Related Studies

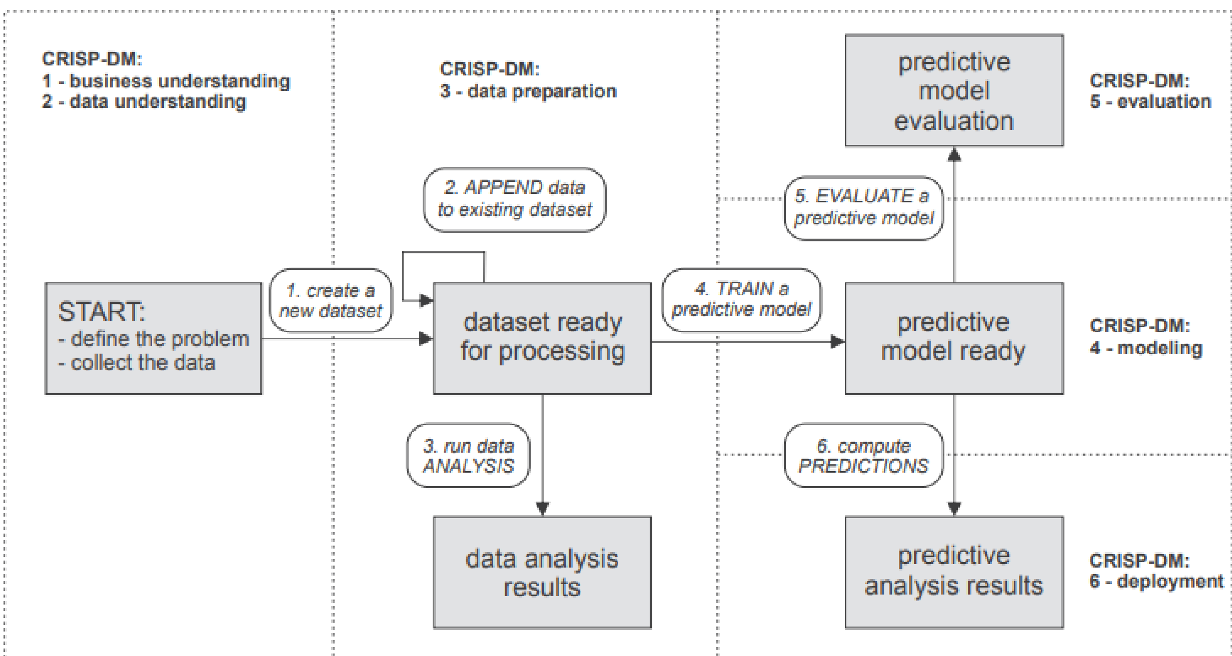
1. **Crop Models: Important Tools in Decision Support System to Manage Wheat Production under Vulnerable Environments**
    a. **Abstract:** Decision support systems are key for yield improvement in modern agriculture. Crop models are decision support tools for crop management to increase crop yield and reduce production risks. Decision Support System for Agrotechnology Transfer (DSSAT) and an Agricultural System simulator (APSIM), intercomparisons were done to evaluate their performance for wheat simulation. Two-year field experimental data were used for model parameterization. The first year was used for calibration and the second-year data were used for model evaluation and intercomparison. Calibrated models were then evaluated with 155 farmers' fields surveyed for data in rice-wheat cropping systems. Both models simulated crop phenology, leaf area index (LAI), total dry matter and yield with high goodness of fit to the measured data during both years of evaluation. DSSAT better predicted yield compared to APSIM with a goodness of fit (R^2) of 64% and 37% during evaluation of 155 farmers' data. Comparison of individual farmer's yields showed that the model simulated wheat yield with percent differences (PDs) of −25% to 17% and −26% to 40%, Root Mean Square Errors (RMSEs) of 436 and 592 kg ha^{-1} with reasonable d-statistics of 0.87 and 0.72 for DSSAT and APSIM, respectively. Both models were used successfully as decision support system tools for crop improvement under vulnerable environments.
    b. **Discussion:** Comparison of crop simulation models can be used for assessing their ability to predict crop phenology, growth, development and yield. A single model can give promising results in a certain region and specific agro-ecological environments, but a multi-model comparison approach could be reliable for yield estimation and uncertainty analysis among models. DSSAT-CERES and APSIM-wheat differ to some degree regarding their equation structure. CERES-wheat is complex for some processes while APSIM-wheat also shows the complexity by interacting various inputs, including phosphorous, soil residues, soil-water dynamics interactions.
    c. **Reference:** Wajid, A., Hussain, K., Ilyas, A., Habib-ur-Rahman, M., Shakil, Q., & Hoogenboom, G. (2021). Crop models: Important tools in decision support system to manage wheat production under Vulnerable Environments. *Agriculture*, *11*(11), 1166. https://doi.org/10.3390/agriculture11111166

