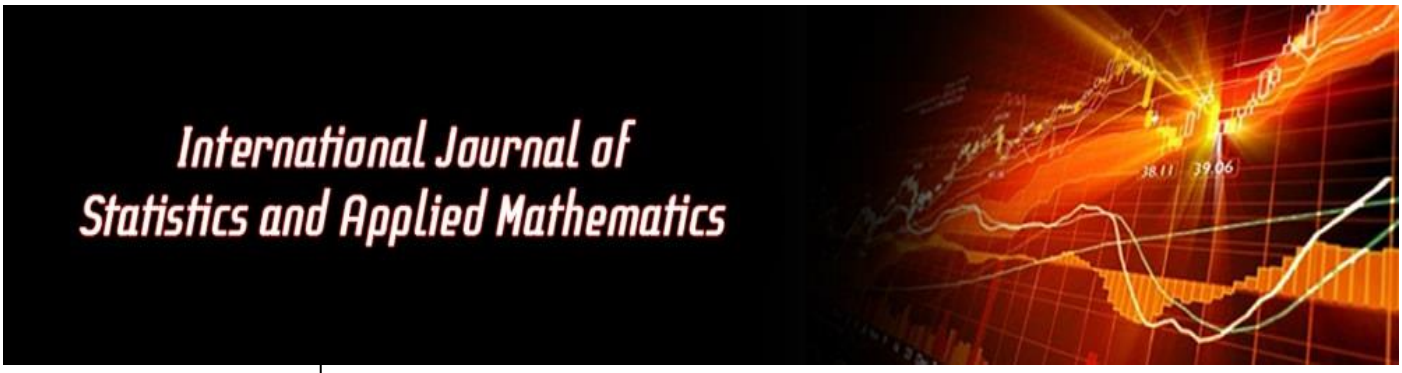

ISSN: 2456-1452
Maths 2023; SP-8(6): 405-414

https://www.mathsjournal.com
Received: 16-05-2023
Accepted: 22-06-2023

DRK Saikanth
SRF, ICAR-ATARI, ZONE-X Hyderabad, India

Karuna Jeba Mary
PDF, Department of Agricultural Extension, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Ashish Kumar Nagar
Research Scholar, Department of Extension Education, JNKVV, Jabalpur, Madhya Pradesh, India

Rishabh Yadav
Research Scholar, Department of Agricultural Extension Education, Sardar Vallabhbhai Universuty of Agriculture and Technology, Modipuram, Meerut, Uttar Pradesh, India

Abhijeet
Research Scholar, Deptment of Agricultural Extension, Chandra Shekhar Azad University of Agriculture, Kanpur, Uttar Pradesh, India

P Thilagam
Associate Professor, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Horticultural College and Research Institute, Jeenur Krishnagiri, Tamil Nadu, India

Shubham Singh
Research Scholar, Department of Agricultural Extension Education, Sardar Vallabhbhai University of Agriculture and Technology, Modipuram, Meerut, Uttar Pradesh, India

Corresponding Author:
Rishabh Yadav
Research Scholar, Department of Agricultural Extension Education, Sardar Vallabhbhai Universuty of Agriculture and Technology, Modipuram, Meerut, Uttar Pradesh, India

Mobile applications for agricultural transformation: Types, impacts, case studies, and recommendations

DRK Saikanth, Karuna Jeba Mary, Ashish Kumar Nagar, Rishabh Yadav, Abhijeet, P Thilagam and Shubham Singh

DOI: https://doi.org/10.22271/maths.2023.v8.i6Sf.1408

Abstract
In an era characterized by rapid technological advancements and the growing significance of agriculture in India's economy, a suite of mobile applications has emerged to revolutionize the way farmers engage with and manage their agricultural practices. These apps, including Pusa Krishi, Kisan Suvidha, Farm-o-pedia, and Meghdoot, play pivotal roles in addressing a diverse array of agricultural challenges. Pusa Krishi serves as an innovation hub, delivering cutting-edge agricultural technology, while Kisan Suvidha empowers farmers with real-time information on weather, market prices, and more. Farm-o-Pedia is a comprehensive resource for rural Gujarat, offering crop recommendations and weather updates, and Meghdoot ensures timely weather forecasts and agro advisories in multiple languages. These apps collectively embody the fusion of technology and agriculture, enhancing the productivity, sustainability, and overall well-being of India's farming community. The future of agriculture lies in the hands of these digital solutions, where knowledge, information, and innovation converge to shape a brighter and more prosperous agricultural landscape in India.

Keywords: Mobile apps, Meghdoot, Farm-O-Pedia, digital solution

1. Introduction

Background and Significance

In recent years, the agricultural landscape has witnessed a significant transformation driven by the integration of modern technologies. One of the most notable advancements has been the proliferation of mobile applications designed to cater to the unique needs and challenges of farmers. Mobile applications, or apps, have emerged as powerful tools that bridge information gaps, empower decision-making, and enhance overall agricultural productivity Singh, N. K. *et al.* 2023 [1]. These digital solutions have the potential to revolutionize traditional farming practices and contribute to food security, sustainability, and rural development Kareska, K. (2023) [2]. Farmers across the globe face multifaceted challenges such as access to timely and relevant agricultural information, market linkages, weather forecasting, crop management, financial management, and more Rahman, M. S. *et al.* (2020) [3], Ferroni, M., & Zhou, Y. (2012) [4]. Mobile applications have stepped in to address these challenges, offering a diverse range of functionalities that assist farmers in various aspects of their work Qiang, C. Z. (2012) [5]. These applications are not just tools but enablers of change, fostering a more efficient, resilient, and connected agricultural ecosystem. Bhaskara, S., & Bawa, K. S. (2021) [6].

Objectives of the Review

This comprehensive review aims to shed light on the world of mobile applications tailored for farmers. It seeks to provide insights into the types of mobile applications available to farmers, the benefits and positive impacts they bring, the challenges and limitations they pose, and their role in reshaping agriculture. The objectives of this review can be summarized as follows:

1. To categorize and describe various types of mobile applications designed for farmers.
2. To analyze and highlight the benefits and positive impacts of these applications on agricultural practices and livelihoods.

3. To examine the challenges and limitations that farmers and app developers face in the context of mobile application adoption.
4. To explore emerging trends and technologies in agricultural mobile applications.
5. To provide recommendations for farmers, app developers, policymakers, and future research directions.

Scope and Methodology

This review encompasses a wide array of mobile applications targeted at farmers, spanning different agricultural domains and geographic regions. The scope includes apps that assist with agricultural information and knowledge dissemination, market access, weather forecasting, crop and livestock management, financial management, social networking, and other specialized functionalities. The geographic focus is global, recognizing that mobile technology's influence extends to both developed and develop ping agricultural systems.

