morning at 8:00 AM local time and fill in the rainfall observation taken from local measurements. This feature also served as a database for local rainfall that is used to evaluate the performance of the SF and LF forecasts.

Ghana
Current
The app was co-developed together with UDS and is being tested in communities around Tamale, northern Ghana. During the SAFE4ALL technical days in March – April 2025, we visited Nakpanzoo, one of the communities that the DROP app was initiated, and it is still active.

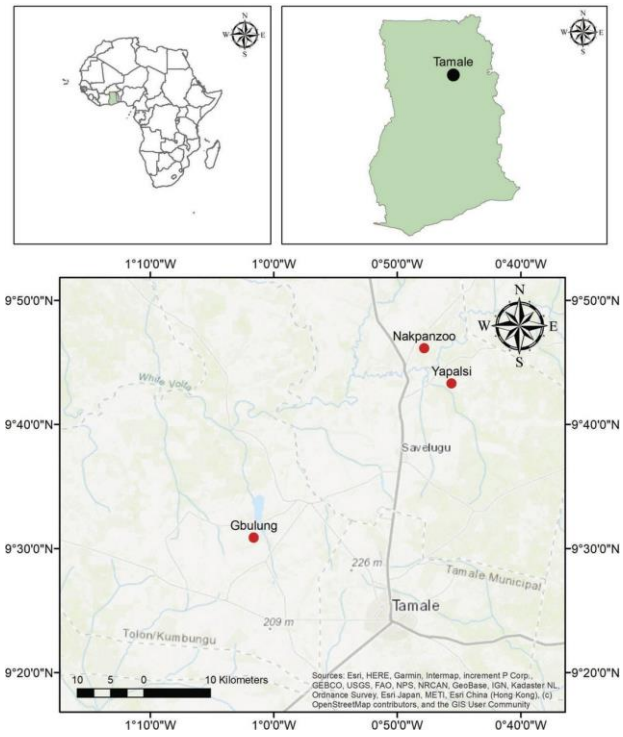


Figure: Map showing locations of the DROP app implementation area in northern Ghana. Gbulung is located in the Kumbungu district and Nakpanzoo and Yapalsi are located in the Savelugu district.

During the visit in Nakpanzoo, on Thursday, April 3rd 2025, we engaged with farmers that were using the app and asked them to show us how they are currently using it. Farmers were extremely enthusiastic to show us the weather, also because the timing of the visit coincided with what traditionally is the onset of the rainy season in northern Ghana (beginning of April). However, the app was saying that there will be no rain up until the middle of the month, which is also what farmers believed themselves having seen their local ecological indicators they use for local weather forecasting.

Figure: Training session on the DROPapp at Nakpanzoo (Ghana), Thursday 3rd of April 2025.

Future

During the SAFE4ALL Technical Days in Accra (28th of March 2025), we held a parallel session on the DROP app. Multiple agricultural extension officers were presented and they were introduced to the DROP app and its functionalities. The extension officers asked several locations in the Greater Accra region, south Ghana, to be added in the DROP app and they gained access to use it to their respective locations (Ga Central, Sowutuom, Agape, Chantan, Ablekuma, Antie AKM, Santa Maria and Weija).

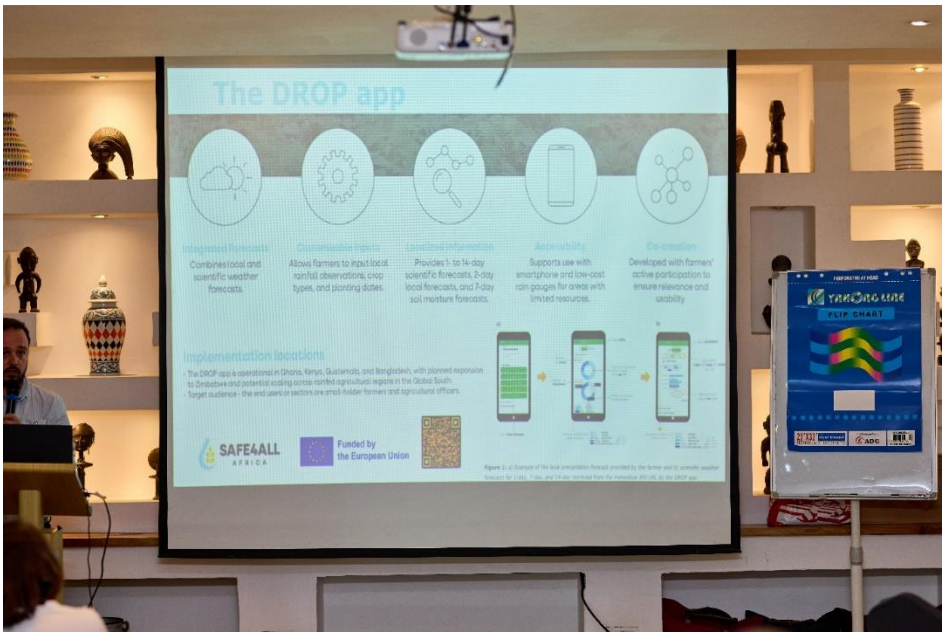


Figure: SAFE4ALL Technical Days session on the DROP app (Friday 28th of March 2025).