2. **AgroDSS: A decision support system for agriculture and farming**
    a. **Abstract:** Decision support systems, data analysis and data mining have become significant tools for improving business in professional world. The

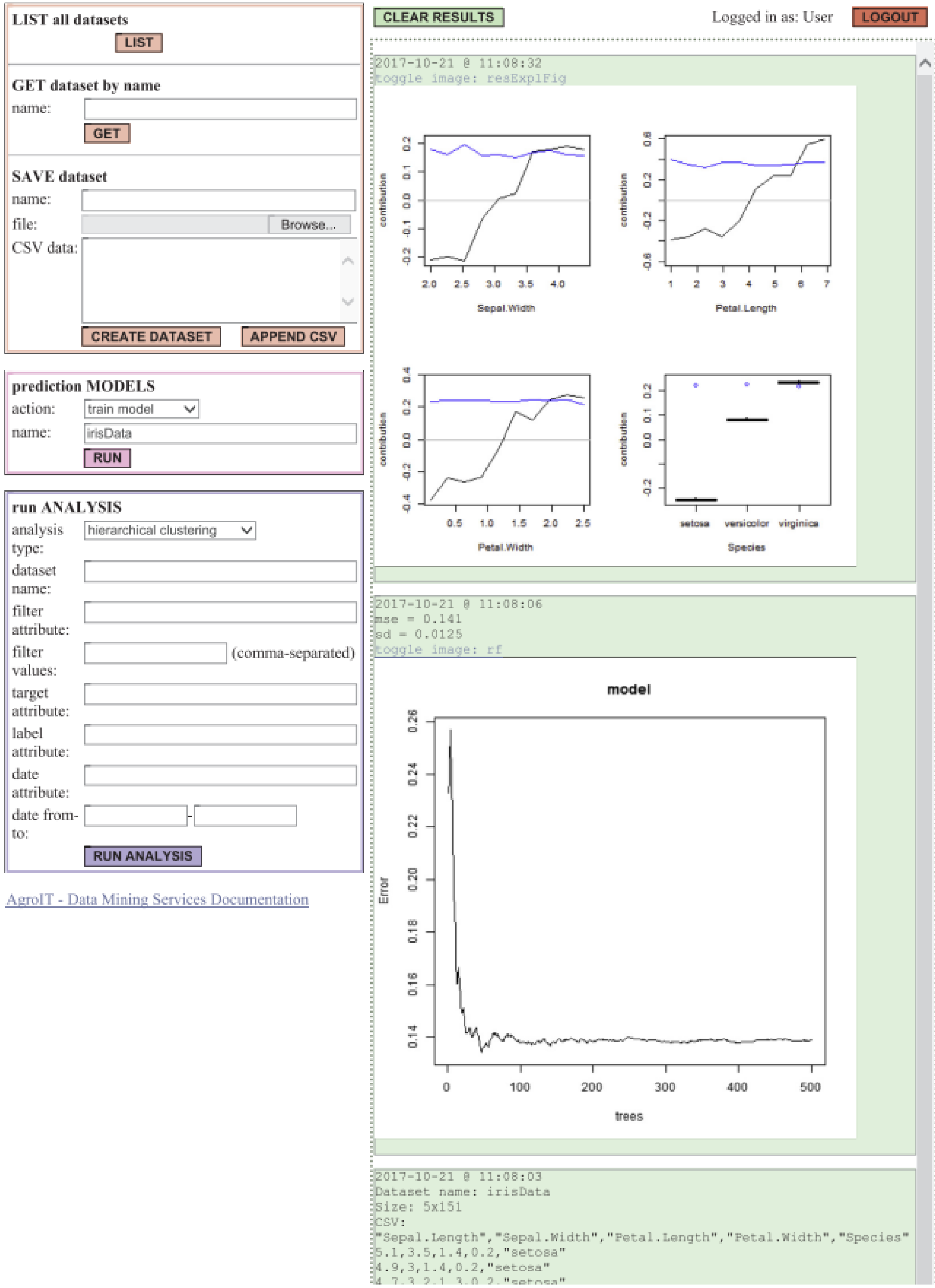
emerging technologies are making the precision agriculture omnipresent and allow potential for enriching it with computer-assisted decision support systems for farm management. In this paper we describe a novel system AgroDSS that bridges the gap between agricultural systems and state-of-the-art decision support methodology. The described system is intended for integration into the existing farm management information systems and provides a cloud-based decision support toolbox, allowing farmers to upload their own data, utilize several data analysis methods and retrieve their outputs. The implemented tools include predictive modeling with explanation, accuracy evaluation, time series clustering and decomposition, and structural change detection. They can help users make predictions for simulated scenarios and better understand the dependencies (interactions) within their domain. We apply the AgroDSS system on a case study of pest population dynamics, illustrating the potential for its use.