To compile the information presented in this review, a systematic approach to literature search and selection was employed. Academic databases, library resources, and reputable online sources were utilized, with a focus on scholarly articles, reports, and studies published between [2011 to 2023]. The selected literature was assessed for relevance to the review's objectives, and inclusion criteria were rigorously applied. The methodology ensured that the sources used are reliable and representative of the current state of the field.

2. Types of Mobile Applications for Farmers

a. Pest Mobile App: In the context of agricultural advancement, effective pest monitoring and management play pivotal roles in ensuring crop health and productivity. The integration of digital tools, such as the Mobile and Web Early Warning System (EWS), allows us to transition swiftly from traditional analog monitoring to precise digital methods. EWS provides timely insights into the distribution and severity of pest infestations, facilitating the development of efficient pest control strategies. Moreover, it emphasizes the significance of natural predators and favorable plant environments for beneficial insects Nasir, H. *et al.* 2018 [7]. For instance, real-time data from EWS indicated safe conditions observed from August to December 2019, as well as instances of escalating pest populations, exemplified by the bagworm population dynamics in February - March 2020. Allen-Sader, C., *et al.* 2018 [8], Srivastava, S. K., *et al.* 2020 [9].

Following the principles of Integrated Pest Management (IPM), control measures are initiated when pest density approaches economic thresholds but remains below the Economic Injury Level Ghaderi, S 2019 [10]. This approach places a premium on biocontrol methods, minimizing reliance on chemical pesticides. Chemical intervention is considered a last resort, as evidenced by data indicating that chemical measures were employed only after exhausting alternative control options. This data-driven approach underscores the importance of early and continuous pest monitoring in guiding proactive decisions. It also highlights the necessity of an IPM strategy that values eco-friendly controls, with chemical interventions as a final recourse.

b. Soil Health Card (SHC) Mobile App: The introduction of the National Project on Management of Soil Health and Fertility, in conjunction with the Rainfed Areas Development Programme (RADP), recommended a comprehensive range of soil management practices Reddy, A. (2018) [11]. These included conservation agriculture, integrated nutrient management, carbon sequestration, erosion control, management of saline and alkaline soils, legislation for soil protection, development of remote sensing and GPS-based Decision Support Systems (DSS), and the remediation of polluted soils. This initiative was further augmented in the 12th plan with the launch of the 'National Project on Management of Soil Health & Fertility' (NPMSH&F) Dalwai, A., & Dwivedi, V. (2016) [12]. Under this scheme, soil health cards were introduced, accompanied by the strengthening of soil testing laboratories and an expansion of their testing capabilities. Additionally, the Nutrient-Based Subsidy (NBS) system was implemented Mandi, K., & Patnaik, N. M. (2019) [13].

In recent years, several states, such as Karnataka and Gujarat, have launched soil management programs like Bhoochetana and Krishi Mahotsav. These initiatives have yielded valuable insights and lessons that complement central schemes. The Soil Health Card App plays a pivotal role in this landscape by providing farmers with information about the nutrient status of their land holdings. It also offers recommendations regarding fertilizer dosages and soil amendments necessary for long-term soil health maintenance. The app facilitates corrective actions based on nutrient deficiencies identified in soil health cards, and it automatically captures latitude and longitude when "Location" is enabled. It allows farmers to input their details, land particulars, crop information, and fertilizer details with ease, making it a valuable tool for informed decision-making in agriculture Reddy, A. A. (2020) [14].

c. Pusa Krishi: Pusa Krishi stands as an agricultural innovation hub renowned for its world-class technology, profound sector knowledge, and transformative impact. Operating as the sole nodal agency under the Ministry of Agriculture & Farmers' Welfare, Government of India, for the prestigious agri-business incubation scheme RKVY-RAFTAAR, it plays a pivotal role in assisting farmers in achieving improved livelihoods through agriculture practices that are easy, inclusive, and financially rewarding. The platform offers valuable insights into new crop varieties developed by the Indian Council of Agricultural Research (ICAR), resource-conserving cultivation methods, the effective implementation of farm machinery, and cutting-edge production technologies. It fosters a direct channel of communication between farmers and stakeholders through a feedback section, enabling real-time conversations Meena, R. L. *et al.* 2018 [15].

Through the Pusa Krishi mobile app, farmers gain easy access to solutions for their agricultural challenges. Weather-related information empowers farmers to take proactive measures to protect their crops, while updates on new crop varieties, resource-efficient cultivation practices, and farm machinery implementation enhance their knowledge base and productivity. This app serves as a bridge between farmers and advancements in agriculture, enabling them to make informed decisions and engage in meaningful dialogues with key stakeholders Mandi, K., & Patnaik, N. M. (2019) [13].

d. Kisan Suvidha: Kisan Suvidha emerges as a comprehensive mobile app designed to provide quick and relevant information to farmers, empowering them with valuable insights at their fingertips. With a simple click, farmers can access critical data such as current and upcoming

weather forecasts, dealer information, market prices, agro advisories, plant protection guidelines, and Integrated Pest Management (IPM) practices. The app includes unique features like extreme weather alerts and real-time commodity prices in the nearest area, along with maximum price data for the state and the entire country. These features are tailored to equip farmers with the information they need in the most efficient manner Mandi, K., & Patnaik, N. M. (2019) [13].
Kisan Suvidha reflects a commitment to facilitating farmers' access to essential information that can significantly impact their agricultural decisions Naidu, V. S. G. R (2018) [16]. Whether it's staying prepared for adverse weather conditions or making informed choices in the marketplace, this app is a valuable tool in the hands of farmers. It empowers them to make well-informed decisions, enhances their awareness of market dynamics, and ultimately contributes to their overall agricultural success and financial well-being.

e. Kisaan Market: Kisaan Market serves as an empowering platform for Indian farmers, enabling them to establish direct connections with buyers while eliminating the need for intermediaries and reducing expenses related to brokerage and transportation Karkhile, S. G., & Ghuge, S. G. (2015) [17]. This direct interaction multiplies the benefits reaped by farmers, offering them the latest updates on Mandi prices, agricultural tips, weather forecasts, and news tailored to their location and language preferences. The app not only delivers crucial information but also keeps farmers informed about government announcements, policy decisions, and market intelligence Purushotham, P. (2023) [18].
Accessible on any Android mobile phone across all network operators with an internet connection, Kisaan Market prioritizes personalization. Farmers can customize their information, update market details, location settings, and language preferences. Additionally, the app facilitates information sharing among fellow farmers, fostering a sense of community and collaboration. Kisaan Market embodies the spirit of empowering Indian farmers to take charge of their agricultural endeavors and financial well-being Saravanan, R., & Bhattacharjee, S. (2014) [19].