Kenya

Current

We visited Kenya in October 2024, to introduce the DROP app to several Kenyan stakeholders. We held a session in Nairobi where we showcased the app to the participants. Local Kenyan stakeholders, especially agricultural extension officers, showed great interest in adopting the app, since it is easy to be obtained from the Google Store

and installed on their phones. They requested to add more Kenyan locations on the app so to use it in their respective localities around Nairobi and Narok.

Figure: Presentation by Spyros Paparrizos of the SAFE4ALL project, that included among other a hands-on session of the DROP app.

We continue our field visit to Narok, Kenya, where we had the possibility to interact with farmers, inquiry about their agricultural activities and introduce them to the app functionalities.

Figure: Stakeholder engagement session during the SAFE4ALL Workshop on the 29th of October.

Figure: Field visit in Narok where we had the possibility to interact with local farmers and showcase the DROPapp functionalities.

Future

In the future, together with JKUAT and the network of Agricultural extension officers that were present in the Workshop in Nairobi, we plan to expand the implementation of the app in the rest SAFE4ALL counties (Nyandarya and Kissumu). In fact, in Kissumu, implementation of the DROP app has already been started with the help of Wageningen University (WU) and local JKUAT students.

Zimbabwe

Current

We have visited Zimbabwe the last week of June 2025 to initiate our engagement with local farming communities and showcase the DROP app. SAFE4ALL partner Zimbabwe Farmers' Union (ZFU) is expected to play a key role in the trainings and upscaling of the capacity building and outreach activities regarding the DROP app. During the fieldwork, we visited two Zimbabwean communities to showcase the app, install it in the phones of several smallholder farmers and agricultural extension officers, and receive feedback through whatsapp groups we established for each region to refine and tailor its use to the specific communities around Marondera and Harare.

Figures: Showcasing and implementing the DROP app in two Wards around Marondera and Harare, June 2025

Future

In the future, we will continue to showcase the DROPapp to more Wards with the help of Zimbabwe Farmer's Union (ZFU). We are in discussions with the in-country met offices and other agricultural organizations to see how the DROP app can be uptaken and upscaled in the longer-term in as many wards as possible, also beyond project duration.

A recent publication showcases the DROPapp information service:

Sutanto, S.J., Paparrizos, S., Nauta, L., Supit, I., Lefevre, V., Kranjac-Berisavljevic, G., Gandaa, B.Z., Dogbey, R., Jamaldeen, B.M., & Ludwig, F. 2025. DROP app: a hydroclimate information service to deliver scientific rainfall, local rainfall, and soil moisture forecasts for agricultural decision-making. Heliyon, 11(4), e42740

