Makara App: A Case Study in Digital Innovation for Enhanced Agricultural Productivity and Sustainability

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Abstract. The agricultural sector, particularly in rural areas, faces numerous challenges including labor shortages, fluctuating costs, and unpredictable weather patterns. The Makara app emerges as a pioneering digital solution, specifically designed to address the multifaceted needs of small-scale farmers. This paper presents a case study on the Makara app, highlighting its role in transforming agricultural practices through digital innovation. The app provides a comprehensive platform for farmers to manage their land, crops, and financials effectively. It offers detailed land and crop management, budgeting, and activity management. Additionally, Makara's day-to-day advisory service and risk prediction module assist farmers in optimizing resource use and enhancing productivity. The app's multilingual interface and offline mode ensure accessibility and usability in remote areas. This study analyzes the software development, farmer engagement, feedback collection, software refinement, and deployment process of the Makara app among the select farmers of the Nagpur region in Maharashtra, India. The Makara app exemplifies the potential of digital tools in promoting sustainable and profitable farming practices in rural communities.

Keywords: Digital innovation, Agriculture, Yield prediction, Farmer engagement.

1 Introduction

The Indian agricultural sector contributes 18% to GDP, employs 54% of the workforce, and accounts for 11% of exports [1][2]. In 2022, 45% of the land was cultivated, with 68% of farmers holding less than 1 hectare, and 18% holding 1-2 hectares [2]. India produced 286 million tons of food in 2022-23, with major produce including rice, wheat, and sugarcane [2]. The Green Revolution increased production from 50.82 MT in 1950-51 to 284.83 MT in 2017-18, but also led to a 7-fold increase in fertilizer use and a 375-fold increase in pesticide use, causing ecological degradation [3]. Mechanization reduced the use of animal and human power from 97.4% in 1951 to 12% in 2013-14, but smallholders, who are 85% of the farming community, face disadvantages due to scale, weak institutional support, and market access [4][5].

Modern agriculture poses significant challenges for small rural farmers, including labor shortages, fluctuating costs, unpredictable weather, and complexities in managing

fertilizers, pesticides, and market dynamics. These obstacles often impede farmers' ability to make timely decisions to maximize revenue and minimize costs. The Makara app emerges as a groundbreaking agricultural management tool, offering a digital platform tailored to the diverse needs of farming. It allows farmers to input detailed information about their lands, including, location, area, soil health, water sources, and irrigation methods. Makara supports configuring multiple crops for each land and season, allowing flexible farming management. Makara assists farmers in recording expenses for seeds, fertilizers, and labor activities such as irrigation, weeding, land preparation, and harvesting. Its day-to-day advisory service provides guidance on best practices for each of the crop growth stages for better farm activity management. The Makara app provides estimated crop yields, based on weather, location, soil, crop, and irrigation, enabling farmers to estimate potential income and profits. Makara is designed for user-friendliness and accessibility, with a multilingual interface and an offline mode to ensure uninterrupted operation [6].

This paper introduces the Makara app, detailing its functionalities, deployment strategies, and design considerations. In the rest of the paper we present the related works, details of the high-level design and functionalities, challenges faced and the adopted solutions, deployment plan and progress details, and end with conclusion.

2 Related Works

Digital agriculture encompasses five thematic areas: technology adoption, impact on farmer identity and labor, power and ethics, knowledge systems influence, and economic effects [7]. It involves IoT, cloud computing, robotics [8], and big data [9], with a focus on inclusivity and privacy. Makara, centered on cloud computing, acts as a farm's digital twin, enabling real-time activity tracking.

Reference [10] details a survey of 500 Brazilian farmers' experience with digital farm management technologies, covering a diverse range of farm sizes and methods, including chemical, organic, and no-till. These farmers engaged with a variety of digital tools for diverse purposes such as property, input, and production management, livestock care, and the management of weeds, pests, and diseases. Farmers reported finding that FMPs are beneficial for reducing costs, enhancing revenue, and improving task management. Sensors, machinery, and robots were highly valued for boosting productivity, quality, and efficiency. Challenges noted were high initial costs, poor internet access, insufficient training, and the complexity of selecting the right technology.