f. IFFCO Kisan: "IFFCO Kisan" stands as a dedicated Indian agricultural app designed to provide farmers, or "Kisaan," with tailored agricultural information to support their decision-making process Naseera, S., & Jeelan, S. A. (2017) [20]. This app offers a wide array of features, including the latest Mandi prices, weather forecasts, agricultural advisories, best practices in agriculture, tips related to animal husbandry and horticulture, and a platform for buyers and sellers. It also serves as a comprehensive source for agricultural news and government schemes Kumar, G. D. S 2014 [21].
One of the app's standout features is its commitment to linguistic diversity, providing agriculture alerts and advisories in 11 Indian languages, including text and audio clips. This language accessibility ensures that farmers can access information in the language they are most comfortable with. "IFFCO Kisan" is not just an app; it's a "suvidha" or facilitator for farmers, enabling them to make informed decisions and enhance their agricultural practices. It exemplifies the fusion of technology and agriculture, delivering valuable insights and support to Indian farmers in their agricultural journey Kollinal, R. K *et al.* 2019 [22].

g. Pashu Prajnan (Animal Reproduction) App: The "Pashu Prajnan" or Animal Reproduction App represents a significant advancement in veterinary knowledge dissemination and livestock management. Developed collaboratively by ICAR-IVRI, Izatnagar, and IASRI, New Delhi, this app serves as a comprehensive resource for veterinarians, veterinary officers, and livestock entrepreneurs. Its primary focus is to impart knowledge and act as a quick reference guide for addressing reproductive problems in cattle and buffaloes, offering insights into diagnosis, treatment, and control measures Kumar, J *et al.* 2021 [23].
The app covers a wide range of reproductive diseases and disorders, including Anoestrus, Repeat Breeding, Uterine Torsion, Dystocia, and Brucellosis, among others. It also provides essential information on Artificial Insemination techniques in cattle and buffaloes, making it a valuable tool for practitioners in the field. Furthermore, the availability of the app in multiple languages, including Hindi, English, Punjabi, and others, ensures that a diverse audience can access this vital knowledge. "Pashu Prajnan" stands as a testament to the potential of digital solutions in improving livestock health and management, ultimately contributing to the welfare of farmers and the dairy industry Jadoun, Y. S *et al.* 2023 [24].

h. Pashu Poshan App: The "Pashu Poshan" app, developed by the National Dairy Development Board (NDDB), is a transformative digital tool designed to optimize livestock nutrition, specifically for cattle and buffaloes. In the context of dairy farming, nutrition plays a pivotal role in enhancing animal health, milk production, and overall productivity. This app offers a sophisticated solution for formulating balanced rations, taking into account critical factors such as the animal's profile, age, milk production, and feeding regime while also optimizing costs Jayalakshmi, M *et al.* 2022 [25], Kumar, J 2021 [26].
One of the app's standout features is its ability to provide practical advice to milk producers, enabling them to adjust the quantity of locally available feed ingredients and mineral mixtures. By doing so, it ensures that cattle and buffaloes receive a nutritionally balanced diet, thereby improving their overall well-being and milk production. "Pashu Poshan" aligns perfectly with the goals of the dairy industry, offering a user-friendly and efficient approach to livestock nutrition management. It represents a pivotal step in the quest for improved dairy farming practices, ultimately benefiting both milk producers and the industry as a whole.

i. Meghdoot App: The "Meghdoot" app, developed by the India Meteorological Department (IMD), is a revolutionary digital tool that harnesses the power of timely weather forecasting to benefit farmers across India. In an agricultural landscape heavily influenced by climate conditions, this app serves as a vital lifeline for farmers by delivering weather forecast-based agricultural advisories in 10 languages. The significance of "Meghdoot" lies in its ability to empower farmers with real-time weather information and crop-specific guidance, enhancing their decision-making processes Dhulipala, R. K. *et al.* 2021 [27].
This app not only provides essential weather forecasts but also offers agricultural advisories tailored to the specific needs of farmers. With its multilingual interface, it ensures accessibility for a wide and diverse audience. "Meghdoot" plays a pivotal role in helping farmers plan their planting and harvesting activities, manage irrigation effectively, and stay prepared for adverse weather events. It exemplifies the transformative potential of technology in strengthening Indian

agriculture and building climate-resilient farming communities Kumar, Y. 2022 [28].

j. MKisan App: The "MKisan" app, developed by an in-house IT team of the Department of Agriculture and Cooperation (DAC) in collaboration with C-DAC Pune, signifies a significant leap in farmer-centric digital communication. This innovative platform provides a direct channel for sending critical alerts and information to farmers, enabling them to stay informed and make informed decisions. One of its key features is that farmers can personally register to receive messages and updates, putting them in control of their communication preferences Costopoulou, C., 2016 [29].
The "MKisan" app bridges the gap between government agencies and farmers, facilitating the seamless flow of essential information related to agriculture, weather, market prices, and more. It empowers farmers with the knowledge they need to optimize their farming practices and adapt to changing conditions. By putting information directly in the hands of farmers, "MKisan" strengthens the farmer-government relationship and supports agricultural development initiatives. This app embodies the principle of inclusive technology, ensuring that farmers have easy access to valuable insights and alerts for improved agricultural outcomes Malhotra, C., & Anand, R. (2020) [30].

Farm-o-pedia App: The "Farm-o-pedia" app, developed by CDAC Mumbai, is a multifaceted Android application tailored to meet the agricultural needs of rural Gujarat. This innovative app serves as an informative resource and a practical tool for daily agricultural routines, benefiting farmers and anyone connected to agriculture. Available in both English and Gujarati languages, "Farm-o-pedia" ensures accessibility for a wide range of users, making it an invaluable addition to the farming landscape Barh, A., & Balakrishnan, M. (2018) [31].
The app offers a comprehensive set of functionalities designed to enhance agricultural practices:

1. Crop Recommendations:"Farm-o-pedia" assists farmers in selecting suitable crops based on soil type and the prevailing season. This feature empowers farmers to make informed decisions and optimize crop choices for maximum yield.
2. Crop Information: Beyond recommendations, the app provides in-depth information about various crops, covering cultivation techniques, disease management, and harvesting practices. This knowledge equips users with the insights needed to enhance crop productivity.
3. Weather Forecast: Timely access to weather updates is essential for effective farm planning. "Farm-o-pedia" delivers real-time weather information, enabling farmers to plan their agricultural activities and respond to adverse weather conditions proactively.
4. Cattle Management: Recognizing the integral role of livestock in agriculture, the app includes tools for managing cattle, ensuring their well-being and productivity. This feature highlights the app's holistic approach to agricultural support.
5. "Farm-o-pedia" represents a convergence of agricultural knowledge and practical utility, aimed at uplifting the lives of rural farmers in Gujarat. By providing essential information and tools, the app empowers farmers to make informed decisions, maximize crop yields, and manage their livestock effectively. It embodies the potential of technology to drive agricultural prosperity and contribute to the sustainable development of rural communities Meena, R. L. *et al.* 2018 [15].

3. Benefits and Positive Impacts

Mobile applications tailored for farmers have ushered in a range of benefits and positive impacts within the agricultural sector Mehta, C. R. (2020) [32], Umadikar, J. (2014) [33]. This section delves into the transformative effects of these applications on farming practices and livelihoods.