Activities

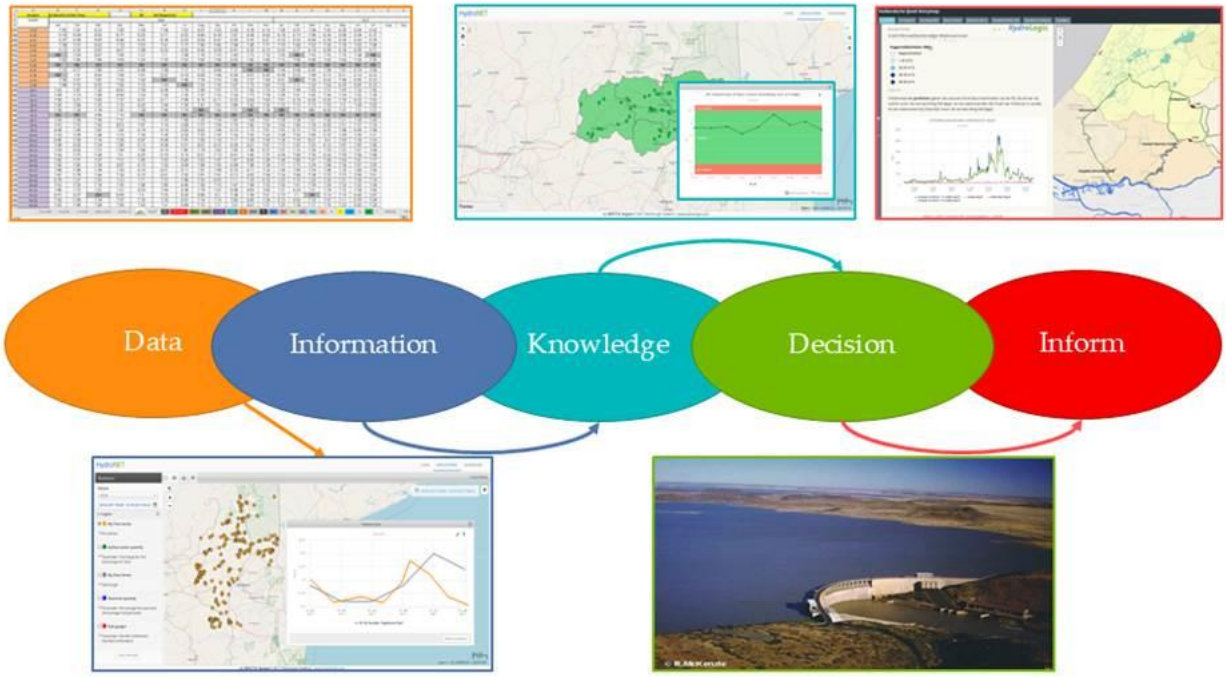
- October 2024 – Introduction workshop on the DROPapp for several stakeholders in *Nairobi, Kenya*
- March 2025 – Workshop session during the GA in *Accra, Ghana* with agricultural extension officers
- April 2025 – Community visits in *northern Ghana*, to Nakpanzoo, one of the communities that the DROPapp was initiated, and it is still active
- April 2025 - field visit to *Narok, Kenya* to interact with local smallholder farmers
- June 2025 – Workshop in *Harare, Zimbabwe* on the DROPP app with several academic, governmental, civil society stakeholders.
- June 2025 – Community visits in *Marondera, Zimbabwe* to introduce the DROP app in two wards around the area together with Zimbabwe Farmer's Union, Meteorological Service Department of Zimbabwe, and several agricultural extension officers.

TWIGA Platform

Current (valid for all 3 Countries)

The TWIGA Platform was designed during the EU funded Horizon 2020 TWIGA Project (https://twiga-h2020.eu/) building on the framework of the HydroLogic BV. HydroNET platform. The platform enables the delivery and ingestion of geodata and climate services within the SAFE4ALL project. Since the services are still at an initial stage and being customized, this platform has not been fully exploited. The structure of the platform enables the development of a full chain of added functionality to the services being developed within SAFE4ALL as a result of its' integration capabilities based on in situ data (data from TAHMO stations and that of the Meteorological Services – Kenya, Ghana and Zimbabwe) as well as satellite data and simulation models results.

The platform enables the collection of various data sets (timeseries and raster) for spatial and temporal analysis. These analyses lead to the generation of information that provides insights to support data-based decision-making using reports, sms and dashboards with easy-to-use visualisations. The platform allows for the integration of data collected within SAFE4ALL into GEOSS. The connection with GEOSS has not been established yet due to current challenges with GOESS which is beyond the scope of this project. The connection will be established once GEOSS is fully operational.



Figures: TWIGA Platform Functionality (Source: TWIGA WP6 Presentation, 2022)