Various FMPs are evaluated in reference [11], which distinguishes them based on functionalities such as farm digitalization, GIS, task and cost management, and livestock and order management, with platforms like Agrivi, FarmERP, FarmBrite, and EasyFarm being notable examples [12]. Despite the comprehensive features, years of development, wide adoption, and substantial funding of these platforms, disparities remain for small and medium-scale Indian farmers. Challenges include the need for a multilingual interface, precise guidance on optimal farming practices, on-site support, free service provision, support for inter-cropping and multi-cropping, yield prediction, and an audio-guided user interface. Numerous agricultural apps designed for Indian farmers, like riceXpert and Crop Doctor [13], specialize in areas such as pest

management or fertilizer guidance. However, these apps often support only a few regional languages, and lack comprehensiveness, focusing only on specific functions. The Makara app offers a user-friendly, multilingual interface with audio support in Hindi and Marathi, in addition to English, and can rapidly integrate additional Indian languages. It features yield predictions and customized best practice recommendations, all available free of charge to farmers. Furthermore, it includes on-the-ground support to ensure farmers can fully leverage the app's capabilities.

3 Introduction to Makara

Makara App offers land setup, financial management, activity planning, and AI-powered yield prediction to optimize farm operations and profitability.

3.1 Core Features

The Makara App helps streamline farm management and reduce financial risks.

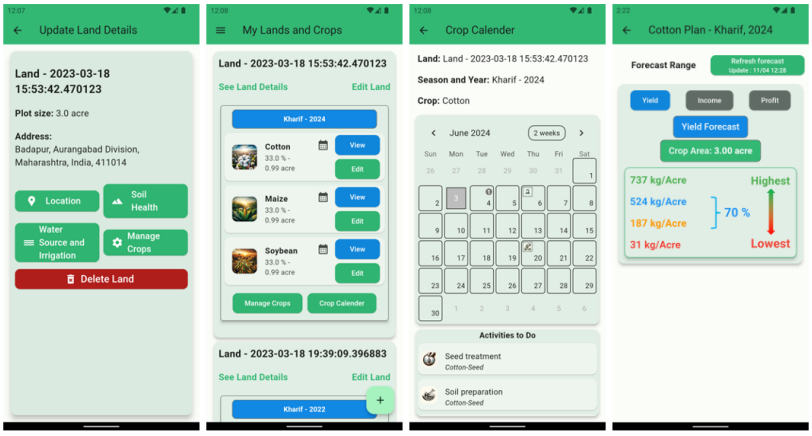
Farm Setup. Farmers configure their parcels of land, including size, soil type, and water sources. Makara facilitates uploading soil type and test reports. Makara also keeps a record of livestock, investments, interest rates, and family members for usage in the socio-economic model as part of yield prediction (see Fig. 1(a)).

Crop Management. Farmers can plan diverse crops each season, choosing multi or intercropping layouts by area percentage or row count on the land, and track spending on fertilizers, pesticides, and seeds. Admins can set up growth stages and related tasks, providing precise best-practice instructions for every crop and season (see Fig. 1(b)).

Activity Journal. The best practice recommendations configured for each crop and season will be listed as tasks on the calendar interface for the farmers. It encourages optimal task performance for crops and allows the recording of all additional farm activities to maintain a detailed journal of farming operations (see Fig. 1(c)).

Yield Prediction. Utilizing a proprietary AI/ML model, the app elevates farming strategies by predicting yield and revenue based on geographical data, soil characteristics, chosen crops, weather patterns, historical performance, market trends, socioeconomic parameters [14], and the activity journal (see Fig. 1(d)).

The Makara App acts as a partner in the farming journey. With its predictive capabilities, farmers can make informed decisions for future-proofing their agriculture.