Improved Access to Agricultural Information

Mobile applications have democratized access to agricultural information, empowering farmers with up-to-date knowledge and insights Singh, N. K. *et al.*(2023) [1], Kamal, M., & Bablu, T. A. (2023) [34]. This access leads to Timely advice on crop management and pest control Singh, N., & Gupta, N. (2016) [35], Vijayakumar, S. (2022) [36], Ristaino, J. B. *et al.* (2021) [37], Access to market prices and marketing strategies. Qiang, C. Z. 2012 [38], Real-time weather forecasts and climate information Caine, A. *et al.* (2015) [39] and Increased awareness of government agricultural programs and subsidies Qiang, C. Z. 2012 [38].

Enhanced Decision-Making and Crop Management

Farmers armed with mobile applications make informed decisions that optimize resource utilization and improve crop management. Khan, A., and Shahriyar, A. K. (2023) [40] which helps in Data-driven decisions based on crop health monitoring Suneja, B. *et al.* 2022 [41] Herrick, J. E *et al.* 2017 [42], Precision farming techniques for resource efficiency Obayelu, A. E. *et al.* 2023 [43], Rapid response to pest and disease outbreaks Ristaino, J. B.et. al. (2021) [37] Dutta, J. (2020) [44] and Improved crop planning and rotation strategies.

Increased Market Access and Sales

Mobile apps have bridged the gap between farmers and markets, facilitating direct connections and boosting agricultural trade Mandi, K., and Patnaik, N. M. (2019) [45] SOUMEN PAL 2019 [46] results in Elimination of intermediaries leading to better prices for farmers Kamble, S. S. 2020 [47], Expanded market reach and access to a broader customer base Van Alstyne *et al.* 2016 [48], Efficient logistics and reduced post-harvest losses Beriya, A. (2021) [49] and Enhanced bargaining power in negotiations Baumüller, H. (2015) [50].

Weather Forecasting and Risk Reduction

Access to accurate weather forecasts and climate information mitigates weather-related risks like Improved resilience against climate change Balogun, A. L. 2020 [51] Nyambane, A. *et al.*2018 [52], Reduced crop losses due to adverse weather conditions Furuholt, B., & Matotay, E. (2011) [53], Efficient allocation of resources based on weather predictions Mironkina, A. *et al.* 2020 [54] and Better preparedness for natural disasters Kapucu, N. *et al.* (2013) [55].

Financial Management and Access to Credit

Mobile apps help farmers manage their finances more effectively and access financial services Quayson, M., *et al.* 2020 [56] such as Streamlined financial record-keeping and expense tracking Nitin, K. S *et al.* 2020 [57], Improved creditworthiness and access to agricultural loans Chinaka, M. (2016) [58]. and Increased savings through better financial planning Rose, D. C. *et al.* 2016 [59].

Farmer Networking and Knowledge Sharing

Social networking apps and farmer communities foster collaboration and knowledge exchange Phillips, T. 2018 [60] i.e. Learning from peers and sharing experiences Chinaka, M. (2016). [58], Collaboration on group farming initiatives Goundar, S. *et al.* [62], Access to agricultural experts and extension services Chandrasekhar, V. (2020). [63] and Building a sense of community and support among farmers Chen, W., & Tan, S. (2019) [64].

4. Challenges and Limitations

While mobile applications have demonstrated significant potential in transforming agriculture, their adoption and usage are not without challenges and limitations. This section examines the hurdles faced by farmers and app developers alike.

Technology Adoption Barriers

1. Digital Divide: In many regions, there exists a digital divide where farmers lack access to smartphones, internet connectivity, or the necessary hardware for app usage Hadi, A. (2018) [65].
2. Limited Technology Literacy: Some farmers may have limited familiarity with smartphones and mobile technology, making it challenging for them to effectively use agricultural apps Irungu, K. R. G 2015 [66].

Connectivity and Infrastructure Issues

1. **Poor Network Coverage:** In remote and rural areas, inadequate mobile network coverage can hinder farmers' ability to access and use mobile applications Syiem, R., & Raj, S. (2015) [67].
2. **Data Costs:** High data costs can discourage app usage, especially among small-scale and resource-constrained farmers. Azadi, H. *et al.* 2016 [68].

Usability and User Experience Challenges

1. **App Design:** Poorly designed apps with complex interfaces or language barriers may deter users from adopting and benefiting from these tools Dodson, L. L. 2013 [69].
2. **Compatibility:** Compatibility issues with various smartphone models and operating systems can limit the reach of mobile applications Othman, M. **[70]**.

Data Privacy and Security Concerns

1. **Data Privacy:** Concerns about data privacy and the security of personal and farm-related information can lead to reluctance in using certain apps Kenny, U., & Regan, A. (2021) [71].
2. **Cybersecurity Threats:** As mobile applications handle sensitive agricultural data, they may be susceptible to cybersecurity threats and data breaches Demestichas, K. 2020 [72].

Language and Literacy Barriers

1. **Language Diversity:** Mobile applications may not always be available in local languages, making them less accessible to farmers with limited proficiency in the dominant language Joshi, P. 2019 [73].
2. **Low Literacy Levels:** Illiteracy or low literacy levels can pose challenges in understanding and effectively using mobile applications Dodson, L. L. 2013 [74].

Sustainability and Maintenance Challenges

1. **App Sustainability:** Some mobile apps may lack continuous support and updates, leading to issues with functionality and compatibility over time Aungst, T. D. (2013) [75].
2. **Dependency on External Factors:** App reliability can be affected by external factors such as changes in weather data sources or reliance on third-party services Banerjee, A., 2014 [76].

Understanding these challenges and limitations is crucial for developing strategies to address them and ensure that mobile applications for farmers are accessible, user-friendly, and effective.

5. User Adoption and Usability

User adoption and usability are pivotal factors in the success of mobile applications for farmers. This section delves into the various aspects that influence farmer adoption and how usability impacts their experience Flecher, S. (2013) [77].

Factors Influencing Farmer Adoption

1. **Awareness and Training:** The level of awareness among farmers regarding the existence and benefits of agricultural apps significantly influences adoption Smidt, H. J., & Jokonya, O. (2022) [78]. Adequate training and capacity-building programs are essential to bridge knowledge gaps Meuwissen, M. P., *et al.* 2019 [79].
2. **Perceived Value:** Farmers assess the perceived value of an app in relation to their specific needs and challenges Lee, I., & Shin, Y. J. (2020) [80]. Apps that offer tangible benefits tend to have higher adoption rates Ni, L., Liu *et al.* 2023 [81] Peleg-Adler 2018 [82].
3. **Usability and User Experience:** The ease of use and user-friendliness of an app play a crucial role in adoption. Apps with intuitive interfaces and straightforward navigation are more likely to be embraced Sennuga, S. O. *et al.* 2023 [83] Øksnebjerg, L. 2019 [84].
4. **Trust and Reliability:** Farmers are more likely to adopt apps that they perceive as trustworthy and reliable sources of information. Positive experiences and word-of-mouth recommendations contribute to trust Ishida, K. *et al.* 2016 [85].
5. **Access to Devices:** Farmers must have access to smartphones or other compatible devices to use mobile applications. Lack of device access can be a significant adoption barrier Drewry, J. L. *et al.* 2019 [86].