b. **Discussion:** The AgroDSS system uses data mining approaches to determine useful information from large volumes of data such as trends, patterns and distributions. This allows for better understanding of data and help predict future impacts of different actions. The farmers as well provide information for the system and the problems would like answers to such as seasonality analysis.

c. **AgroDSS workflow:**



d. **AgroDSS UI:**



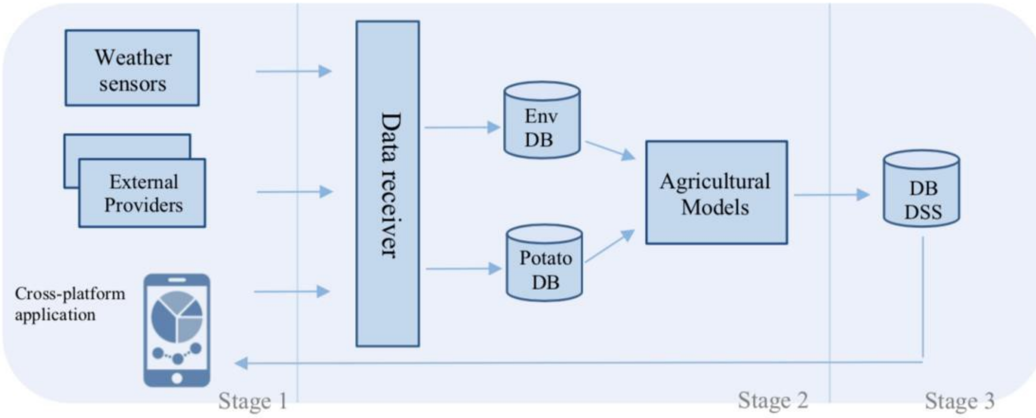
e. **Reference:** Rupnik, R., Kukar, M., Vračar, P., Košir, D., Pevec, D., & Bosnić, Z. (2018). AgroDSS: A decision support system for agriculture and farming. Computers and Electronics in Agriculture. doi:10.1016/j.compag.2018.04.001