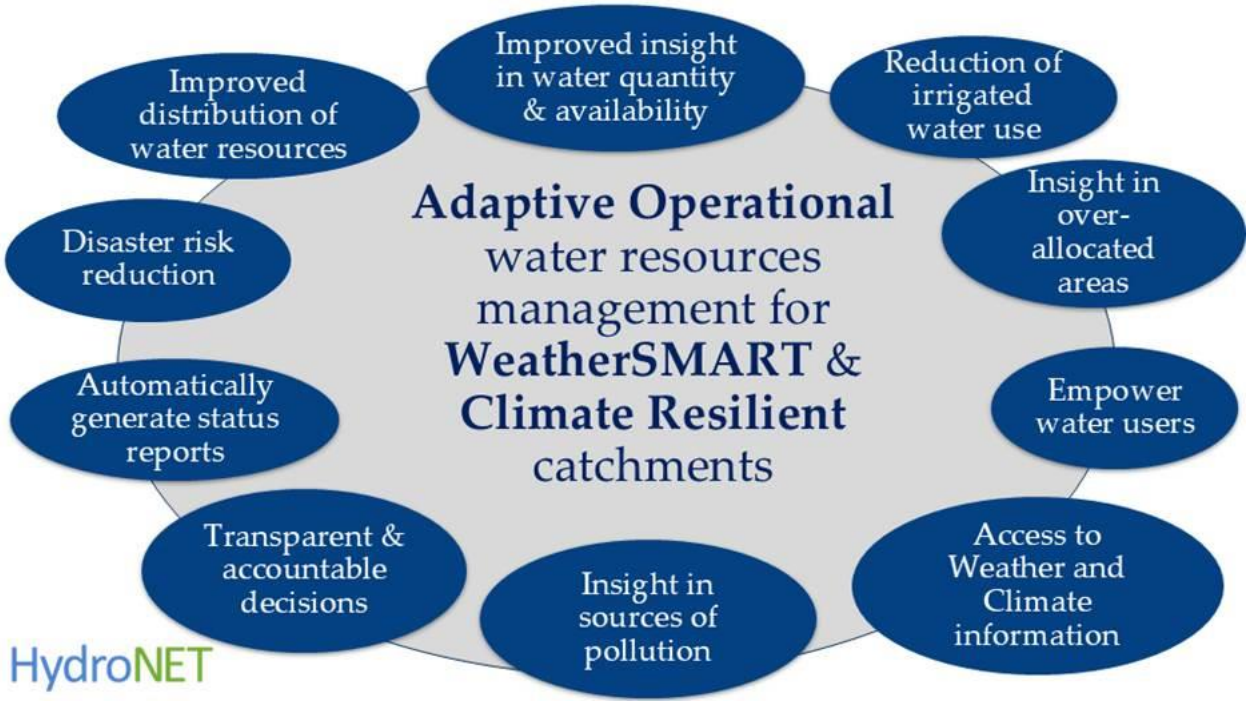


Figure: TWIGA Platform Potential (Source: TWIGA WP6 Presentation, 2022)

Future (valid for all 3 countries)

The SAFE4ALL project plans to use the TWIGA platform to first support the integration of data from the Meteorological Services as well as model results from the weather/climate and hydrological forecasts (WP results) in the three (3) countries (Kenya, Ghana and Zimbabwe). It must be noted that the Platform is meant for "high-level" end-users (such as Waterboards, Water Authorities, Irrigation Authorities, Dam Operators) and not to be used directly by farmers or the public. TAHMO and Weather Impact with the support of TU Delft will facilitate the use of the platform as its' use and need become more apparent and the services being developed within the SAFe4ALL project becomes more mature.

The connection of the platform with GEOSS will be established once GEOSS is fully operational again to make the SAFE4ALL data sets and model results more Findable Accessible, Interoperable and reusable (FAIR).