By understanding the factors that influence adoption and focusing on user-centered design and usability, app developers can create applications that are not only embraced by farmers but also enhance their overall farming experience.

6. Case Studies and Exemplary Applications

The best way to understand the practical impact of mobile applications for farmers is through real-world examples and case studies. In this section, we present case studies and highlight exemplary applications that have transformed agricultural practices and improved the livelihoods of farmers.

Showcase of Successful Mobile Applications

1. **AgroStar:** AgroStar is an Indian mobile app established in 2013 that provides farmers with access to agricultural inputs, expert advice, and market information Deshmukh, S., & Patil, S. (2021) [87]. A farmer connects with AgroStar either through a missed call on a toll-free

number or through an 'AgroStar' android app. It has successfully connected millions of farmers s across Gujarat, Maharashtra, and Rajasthan within two years with reliable agricultural solutions. It has grown over 300% in the last two years (AgroStar case study, 2018).

2. **NETAFIM:** India undertook a digital marketing campaign to introduce FlexNet flexible pipes, aiming to create awareness, demonstrate the product's value proposition, and generate traction in the market. Named FarmingSimplified, the campaign centered around the concept that farming could be made more straightforward with the use of FlexNet pipes, offering farmers greater flexibility compared to traditional pipe methods. The campaign commenced with intriguing teasers that raised questions about simplifying farming, cost-effectiveness, and innovation in agriculture. Subsequently, a comprehensive FlexNet film was unveiled, emphasizing the product's benefits, including superior performance, durability, flexibility, ease of use with connectors, and reduced labor costs for irrigation systems. To ensure a wide reach and relevance, a multi-lingual approach was adopted to launch the product across diverse regions in India. The digital campaign yielded substantial results, reaching over 5.6 million viewers and actively engaging 2.1 million people. Furthermore, it generated 1855 valuable leads, demonstrating the campaign's effectiveness in promoting Flex Net flexible pipes Deshmukh, S., & Patil, S. (2021) [87].
3. **iCow:** iCow is a Kenyan app designed to support dairy farmers. It offers personalized advice on livestock management, breeding, and nutrition, contributing to increased milk yields and income for farmers Irungu, K. R. G. *et al.* (2015) [88] Chagunda, M. G. *et al.* (2016) [89].
4. **Plantix:** Plantix is a global plant disease diagnostic app that uses image recognition to identify crop diseases and offer treatment recommendations. It has helped farmers worldwide combat pest and disease issues Sibanda, B. K. *et al.* (2021) [90].
5. **M-Farm:** M-Farm, based in Kenya, connects farmers directly with buyers and provides market price information. It has empowered smallholder farmers to negotiate fair prices for their produce Dabbara, R. *et al.* (2020) [91].

Real-World Examples of Impactful Implementations

1. **The e-Choupal Initiative (India):** The e-Choupal project by ITC transformed rural agriculture by providing farmers with internet access, agricultural information, and e-commerce services. It improved market access and increased farmers' incomes Dabbara, R. *et al.* (2020) [91].
2. **The Climate Corporation's Field View (United States):** Field View utilizes data analytics and weather information to help farmers make precise planting and harvesting decisions. It has improved yield outcomes and resource efficiency Saiz-Rubio, V., & Rovira-Más, F. (2020) [92].
3. **MUIIS Project (Uganda):** The Mobile Tech Solutions for Agribusiness and Market Information (MUIIS) project provides farmers with weather data and agronomic advice via mobile apps, enhancing crop productivity and resilience Sawant, M. *et al.* (2016) [93].
4. **Hello Tractor (Nigeria):** Hello Tractor's app connects tractor owners with smallholder farmers who need mechanized farming services. It has mechanized farming operations and increased agricultural productivity Birner, R. *et al.* (2021) [94] Daum, T., & Birner, R. (2020) [95].

These case studies and exemplary applications demonstrate the tangible impact that mobile applications can have on agriculture. They serve as inspirational examples of how technology can enhance farming practices, boost yields, and improve the livelihoods of farmers.

7. Recommendations and Best Practices

Drawing upon the findings and analysis presented in this review, this section offers a set of recommendations and best practices aimed at maximizing the benefits of mobile applications for farmers and fostering sustainable growth in the agricultural app ecosystem.

Recommendations for Farmers and End-Users

1. Stay Informed: Farmers should actively seek information about relevant mobile applications and stay informed about the latest updates and features Naika, M. B. *et al.* 2021 [96].
2. Select Apps Wisely: Choose mobile applications that align with specific farming needs and objectives. Consider factors such as usability, reliability, and local relevance Sarku, R. *et al.* (2022) [97].
3. Participate in Training: Farmers should participate in training programs and workshops to enhance their digital literacy and maximize the benefits of agricultural apps Law, N. W. Y. (2018) [98].
4. Collaborate and Share: Engage with farmer communities and networks facilitated by mobile apps to share experiences, seek advice, and collaborate on farming initiatives Šūmane, S. (2018) [99].

8. Conclusion

In the evolving landscape of modern agriculture, mobile applications tailored for farmers have emerged as powerful tools that hold the potential to transform traditional farming practices. This concluding section encapsulates the key findings and insights from our comprehensive review of mobile applications for farmers.

Unlocking the Potential of Mobile Applications

Mobile applications have bridged critical gaps in agriculture, offering farmers a wide array of functionalities, including access to agricultural information, market opportunities, weather forecasts, and financial management tools. These applications have become indispensable aids in decision-making, crop management, and market access.

Transforming Agriculture and Livelihoods

The positive impacts of mobile applications on agriculture and livelihoods are unmistakable. Farmers equipped with these tools have experienced increased crop yields, enhanced market access, improved financial management, and greater resilience to climate-related challenges. The case studies presented here offer concrete evidence of the transformative potential of these apps.

Challenges and the Way Forward

While mobile applications offer immense promise, they are not without challenges. Digital divides, connectivity issues, and usability barriers persist. Policymakers, app developers, and stakeholders must address these challenges to ensure equitable access and usability.

Recommendations for a Digital Future

The recommendations outlined in this review provide a roadmap for farmers, app developers, governments, and researchers to harness the full potential of mobile applications in agriculture. User-centered design, data security, digital literacy, and supportive policies are essential elements of a digital future for farming.

Embracing Innovation and Collaboration

As we move forward, it is clear that the fusion of emerging technologies, including AI, IoT, blockchain, and AR/VR, will continue to shape the landscape of agricultural mobile applications. Collaboration between farmers, entrepreneurs, researchers, and policymakers will be essential in driving innovation and ensuring the sustained growth of this vital sector.