3. **Model for Predicting Rice Yield from Reflectance Index and Weather Variables in Lowland Rice Fields**
    a. Primary focus was to present and optimize a multi-purpose forecasting model that manages farming resources such as fertilizer and irrigation water supply through an effectiveness analysis on in-season estimations of rice yield in northwest Cambodia by comparing yield estimates between two active-sensor tools and determining which was far more suitable for rice-yield production:
        i. Weather data and vegetation cover information was measured using **Canopeo, GreenSeeker-NDVI** and a generalized additive model (**GAM**):
            1. **Canopeo**: A free-for-use active sensing mobile application tool that employs spectral RGB values to determine plant health and to estimate crop biomass that can be used to estimate a crop model that showcases extensive crop-canopy attribute ranges (to possibly predict a relationship between biomass estimates and yield-related traits in specific crops).
                a. Yield prediction models are noted to improve through long time weather data series as it provides an estimate of crop yield in advance under weather-based influence, especially on vegetative growth and development.
            2. **GreenSeeker-NVDI:** A commercial handheld device used to measure the normalized difference vegetative index (NVDI).
                a. The NVDI is a prediction model conventionally used to estimate rice biomass at critical growth stages on small-scale rice fields.
            3. **GAM**: Explores the non-linear relationships between the dependent variables and the independent variables since the relationships depend linearly on unknown, smooth functions of some predictor variables. As such, the main focus was on the interference from these smooth functions to determine a relationship between predictors and the response variable.
                a. The study presented its GAMs by plotting fitted smooths against yield, which would hypothetically clarify crop-vegetation indices-weather interactions.
    b. The study compared both yields using Canopeo and GreenSeeker-NVDI used on data from on-farm field experiments in the rice growing regions between 2018 to 2019, alongside average temperature and cumulative rainfall that were calculated at panicle initiation and pre-heading stages when the crop cover index was measured. A generalized additive model

(GAM) was made through transformed data of grain yield with canopy cover predictors and weather data.

c. Overall, it was determined that the Canopea index model explained 65% of the variability in yields through the input data and the NVDI-weather model only explained 62% of the variability.
d. The researchers concluded that Canopea was a far more flexible and effective tool for small-scale rice farmers within their locale to improve limited farming resources management, such as fertilizer, in terms of performance and accessibility.
e. **Reference:** https://www.mdpi.com/2077-0472/12/2/130

4. **DSS LANDS: A Decision Support System for Agriculture in Sardinia**
   a. The goals of this DSS were as follows:
      i. optimize the resources management through reduction of certain inputs (e.g., chemicals and naturals resources, etc.)
      ii. predict crop risk situations (e.g., diseases, weather alerts etc.)
      iii. increase the quality of decisions for field management
      iv. reduce environmental impact and production cost; integrating different and specific modules for monitoring the main crop productions in Sardinia (citrus, artichoke, wheat, corn, olive, potato, peach, tomato, rice, vine)
   b. The prototype DSS collects, organizes, integrates and organizes several types of data with different mathematical models. It comprises of three components:
      i. An integrated system for semi-real time monitoring of crop components and storage of their data;
      ii. A models system which performs through several mathematical and forecasting models a cross and dynamic analysis of different types of data. This allows strategies to be employed in the field to avoid risks of damaging production;
      iii. A cross-platform application used by LAORE technical and farmers to upload crop data collected during the field survey and to visualize the up-to- date information for managing the cultivation in the form of alerts and decision support. This allows farmers to access the application without worrying about the device in use. All information given by the application is in graphic format that uses visual aids to relay information immediately, effectively and unambiguously. Internet connectivity also allows timely updating of the features once new analysis results are available.