(a) (b) (c) (d)

Fig. 1. Makara App screens. (a) Farm setup, (b) Crop management, (c) Activity journal, and (d) Yield prediction.

3.2 Data Model

Makara's data model meticulously mirrors the real-world farm, accommodating various lands, crops, and configurations. It includes a Farmer table with personal and financial details, a Land table for location, size, and soil details, and a LandSection table detailing crops, layout, and planting area for each season. The Crop and CropVariety tables document supported crops and cultivation instructions, including watering and treatment needs. The GrowthStage table outlines necessary activities for each plant stage, appearing as tasks on the farmer's calendar. Lastly, the Activity Journal logs completed tasks and any additional farmer actions (see Fig. 2).

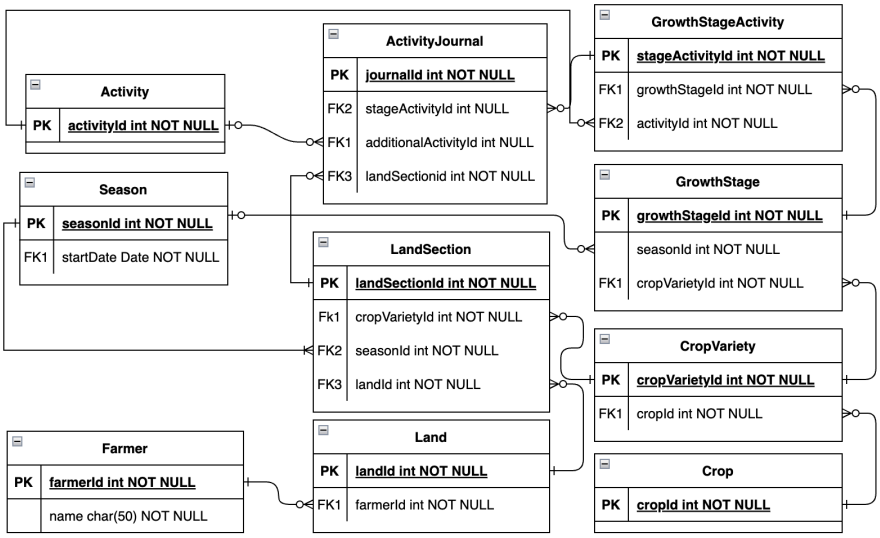


Fig. 2. Entity Relation diagram of Makara digital farm

3.3 Technology

The Makara app is built using Flutter's cross-platform framework, with code crafted in Dart. Local data caching on the device is managed through an SQLite database. On the server side, the infrastructure operates on the NodeJS framework with JavaScript coding. Data storage is handled by MySQL. HTTP request routing is conducted via the ExpressJS package, while push notifications between server and client are facilitated by the socket.io package [15]. The Local database cache stores farmer data on the device, so that the farmer can operate the app even without a network. The local database cache, along local memory cache, and server memory cache, achieves the performance, bandwidth optimization, and offline mode [16] (see Fig. 3).

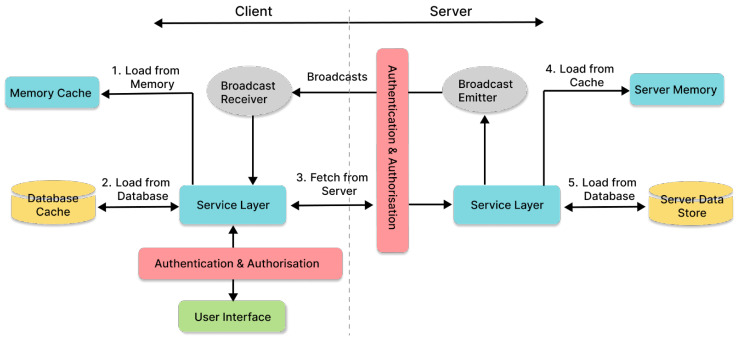


Fig. 3. Offline-Mode & Cache Framework

3.4 Security and Privacy

The Makara platform employs a robust authentication and authorization scheme to ensure stringent data security and privacy. Authentication is facilitated through a combination of mobile number and password. Upon successful login, the server generates an AUTH Token, which the client sends with each subsequent request to validate the user account. Our role-based authorization mechanism prevents unauthorized users, including other farmers, from accessing individual farmer data.