In conclusion, mobile applications for farmers have not only revolutionized agriculture but also played a pivotal role in improving the lives of millions who till the land. By recognizing the opportunities, addressing the challenges, and fostering collaboration, we can collectively propel agriculture into a digitally empowered and sustainable future.

9. References

1. Singh NK, Sunitha NH, Tripathi G, Saikanth DRK, Sharma A, Jose AE, *et al.* Impact of Digital Technologies in Agricultural Extension. Asian J Agric. Ext. Econ. Soc. 2023;41(9):963-970.
2. Kareska K. Digital Agriculture as a Response to the Challenges in the Modern Agricultural Sector. Available at SSRN 4549236; c2023.
3. Rahman MS, Haque ME, Afrad MSI. Utility of mobile phone usage in agricultural information dissemination in bangladesh. East African Scholars Journal of Agriculture and Life Sciences. 2020;3(6):154-170.
4. Ferroni M, Zhou Y. Achievements and challenges in agricultural extension in India. Global Journal of Emerging Market Economies. 2012;4(3):319-346.
5. Qiang CZ, Kuek SC, Dymond A, Esselaar S. Mobile applications for agriculture and rural development; c2012.
6. Bhaskara S, Bawa KS. Societal digital platforms for sustainability: Agriculture. Sustainability. 2021;13(9):5048.
7. Nasir H, Aris AN, Lajis A, Kadir K, Safie SI. Development of android application for pest infestation early warning system. In 2018 IEEE 5th International Conference on Smart Instrumentation, Measurement and Application (ICSIMA). IEEE; c2018, Nov. p. 1-5.
8. Allen-Sader C, Thurston W, Meyer M, Nure E, Bacha N, Alemayehu Y, *et al.* An early warning system to predict and mitigate wheat rust diseases in Ethiopia. Environmental Research Letters. 2019;14(11):115004.
9. Srivastava SK, Ghosal S, Langlentombi LC. Higher Production of *Flemingia semialata* Seeds by Mulching with Silver/Black Polyethylene; c2020.
10. Ghaderi S, Fathipour Y, Asgari S, Reddy GV. Economic injury level and crop loss assessment for Tuta absoluta (Lepidoptera: Gelechiidae) on different tomato cultivars. Journal of Applied Entomology. 2019;143(5):493-507.
11. Reddy A. Impact study of soil health card scheme. National Institute of Agricultural Extension Management (MANAGE), Hyderabad-500030. 2018, 106.
12. Dalwai A, Dwivedi V. Soil health mission: Government initiatives. Soil Health. 2016, 66.
13. Mandi K, Patnaik NM. Mobile apps in agriculture and allied sector: An extended arm for farmers. Agriculture Update. 2019;14(4):334-342.
14. Reddy AA. Impact Study of Soil Health Card Scheme, National Institute of Agricultural Extension Management (MANAGE), Rajendranagar, Hyderabad–500030, Telangana State, India; c2020. p. 106.
15. Meena RL, Jirli B, Kanwat M, Meena NK. Mobile applications for agriculture and allied sector; c2018.
16. Naidu VSGR, Shankar HR, Dhagat S. Information and communication technologies in weed management. Indian Society of weed science; c2018.
17. Karkhile SG, Ghuge SG. A modern farming techniques using android application. International Journal of Innovative Research in Science, Engineering and Technology. 2015;4(10):10499-10506.
18. Purushotham P, Sreeja RK, Keerthika V. Kissan mart using mobile application. In AIP Conference Proceedings. AIP Publishing. 2023 May, 2492(1).
19. Saravanan R, Bhattacharjee S. Mobile phone applications for agricultural extension in India. Mobile phones for agricultural extension: Worldwide mAgri Innovations and Promise for Future. (Edited by Saravanan, R); c2014. p. 1-75.
20. Naseera S, Jeelan SA. Kisan Nestham-AN Android Application for farmers. Journal on Software Engineering. 2017, 11(4).
21. Kumar GDS, Padmaiah M, Alivelu K. Evaluation of a mobile phone based agro-advisory Programme on sunflower (*Helianthus annuus* L.); c2014.
22. Kollinal RK, Moolakkattu DJS, Paul DV. Digital India-the Great Dream. International Journal of Computer Engineering and Technology. 2019;10(3):87-93.
23. Kumar J, Sharma S, Sharma P, Sharma PK, Sharma R. Usage of Farming Mobile Apps by Field Functionaries in Jammu and Kashmir; c2021.
24. Jadoun YS, Mukhopadhyay CS, Singh A, Kaur NE-. Agriculture Diaspora: Heralding A New Era of Animal Farming and Agricultural Practices. In Biotechnological Interventions Augmenting Livestock Health and Production. Singapore: Springer Nature Singapore; c2023. p. 435-451.
25. Jayalakshmi M, Prasadbabu G, Chaithanya BH, Lavanya A, Srinivas T. Usages of Mobile Application Developed by Krishi Vigyan Kendra Banavasi. Indian Journal of Extension Education. 2022;58(1):72-75.
26. Kumar J, Sharma S, Sharma P, Sharma PK, Sharma R. Usage of Farming Mobile Apps by Field Functionaries in Jammu and Kashmir; c2021.
27. Dhulipala RK, Gogumalla P, Karuturi R, Palanisamy R, Smith A, Nagaraji S, *et al.* Meghdoot—a mobile app to access location-specific weather-based agro-advisories pan India. CGIAR Research Program on Climate Change, Agriculture and Food Security Working Paper; c2021.
28. Kumar Y, Fatima K, Raghuvanshi MS, Nain MS, Sofi M. Impact of Meghdoot Mobile App-A Weather-based Agro-advisory Service in Cold arid Ladakh. Indian Journal of Extension Education. 2022;58(3):142-146.
29. Costopoulou C, Ntaliani M, Karetsos S. Studying mobile apps for agriculture. IOSR J Mob. Comput. Appl. 2016;3(6):44-49.