c. The system underwent a test in 2018 in the spring in hopes of forecasting and evaluating the risk of potato blight, which devastates potato crops all over the world including Sardinia. It was determined that within the region, climate change such as rains occurring in frequent proximity of one another, high humidity and abrupt temperature changes were the leading cause of hampered potato production.
   i. The researchers employed two predictive models: **Negative Prognosis model** and **Fry model**.
      1. The **Negative Prognosis model** predicts the period where the blight is not likely to occur alongside determining the perfect time frame to introduce blight treatment. Accurate prediction was achieved using the following data: hourly temperature (°C), relative humidity (%), and rainfall (mm). The model then calculates the risk values and the accumulated risk values which allow for further analysis into the specific date to begin the first treatment.
      2. The **Fry Model** was employed to estimate treatment after the first introduction by calculating the spraying intervals by analyzing blight units and fungicide units.
         a. Blight units are calculated according to the number of consecutive hours that relative humidity is greater than or equal to 90%, and average temperature falls within any of six ranges (< 3, 3-7, 8- 12, 13-22, 23-27 and >27 C).
         b. Fungicide units are calculated based on daily rainfall (mm) and time since last fungicide application. Decision rules about when fungicide should be applied are generated based on cumulative blight units or fungicide units since last spray.

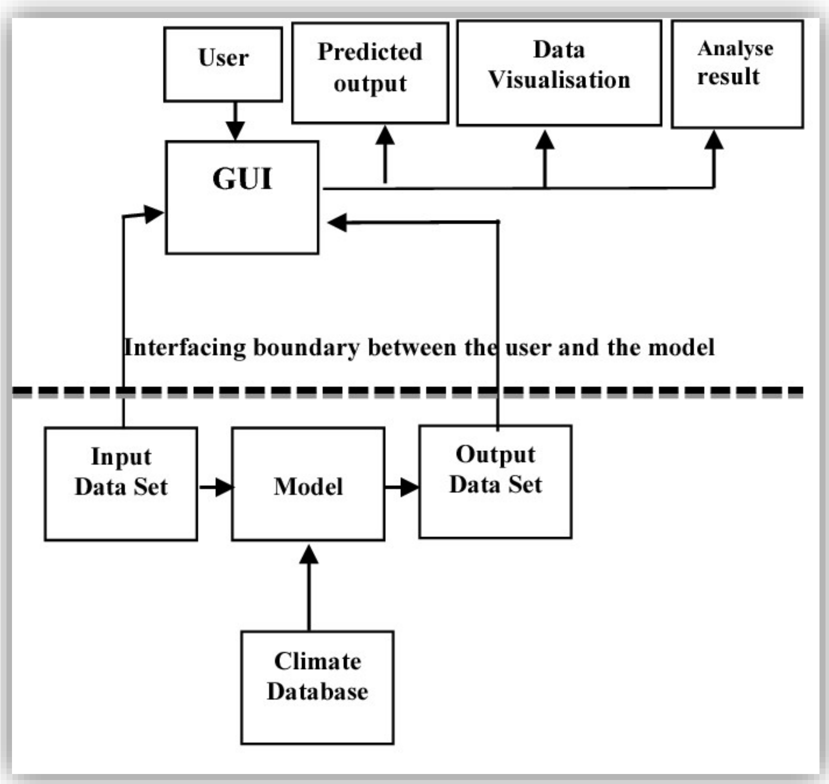
d. Summarily, the researchers were able to determine the best criteria to use for the implementation of their DSS project, focusing on local conditions, which proved that the methods they employed were effective into furthering their goals into the production of this system.