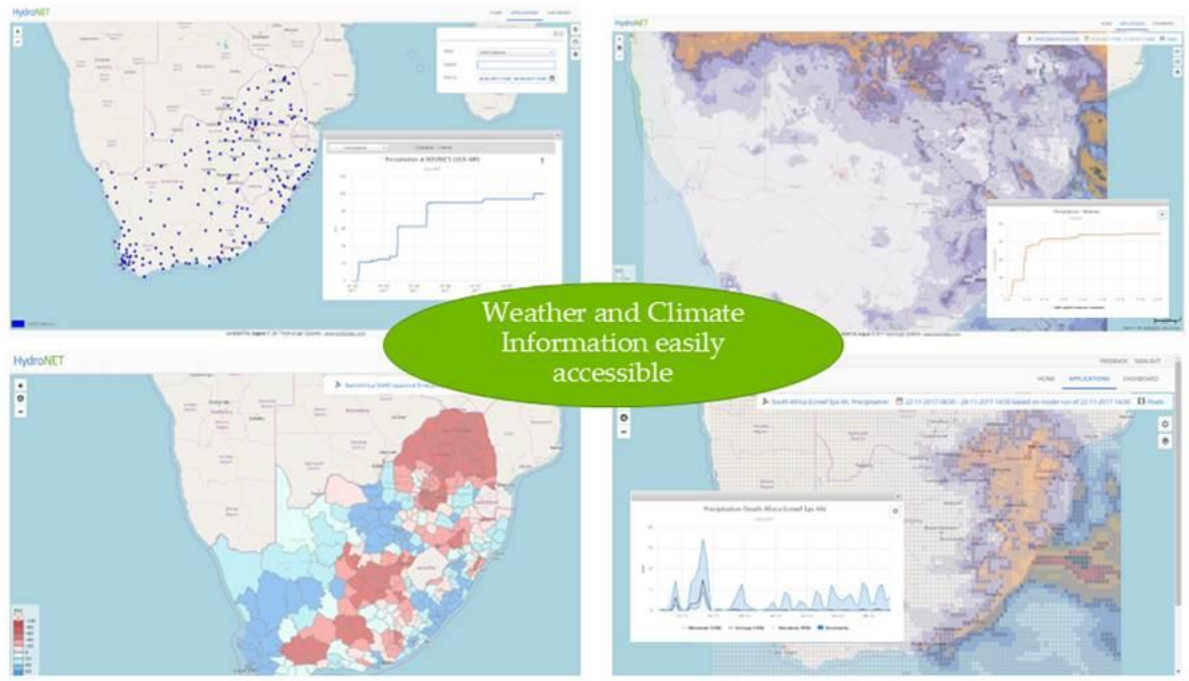


Figure: Use of the TWIGA Platform for accessing weather and climate information (Source: TWIGA WP6 Presentation, 2022)

Hyperlocal Weather Intelligence Engine

Current (valid for all three countries)
The HyperLocal Weather Intelligence Engine currently provides high-resolution weather forecasts. The core of this tool is a SwinIR-GAN hybrid model which was trained for the area of Kenya. The training datasets included low-resolution forecasts from open models and high-resolution hindcasts (2017-2021) generated using a numerical weather prediction model (WRF) and advanced data assimilation techniques. The trained model can currently be used to downscale coarse seasonal forecasts (100km x 100km) to a fine resolution of 2km x 2km with an extremely low computational cost. The model outputs include parameters such as temperature, wind speed and direction, precipitation, evaporation, relative humidity, solar radiation, and soil moisture. Predictions are currently available for a 6-month forecast horizon with monthly updates.
Future (valid for all three countries)
For the remainder of the project, Neuralio will further refine the HyperLocal Weather Intelligence Engine to enhance prediction accuracy and reliability. The tool will incorporate additional satellite and ground observation data to enhance the robustness of its forecasting capabilities. Additionally, efforts will focus on extending the applicability and scalability of the tool across the other pilot areas of the project (Ghana and Zimbabwe) ensuring broader adoption and enhanced local usability. The team will also focus on transferring technical skills to local meteorological agencies to ensure the sustainability of the tool beyond the project's duration.

Activities
During the Technical Days in Accra, Neuralio A.I. participated in a workshop on Data Assimilation, a critical technique underpinning the Hyperlocal Weather Intelligence Engine. The session detailed the theoretical and operational aspects of improving forecast accuracy by correcting the model's initial conditions. Participants were introduced to the 3D-Var (Three-Dimensional Variational) data assimilation method, which systematically integrates diverse observational data, including satellite and ground station measurements, into the model's background state. This activity demonstrated how a more precise representation of the initial atmospheric state is achieved, directly enhancing the reliability and accuracy of the subsequent high-resolution forecasts.

Multi-agent Reinforcement Learning Framework

Current (valid for all three countries)
The Multi-Agent Reinforcement Learning Framework currently integrates Earth Observation data with agent-based models, creating dynamic virtual environments to simulate stakeholder interactions and land-use decisions. Agents operating at micro, meso, and macro levels learn and adapt their strategies using Proximal Policy Optimization (PPO), optimizing for rewards related to economic profitability, resilience, and climate adaptation. This framework has been successfully tested to support decision making processes, particularly in evaluating optimal crop choices and assessing the economic viability of solar energy installations.
Future (valid for all three countries)
Moving forward, Neuralio plans to enhance the Multi-Agent Reinforcement Learning Framework by expanding the complexity and realism of agent interactions to cover more detailed socioeconomic dynamics and climate policy implications. This will be achieved by developing use cases and scenarios for immigration specific for the pilot areas of Kenya, Ghana and Zimbabwe. Continuous improvement will be made in refining reward structures and reinforcement learning methodologies, ensuring alignment with stakeholder priorities in agriculture, energy, and climate adaptation strategies. A significant focus will be placed on deploying this framework to broader regional scales and integrating more detailed policy scenarios to robustly support decision-making processes.

Workshop Ghana during GA
As mentioned previously, during the Technical Days in Accra in March 2025, Neuralio A.I. participated in a workshop on Data Assimilation. This activity demonstrated how a more precise representation of the initial atmospheric state is achieved, directly enhancing the reliability of the subsequent high-resolution forecasts. This enhanced forecast accuracy is not only crucial for the direct outputs of the Hyperlocal Weather Intelligence Engine but also serves as a fundamental input for the Multi-Agent Reinforcement Learning Framework. By providing a more reliable and physically consistent climate scenario, data assimilation ensures that the simulations of stakeholder decisions and land-use changes are grounded in a more realistic representation of future weather conditions, thereby strengthening the validity of the entire impact assessment.

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