30. Malhotra C, Anand R. Accelerating public service delivery in India: application of internet of things and artificial intelligence in agriculture. In Proceedings of the 13th International Conference on Theory and Practice of Electronic Governance; c2020 Sep. p. 62-69.
31. Barh A, Balakrishnan M. Smart phone applications: Role in agri-information dissemination. Agricultural Reviews. 2018;39(1):82-85.
32. Mehta CR, Chandel NS, Rajwade YA. Smart farm mechanization for sustainable Indian agriculture; c2020.
33. Umadikar J, Sangeetha U, Kalpana M, Soundarapandian M, Prashant S, Jhunjhunwala A, *et al.* Mask: a functioning personalized ICT-based agriculture advisory system: implementation, impact and new potential. In 2014 IEEE Region 10 Humanitarian Technology Conference (R10 HTC). IEEE; c2014 Aug. p. 121-126.
34. Kamal M, Bablu TA. Mobile Applications Empowering Smallholder Farmers: An Analysis of the Impact on Agricultural Development. International Journal of Social Analytics. 2023;8(6):36-52.
35. Singh N, Gupta N. ICT based decision support systems for Integrated Pest Management (IPM) in India: A review. Agricultural Reviews. 2016, 37(4).
36. Vijayakumar S, Choudhary AK, Deiveegan M, Thirumalaikumar R, Kumar RM. Android based mobile application for rice crop management. Chronicle of Bioresource Management. 2022;6(1):019-024.
37. Ristaino JB, Anderson PK, Bebber DP, Brauman KA, Cunniffe NJ, Fedoroff NV, *et al.* The persistent threat of emerging plant disease pandemics to global food security. Proceedings of the National Academy of Sciences. 2021;118(23):e2022239118.
38. Qiang CZ, Kuek SC, Dymond A, Esselaar S. Mobile applications for agriculture and rural development; c2012.
39. Caine A, Dorward P, Clarkson G, Evans N, Canales C, Stern D, *et al.* Mobile applications for weather and climate information: their use and potential for smallholder farmers. CCAFS Working Paper; c2015.
40. Khan A, Shahriyar AK. Optimizing Onion Crop Management: A Smart Agriculture Framework with IoT Sensors and Cloud Technology. Applied Research in Artificial Intelligence and Cloud Computing. 2023;6(1):49-67.
41. Suneja B, Negi A, Kumar N, Bhardwaj R. Cloud-based tomato plant growth and health monitoring system using IOT. In 2022 3rd International Conference on Intelligent Engineering and Management (ICIEM). IEEE; c2022 April. p. 237-243.
42. Herrick JE, Karl JW, McCord SE, Buenemann M, Riginos C, Courtright E, *et al.* Two new mobile apps for rangeland inventory and monitoring by landowners and land managers. Rangelands. 2017;39(2):46-55.
43. Obayelu AE, Afolami CA, Folorunso O, Adebayo AM, Ashimolowo OR. Impact of adoption of mobile-based Information Communication Technologies on production efficiencies among smallholder farmers in the southwest of Nigeria. Tropical Agriculture. 2023;100(1):44-58.
44. Dutta J, Dutta J, Gogoi S. Smart farming: An opportunity for efficient monitoring and detection of pests and diseases. J. Entomol. Zool. Stud. 2020;8:2352-2359.
45. Mandi K, Patnaik NM. Mobile apps in agriculture and allied sector: An extended arm for farmers. Agriculture Update. 2019;14(4):334-342.
46. Pal S, Marwaha S, Arora A, Choubey AK, Singh AK, Poswal RS, *et al*. Indian Journal of Agricultural Sciences. Short Communication KVK Mobile App: An ICT tool to empower farmers. 2019;89(8):1362-1365.
47. Kamble SS, Gunasekaran A, Sharma R. Modeling the blockchain enabled traceability in agriculture supply chain. International Journal of Information Management. 2020;52:101967.
48. Van Alstyne MW, Parker GG, Choudary SP. Pipelines, platforms, and the new rules of strategy. Harvard business review. 2016;94(4):54-62.
49. Beriya A. ICT in Agriculture Value Chain, especially during post-harvest operations in India (No. 52). ICT India Working Paper; c2021.
50. Baumüller H. Assessing the role of mobile phones in offering price information and market linkages: The case of M-Farm in Kenya. The Electronic Journal of Information Systems in Developing Countries. 2015;68(1):1-16.
51. Balogun AL, Marks D, Sharma R, Shekhar H, Balmes C, Maheng D, *et al.* Assessing the potentials of digitalization as a tool for climate change adaptation and sustainable development in urban centres. Sustainable Cities and Society. 2020;53:101888.
52. Nyambane A, Nicholas O, Alfred N. Landpks Mobile App as a Tool for Bridging Climate Information Gaps for Improved Agricultural Productivity, Land Use Planning and Climate Change Resilience. AU-STRC Community-Based & Inclusive Innovation Initiative. 2018, 40.
53. Furuholt B, Matotay E. The developmental contribution from mobile phones across the agricultural value chain in rural Africa. The Electronic Journal of Information Systems in Developing Countries. 2011;48(1):1-16.
54. Mironkina A, Kharitonov S, Kuchumov A, Belokopytov A. Digital technologies for efficient farming. In IOP Conference Series: Earth and Environmental Science. IOP Publishing. 2020;578:(1)012017.
55. Kapucu N, Hawkins CV, Rivera FI. Disaster preparedness and resilience for rural communities. Risk, Hazards & Crisis in Public Policy. 2013;4(4):215-233.
56. Quayson M, Bai C, Osei V. Digital inclusion for resilient post-COVID-19 supply chains: Smallholder farmer perspectives. IEEE Engineering Management Review. 2020;48(3):104-110.
57. Nitin KS, Loc HC, Chakravarthy AK. Use of Mobile Apps and Software Systems for Retrieving and Disseminating Information on Pest and Disease Management. Innovative Pest Management Approaches for the 21st Century: Harnessing Automated Unmanned Technologies; c2020. p. 103-117.
58. Chinaka M. Blockchain technology--applications in improving financial inclusion in developing economies: case study for small scale agriculture in Africa (Doctoral dissertation, Massachusetts Institute of Technology); c2016.
59. Rose DC, Sutherland WJ, Parker C, Lobley M, Winter M, Morris C, *et al.* Decision support tools for agriculture: Towards effective design and delivery. Agricultural systems. 2016;149:165-174.
60. Phillips T, Klerkx L, McEntee M. An investigation of social media's roles in knowledge exchange by farmers. In 13th European International Farming Systems Association (IFSA) Symposium, Farming systems: facing uncertainties and enhancing opportunities; c2018 July. p. 1-5.