5. **Mobile Based Agricultural Management System for Indian Farmers**
    a. **Abstract:** Agriculture is one of the most powerful tools to eradicate hunger and poverty from the world. Technology has been playing an essential role in the agricultural sector of developed economies, but when it comes to developing and under-developed nations, there is a need to bridge the gap between technology and agriculture. The efficiency in the crop productivity and optimum utilization of resources is a challenge that can be addressed with technological advancement. This study aims to create a knowledge-based system (KBS) in the form of a mobile application to help the Indian farmers for improvement in their agricultural practices and increasing crop productivity. A prototype mobile application, 'Farm-n-pedia,' is used to fulfill the informational needs of the farmers and provide a tool for agriculture management using a single platform. This agricultural knowledge mobile application provides accessibility and personalization, which is long desired by the farmers. It enables the users to access any information they want from all around the globe, get personalized expert guidance, know about the latest farming techniques and technology, and increase agricultural productivity.
    b. **Focus:** To aid farmers in India using a mobile application that has a Knowledge-Based System (KBS). The prototype is called "Farm-npedia." The main features of the system include the user being able to obtain key information regarding crops and agriculture based on the KBS and can also show proper tips and tricks regarding the latest farming techniques.
    c. **Reference:** https://link.springer.com/chapter/10.1007/978-3-03049757-6_11
6. **Exploring Different Architectures to Support Crop Farmers with a Mobile Application on Pesticide Control**
    a. **Abstract:** The MobiCrop app, which is a distributed mobile application has been proposed to aid crop farmers with timely decision making on the applicability of pesticides (i.e., which pesticide to apply, when, where, and how to apply them). Due to the vast amount of pesticide and crop data, the application is designed following the three-tier architecture technique which comprises the mobile devices, a cloud-hosted middleware, and cloud-based database. The idea is to enable the mobile device to retrieve the needed pesticide data from the back-end and when necessary, part of the data can be stored on the mobile through caching for offline accessibility. However, constantly updating the mobile cache through data polling is costly for the wireless bandwidth and energy usage on the mobile. Also, it is difficult to update the stale cache data when there is no wireless connectivity. Hence, this work explores three architectural designs of the MobiCrop app which are the: 1) the standalone (network independent), 2) distributed architecture through data offloading, and 3) distributed architecture through data partitioning.

b. **Focus:** A mobile application to aid farmers about pesticides. The prototype of the system is called "**MobiCrop**." Its features include a three-layer deployment which includes mobile nodes, cloud-hosted middleware, and cloud-hosted database server which contains information regarding pesticides to their assigned crops. This system also supports offline accessibility for the information for reliability.
c. **Reference:** https://www.proquest.com/openview/a73656b74fa9d1545361996346ef17c8/1?pq-origsite=gscholar&cbl=1686342

7. **Proposed decision support system (DSS) for Indian rice crop yield prediction**
   a. **Abstract:** Rice crop production provides more than 40% to overall crop production in India and is essential in ensuring food security. Its production is reliant on favorable climatic conditions. Improving the ability of farmers to predict crop productivity under different climatic scenarios, can assist farmers and other stakeholders in making important decisions in terms of agronomy and crop choice. This paper proposes a decision support system prototype for rice crop yield prediction for Maharashtra state, India. A Graphical User Interface (GUI) has been created in Java using NetBeans tool and Microsoft Office Access database for the ease of farmers and decision makers. The interface allows for the selection of the range of precipitation, minimum temperature, average temperature, maximum temperature and reference crop evapotranspiration and predicts the expected class of yield viz., low, moderate or high. The ranges of the parameters were calculated by using historic data from the study area. The classes for the yield were defined as low with 0.15 to 0.60 tonnes/hectare; moderate with 0.61 to 1.10 tonnes/hectare and high with 1.11 to 3.16 tonnes/hectare. The proposed prototype could be used for a bigger dataset and wider study area to predict the crop yield. This will provide a guide to the farmer to assist in decision making on potential crop yield for particular climatic scenario.
   b. **Focus:** A prototype created to guide farmers and assist in the overall potential yield of crops for different weather, season, and climate scenarios. This project's features focus on the GUI which can aid farmers by giving information on expected crop yield depending on the climate's precipitation and temperature.
   c. **Reference:** https://ieeexplore.ieee.org/abstract/document/7801205

d. **Figures**:
    i. Flowchart describing the interactions between the model and the graphical user interface (GUI)