The authentication and authorization processes are implemented across both client and server interfaces (see Fig. 3). Client-side validation ensures that farmers only see information and action buttons relevant to them, enhancing usability and security. Meanwhile, server-side screening safeguards against attacks from third-party client software attempting to emulate the Makara mobile or browser clients.

4 Deployment

The Makara app's rollout in Maharashtra's drought-prone districts—Amravati, Nagpur, Wardha, and Yavatmal—is multi-staged. Following its initial development, group discussions were held with farmers in March 2023, leading to feedback-based improvements. Subsequent virtual meetings in November 2023 elicited additional feedback, which was incorporated into the app (see Fig. 4). With 670 farmers consenting to field trials, 53 were chosen as champions due to their mobile app experience. They provide feedback via four focused group discussions and two campaigns of individual semi-structured interviews. Further, they lead farmer groups, each with a dedicated WhatsApp communication channel. These champions collate subgroup feedback, refining it before sharing it with us for the intended Kharif 2024 crop season.

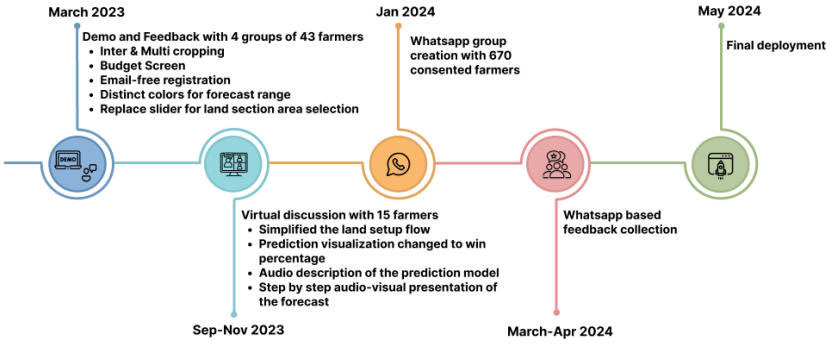


Fig. 4. Deployment stages and intended timeline

5 Challenges, Feedback, and Improvements

Throughout the development of the Makara App, we navigated numerous challenges and integrated extensive feedback. We collected insights through surveys and field trials involving selected farmer groups from March 2023 to March 2024. These surveys probed the app's overall usability and utility, with particular emphasis on key features like yield prediction. By systematically implementing iterative enhancements based on this feedback, we significantly improved the app's ease of use. This led to marked optimism among farmers regarding the app's practical benefits. However, the full utility of the app will only become apparent with extensive use during the upcoming Kharif season. The subsequent sub-sections detail how feedback on specific features was integrated into the app.

5.1 Farm Setup

We tailored Makara's data model to accurately represent real-world farm configurations while considering the digital literacy levels of rural farmers.

Multiple Crops. Recognizing that farmers in our target area practice multi-cropping, we refined our data model to support multiple crops per land and season. Initially, a slider was used to set up crop area percentages, but this proved counterintuitive. We switched to input boxes for clearer, area-specific entries (see Fig. 5.1).

5.2 Yield Prediction

The original forecast graph displayed risks, yield, income, and profit as a color-coded stacked bar graph with five forecast probabilities. Farmers struggled to interpret this due to unclear criteria, reading challenges, and an overload of text (see Fig. 5.2). Initially, farmers also mentioned the overestimation of cotton yields. We then performed crop-specific prediction model calibrations based on data collected during different surveys conducted previously, to improve the quality of the predictions.