61. Nain MS, Singh R, Mishra JR. Social networking of innovative farmers through WhatsApp messenger for learning exchange: A study of content sharing. Indian Journal of Agricultural Sciences. 2019;89(3):556-558.
62. Goundar S, Nguyen TN, Nguyen LM, Nielsen P, Braa J. Building Online Social Capital for Infrastructure Development: The multiple cases studies of infrastructural development in a Southeast Asia country.
63. Chandrasekhar, V. ICT Applications in Fisheries. ICAR-Central Institute of Fisheries Technology; c2020.
64. Chen W, Tan S. Impact of social media apps on producer–member relations in China's community supported agriculture. Canadian Journal of Development Studies/Revue canadienne d'études du développement. 2019;40(1):97-112.
65. Hadi A. Bridging Indonesia's digital divide: Rural-urban linkages. Jurnal. Ilmu. Sosial. Dan. Ilmu. Politik. 2018;22(1):17-33.
66. Irungu KRG, Mbugua D, Muia J. Information and communication technologies (ICTs) attract youth into profitable agriculture in Kenya. East African Agricultural and Forestry Journal. 2015;81(1):24-33.
67. Syiem R, Raj S. Access and usage of ICTs for agriculture and rural development by the tribal farmers in Meghalaya state of North-East India. Agrarinformatika/Journal of Agricultural Informatics. 2015;6(3):24-41.
68. Azadi H, Samiee A, Mahmoudi H, Jouzi Z, Rafiaani Khachak P, De Maeyer P, *et al.* Genetically modified crops and small-scale farmers: main opportunities and challenges. Critical reviews in biotechnology. 2016;36(3):434-446.
69. Dodson LL, Sterling SR, Bennett JK. Minding the gaps: Cultural, technical and gender-based barriers to mobile use in oral-language Berber communities in Morocco. In Proceedings of the Sixth International Conference on Information and Communication Technologies and Development: Full Papers. 2013 Dec;1:79-88.
70. Othman M, Madani SA, Khan SU. A survey of mobile cloud computing application models. IEEE communications surveys & tutorials. 2013;16(1):393-413.
71. Kenny U, Regan A. Co-designing a smartphone app for and with farmers: Empathising with end-users' values and needs. Journal of Rural Studies. 2021;82:148-160.
72. Demestichas K, Peppes N, Alexakis T. Survey on security threats in agricultural IoT and smart farming. Sensors. 2020;20(22):6458.
73. Joshi P, Barnes C, Santy S, Khanuja S, Shah S, Srinivasan A, *et al.* Unsung challenges of building and deploying language technologies for low resource language communities. arXiv preprint arXiv:1912.03457; c2019.
74. Dodson LL, Sterling SR, Bennett JK. Minding the gaps: Cultural, technical and gender-based barriers to mobile use in oral-language Berber communities in Morocco. In Proceedings of the Sixth International Conference on Information and Communication Technologies and Development: Full Papers. 2013 Dec;1:79-88.
75. Aungst TD. Medical applications for pharmacists using mobile devices. Annals of Pharmacotherapy. 2013;47(7-8):1088-1095.
76. Banerjee A, Chong LK, Chattopadhyay S, Roychoudhury A. Detecting energy bugs and hotspots in mobile apps. In Proceedings of the 22nd ACM SIGSOFT international symposium on foundations of software engineering; c2014 Nov. p. 588-598.
77. Flecher S. An Assessment of Technology Adoptability in Sugarcane Burning Smoke Plume Mitigation (Doctoral dissertation, University of South Carolina); c2013.
78. Smidt HJ, Jokonya O. Factors affecting digital technology adoption by small-scale farmers in agriculture value chains (AVCs) in South Africa. Information Technology for Development. 2022;28(3):558-584.
79. Meuwissen MP, Feindt PH, Spiegel A, Termeer CJ, Mathijs E, De Mey Y, *et al.* A framework to assess the resilience of farming systems. Agricultural Systems. 2019;176:102656.
80. Lee I, Shin YJ. Machine learning for enterprises: Applications, algorithm selection, and challenges. Business Horizons. 2020;63(2):157-170.
81. Ni L, Liu W, Huang Y, Pan M. Technology Adoption and Promotion in the Age of Skepticism: Examining COVID-19 Mitigation through Technological and Human Factors. Journal of Promotion Management; c2023. p. 1-22.
82. Peleg-Adler R, Lanir J, Korman M. The effects of aging on the use of handheld augmented reality in a route planning task. Computers in Human Behavior. 2018;81:52-62.
83. Sennuga SO, Ujoyi SA, Bamidele J, Onjewu SS, Lai-Solarin WI. Exploring the Role of Smart-phone Apps for Livestock Farmers Data Management Extension and Informed Decision Making in Nigeria. Int J Probiotics and Dietetics. 2023;3(2):46-53.
84. Øksnebjerg L, Woods B, Waldemar G. Designing the ReACT app to support self-management of people with dementia: an iterative user-involving process. Gerontology. 2019;65(6):673-685.
85. Ishida K, Slevitch L, Siamionava K. The effects of traditional and electronic word-of-mouth on destination image: A case of vacation tourists visiting Branson, Missouri. Administrative Sciences. 2016;6(4):12.
86. Drewry JL, Shutske JM, Trechter D, Luck BD, Pitman L. Assessment of digital technology adoption and access barriers among crop, dairy and livestock producers in Wisconsin. Computers and Electronics in Agriculture. 2019;165:104960.
87. Deshmukh S, Patil S. Transformation of Indian agriculture with digital marketing. International Journal of Agriculture Sciences, ISSN; c2021. p. 0975-3710.
88. Irungu KRG, Mbugua D, Muia J). Information and communication technologies (ICTs) attract youth into profitable agriculture in Kenya. East African Agricultural and Forestry Journal. 2015;81(1):24-33.
89. Chagunda MG, Mwangwela A, Mumba C, Dos Anjos F, Kawonga BS, Hopkins R, *et al.* Assessing and managing intensification in smallholder dairy systems for food and nutrition security in Sub-Saharan Africa. Regional environmental change. 2016;16:2257-2267.
90. Sibanda BK, Iyawa GE, Gamundani AM. Mobile apps utilising AI for plant disease identification: A systematic review of user reviews. In 2021 3rd International Multidisciplinary Information Technology and Engineering Conference (IMITEC). IEEE; c2021 Nov. p. 1-6.
91. Dabbara R, Chandrakumar M, Anandhi V, Muruganandhi D. Data driven marketing applications for agriculture services. Int. J Curr. Microbiol. Appl. Sci. 2020;9(2):2914-2920.

92. Saiz-Rubio V, Rovira-Más F. From smart farming towards agriculture 5.0: A review on crop data management. Agronomy. 2020;10(2):207.
93. Sawant M, Urkude R, Jawale S. Organized data and information for efficacious agriculture using PRIDE™ model. International Food and Agribusiness Management Review. 2016;19(1030-2016-83147):115-130.
94. Birner R, Daum T, Pray C. Who drives the digital revolution in agriculture? A review of supply-side trends, players and challenges. Applied economic perspectives and policy. 2021;43(4):1260-1285.
95. Daum T, Birner R. Agricultural mechanization in Africa: Myths, realities and an emerging research agenda. Global food security. 2020;26:100393.
96. Naika MB, Kudari M, Devi MS, Sadhu DS, Sunagar S. Digital extension service: quick way to deliver agricultural information to the farmers. In Food technology disruptions. Academic Press; c2021. p. 285-323.
97. Sarku R, Van Slobbe E, Termeer K, Kranjac-Berisavljevic G, Dewulf A, *et al.* Usability of weather information services for decision-making in farming: Evidence from the Ada East District, Ghana. Climate Services. 2022;25:100275.
98. Law NWY, Woo DJ, de la Torre J, Wong KWG. A global framework of reference on digital literacy skills for indicator. 2018;4(4):2.
99. Šūmane S, Kunda I, Knickel K, Strauss A, Tisenkopfs T, des Ios Rios I, *et al.* Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture. Journal of Rural Studies. 2018;59:232-241.