8. **GeoFarmer: A monitoring and feedback system for agricultural development projects**
    a. **Abstract**: Farmers can manage their crops and farms better if they can communicate their experiences, both positive and negative, with each other and with experts. Digital agriculture using internet communication technology (ICT) may facilitate the sharing of experiences between farmers themselves and with experts and others interested in agriculture. ICT approaches in agriculture are, however, still out of the reach of many farmers. The reasons are lack of connectivity, missing capacity building and poor usability of ICT applications. We decided to tackle this problem through cost-effective, easy to use ICT approaches, based on infrastructure and services currently available to small-scale producers in developing areas. Working through a participatory design approach, we developed and tested a novel technology. GeoFarmer provides near real-time, two-way data flows that support processes of co-innovation in agricultural development projects. It can be used as a cost-effective ICTbased platform to monitor agricultural production systems with interactive feedback between the users, within pre-defined geographical domains. We tested GeoFarmer in four geographic domains associated

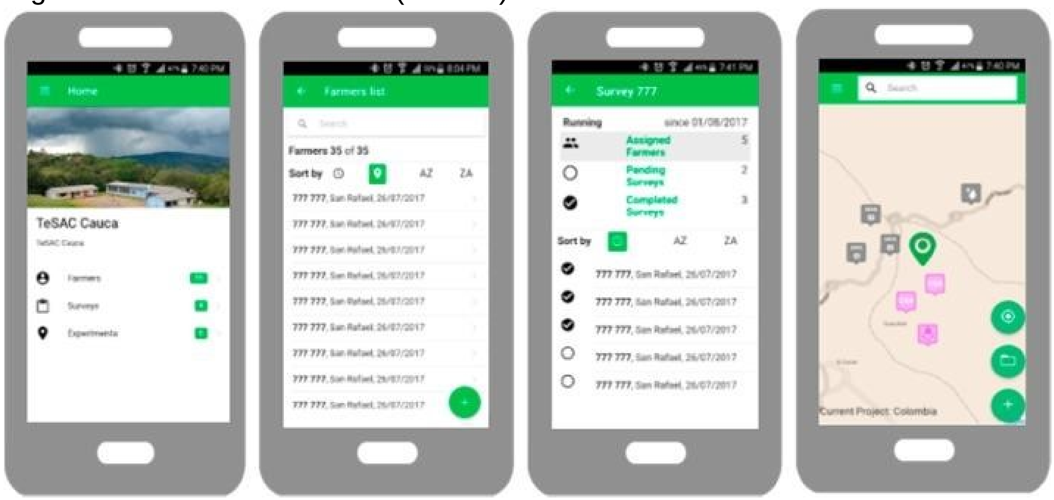
with ongoing agricultural development projects in East and West Africa and Latin America. We demonstrate that GeoFarmer is a cost-effective means of providing and sharing opportune indicators of on-farm performance. It is a potentially useful tool that farmers and agricultural practitioners can use to manage their crops and farms better, reduce risk, increase productivity and improve their livelihoods.

b. **GeoFarmer design as a geospatial cloud-based system**: GeoFarmer employs a layered design with a modular component system that communicates with a central cloud application, which contains a central database where all data is compiled. The backend of cloud applications also interacts with external components and services. The modular structure and multilayer architecture make it easier to create single components for specific usability scenarios, such as a simple user interface for novice users and a more complex interface for experts.
c. **Reference**: https://www.sciencedirect.com/science/article/pii/S0168169918308433
d. **Web dashboard**: The GeoFarmer dashboard is a management tool and integration platform for collecting data in the field. It is the central tool for managing GeoFarmer geographical domains and data. Only registered users with moderator role can log in to the dashboard and access their geographic domains (projects). The moderator creates new surveys and questions, and he approves facilitators that requested a facilitator role through the smartphone application. Collected survey data and results are accessible on the dashboard; the moderator can create public links of results and share them on the internet. The moderators manage the discussion process of smartphone-application users, i.e., set parameters or control user access to the discussion process thus ensuring a free exchange of information between users. Although the facilitators, experts, and farmers do not use the dashboard, their ability to communicate depends on it being well managed.