Blackbox Predictions. Farmers were uncertain about the factors affecting predictions, the factors that could be controlled, and the ones that were beyond their control. We introduced a preliminary screen that clarifies these aspects before displaying the predictions to address this need.

Reading Difficulties. Many rural farmers face literacy challenges, making it difficult for them to read and understand complex sentences. We introduced audio readouts into the screens with complex information and calculations.

Unable to Understand Risk. Many farmers struggled to grasp the 5-level risk graph. We simplified this by showing the two primary yields representing a 70% chance interval, alongside the highest and lowest possible yields (see Fig. 1.d).

Too much information. Farmers felt overwhelmed by the abundance of numbers in the original risk graph displaying yields (see Fig. 5.2). To alleviate this, we implemented a three-step rendering process for the simplified graph. Initially, we display the upper and lower values for the 70% chance interval with accompanying audio. Next, we introduce the highest and lowest possible yield values with new audio. Finally, we present all four values together. This staged approach was well received.

5.3 Activity Management

To enhance the simplicity and intuitiveness of the Makara app, we have implemented the following suggestions based on feedback from farmers:

Unit Conversion. To reduce the complexity of calculations, the costs, revenues, and profits are adjusted to match the specific crop area rather than per unit area. For instance, instead of entering seed costs per acre, farmers enter costs for 3.5 acres tailored to their crop area. Similarly, income and profit are displayed per 3.5 acres. However, yields are still presented per unit area (e.g., 500 kg/acre) to facilitate easy comparisons with other farmers or against historical data (see Fig. 5.3).

Activity Tracker. Originally, the calendar interface displayed pre-scheduled activities based on best practices set by the admin, with activity dates timed to the expected start

of the season. However, this approach did not accommodate yearly or regional variations in monsoon onset, leading to potential confusion, such as advising sowing before the rains. To address this, the system has been made dynamic to adjust activity dates according to the specific crop sowing date entered by the farmer. (see Fig. 5.4).

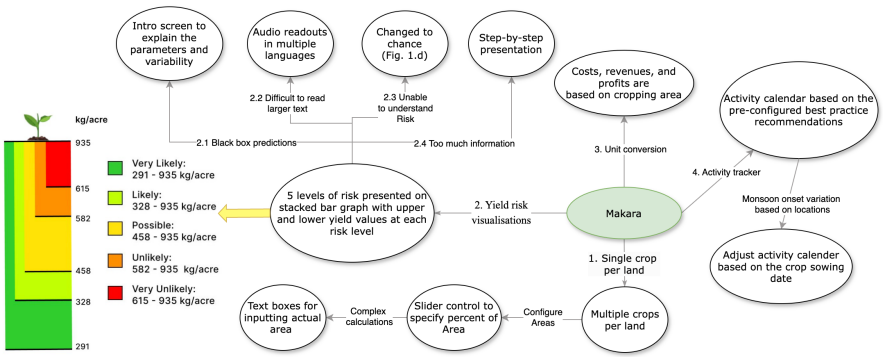


Fig. 5. Challenges and extensions to Makara app

6 Conclusion

We've emphasized the role of digital innovation in agriculture, particularly in aiding small and medium-sized farms, which constitute 85% of India's farming population. The significance of farm management software was outlined, showcasing the Makara app's digital farm management features. Data models and architecture were discussed, with a strong focus on the inclusive development process tailored to the unique feedback from target farmers. Looking ahead, we aim to complete the full deployment during the 2024 Kharif season. We will monitor the accuracy of yield predictions against actual outcomes, address discrepancies, and refine our model. Additionally, we will assess how features like the activity tracker and cost management aid farmers, with particular attention to ease of use and accessibility for those in rural areas.

7 Acknowledgments

We extend our gratitude to Sri Sadguru Mata Amritanandamayi Devi, the Chancellor of Amrita University, for the opportunity to develop Makara. We also thank Solidaridad Asia for the deployment operations to farmers and offering invaluable feedback for further improvements.

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