Systems functionality	Objective	Systems user and roles	Means of interaction
- User registration - Create geographical domain - Edit geographical domain	- Create a new user account - Create a new geographic domain, define the geographic extent, assign moderators - Edit domain parameters, define point categories, add map-layers, manage participants	Moderator *(System Administrator)*	Web dashboard
- Approve user roles - New surveys - See/share survey results - Edit process parameters	- Approval of users as a facilitator/expert - Create surveys and assign surveys to farmer groups; create and add questions, edit survey parameters - Access and share survey results as a public link - Edit process parameters for the discussion process	Moderator	Web dashboard
- User registration - Register farmer	- Create a new user account - Register a farmer in the system	Farmer, Facilitator, Expert Facilitator	Smartphone-application
- Self-registration - List of farmers	- Self-registration of a farmer (profile) - Query/sort/filter list of registered farmers	Farmer Facilitator	Smartphone-application
- Edit Farmers (profile)	- Edit all farmers' profile page - Edit own profile page	Facilitator Farmer	Smartphone-application
- Monitoring (surveys)	- Fill surveys assigned to multiple farmers - Fill surveys assigned to own profile	Facilitator Farmer	Smartphone-application
- Set a point-observation on the map - Communicating	- Geolocation of points on the map viewer - Start a participatory process on a point	Facilitator, Farmer	Smartphone-application
- Solving	- Comment, discuss, ask questions, provide answers - Users can vote (support) for answers	Experts, Farmer, Facilitators	Smartphone-application
- Monitoring (IVR)	- Run survey on IVR service portal - Respond to an IVR call of survey questions	*(System Administrator)* Farmer	IVR call
- Export data (for IVR calls) - Import data (from IVR calls)	- Export farmer lists, survey questions from the database - Import results from IVR service into the database	*(System Administrator)*	Database

* The system administrator is the platform operator.

e. **Smartphone application**: Facilitators and experts use the smartphone application during fieldwork activities while interacting with farmers. Farmers can also use it as an individual user. It is the central data-collection tool (Fig. 5). The smartphone application is simple and optimized for fieldwork usage. After user registration and login, the user can send a request to be a facilitator in a specific geographic domain, which requires approval from the moderator in the web-dashboard, or he logs in as an individual user (farmer).



9. **BrAPI—an application programming interface for plant breeding applications**

   a. **Motivation**: Modern genomic breeding methods rely heavily on very large amounts of phenotyping and genotyping data, presenting new challenges in effective data management and integration. Recently, the size and complexity of datasets have increased significantly, with the result that data are often stored on multiple systems. As analyses of interest increasingly require aggregation of datasets from diverse sources, data exchange between disparate systems becomes a challenge.

   b. **Results**: To facilitate interoperability among breeding applications, we present the public plant Breeding Application Programming Interface (BrAPI). BrAPI is a standardized web service API specification. The development of BrAPI is a collaborative, community-based initiative involving a growing global community of over a hundred participants representing several dozen institutions and companies. Development of such a standard is recognized as critical to a number of important large breeding system initiatives as a foundational technology. The focus of the first version of the API is on providing services for connecting systems and retrieving basic breeding data including germplasm, study, observation, and marker data. A number of BrAPI-enabled applications, termed BrAPPs, have been written, that take advantage of the emerging support of BrAPI by many databases.

   c. **Availability and implementation**: More information on BrAPI, including links to the specification, test suites, BrAPPs, and sample implementations is available at https://brapi.org/. The BrAPI specification and the developer tools are provided as free and open source.

d. **Reference**:
https://academic.oup.com/bioinformatics/article/35/20/4147/5418796