An evaluation of the examples of mobile smart agriculture applications in Turkiye

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Abstract. The technological process of agricultural mechanization has evolved from mechanical, hydraulic, and pneumatic structures to electrical-electronic and mechatronic systems. With the addition of digital technologies in recent years, agricultural mechanization tools have had functions as time-independent, non-spatial, and unmanned. Agricultural production technologies are now equipped with integrated systems with the Internet of Things, cloud informatics, image processing, wireless data transmission, and mobile-portable devices. Today, during the production process, physical, biological, or chemical data detected through sensors from plants, animals, soil, and atmosphere are uploaded to computers and cloud informatic technologies as big data sets. The data is presented to decision-makers via mobile devices connected to the internet. Within the scope of this study, examples of mobile-portable applications used in the field of smart agriculture in the world and our country were generally examined. In addition, technological and sectoral applications for mobile smart agriculture in our country have been taken over. Currently, common application examples of the Ministry of Agriculture and Forestry, and some private sector companies, that produce these technologies and provide them for the end users, have also been researched in this context. In addition to these, the strengths and weaknesses of the current portable mobile applications in agricultural production have been tried to be analyzed in terms of our country's conditions.

1 Introduction

1.1 Smart mobile agriculture and mobile technologies

1.1.1 Smart Agriculture

Today, smart agriculture refers to the technological transformation process that occurs by integrating mechatronics and autonomous systems into the agricultural production process, along with information and digital technologies. In addition, smart agriculture is a technology stage whose application area expands according to the type of agricultural production (plant or animal production) and stages (from soil preparation to post-harvest). On the other hand, the technological process of agricultural mechanization has evolved from mechanical, hydraulic, and pneumatic structures to electrical-electronic and mechatronic systems. With the addition of digital and information technologies in recent years, agricultural mechanization tools have had functions as time-independent, non-spatial, and unmanned. Agricultural production technologies are now equipped with integrated systems with the Internet of Things, smart autonomous vehicles, agricultural robots, GPS systems, drone systems, cloud informatics, data mining techniques, artificial intelligence and deep learning structures, image processing, micro-chips and micro-controllers, wireless data transmission, and mobile-portable devices [1].

Precision agriculture, smart agriculture, digital agriculture, and agricultural technology developments are the most important parameters affecting the productivity of the production process, input costs, time and energy savings, sensitivity of processes, remote access, and instant intervention. These technological developments have also brought about the use of many informatics and software techniques such as farm management systems, decision support systems, precision agriculture solutions, and analysis and reporting of large agricultural data sets.

In this direction, today, countries have placed smart agriculture in their strategic goals; and they have placed this issue among the main priorities in their policy instruments and strategy documents. The US Federal Department of Agriculture provides incentives for integrated technologies for production and offers various supports to farmers so that they can use agricultural technologies. With these incentives and supports, approximately 300 billion dollars worth of agricultural food products are produced annually in America today. On the other hand, the CEMA (European Agricultural Machinery Association) "Agriculture 4.0: Future of Agriculture" report states that there are 4,500 manufacturers in Europe producing 450 different agricultural machines with an annual turnover of 26 billion euros, and 135,000 people are employed in this

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sector. According to the same report, 70% to 80% of new agricultural equipment sold in Europe includes a precision agriculture technology component. Another point emphasized in this report is that smart agricultural practices will be the factor that will affect the agricultural sector the most by 2030 and will play a driving role in ensuring the sustainability of EU agriculture [2].

1.1.2 Smart mobile agriculture and mobile technologies

Technological developments such as big data, cloud computing, the Internet of Things, and 5G are new-generation production inputs in the agricultural sector. Through wireless internet technologies used in smart agriculture applications, data received from new-generation production inputs are transmitted to smart devices, and a connection is provided. On the other hand, with the help of artificial intelligence, agricultural products grown in agricultural areas can be controlled through the consumption process without using human resources [3].

Today, one of the most common uses of mobile applications in smart agriculture is smart greenhouses. These greenhouses have automation management systems that determine the greenhouse climate and plant nutrition according to external weather conditions, greenhouse environmental conditions, plant requirements, and soil characteristics. The smart automation system in greenhouses monitors and reports the situation inside the greenhouse, ensuring that product productivity and operating costs are optimized. In addition, this system receives performance data and GPS location at regular intervals and then displays this data on a laptop or mobile device via a GSM network or an appropriate protocol.

Livestock applications in smart mobile agriculture include Cattle Step and Location Tracking, Milk Measurement, Milking Systems, Tracking Solutions, Smart Barn/Pasture and Herd Management Systems, Poultry House Tracking Systems, and Hive Tracking Systems. Thanks to the appropriate low-frequency (LF) barcodes and tags, one of the animal tracking devices used to create an animal tracking system, cattle and sheep can be tracked. Using RFID Reader Modules, RFID Antennas, and RFID Tag technologies, animal identification is done quickly, safely, and automatically; thus, an effective method for data collection is provided. Animal information recorded in an RFID ear tag, such as date of birth, vaccinations, blood relationship, and reproductive characteristics, allows this animal to be tracked and reported in a computer environment. Thanks to these electronic tags, farm management will be able to track, archive, and report processes such as nutrition, weight measurement, disease management, and breeding electronically.

One of the poultry applications is controlling the internal and external temperature of the chicken coop, ventilation of the coop, monitoring feed and water tanks, temperature control of the water tank, poultry door audio warning system, automatic opening and closing doors that work according to the brightness of the air and the outdoor temperature. These are designs that control important warning systems remotely via a smartphone.

The area of use of smart remote sensing technology in plant protection for diseases and pests is field scanning with drones. In this method, the disease can be detected according to the characteristics of the plant species in the agricultural production area and the required amount of medicine can be applied (Fig. 1) [2].

Fig. 1. Drone image of trees where pesticide application is required (Circles, drone spraying range; Star shapes, calibration points) [2].

One of the most important goals of the smart agriculture system is for an agricultural enterprise to have a farm management system. For this purpose, all processes such as soil analysis, yield map preparation, planting and sowing with automatic steering, fertilization and spraying applications, measurement, and harvesting with sensors are the most ideal solutions in smart agriculture. The most common usage areas of smart mobile systems that can combine all these solution processes are listed below:

- Determination of the farmer information systems and climate change data (agricultural frost, excessive rainfall, hail, pest warning, fertilization calendar, spraying-irrigation recommendations, etc.)
- Yield mapping and comparison, logistics tracking of products, storage, and after-sales services [2]
- Monitoring, planning, and control of agricultural processes using digital technologies and various software and hardware systems
- Collecting data on the agricultural area where sowing or planting is done, using digitalized smart agricultural machines
- Real-time determination of how much fertilization will be applied to the field, the physical condition of the soil, weather conditions, estimated harvest time, and the amount of water needed by the plants.
- Which parts of the land, in what quantities, and what types of fertilizers and pesticides should be applied?
- Determination of minerals and irrigation amount needed by plants, real-time analysis of weather conditions (relative humidity, temperature, evaporation, wind speed, etc.).

Mobile smart agriculture consists of five core technologies, including sensors and robotics, the Internet of Things, cloud computing, data analytics, and a decision support system. Sensors and robots perform sensing and actuation functions according to the needs of the system. While the Internet of Things provides protocol and network-based connectivity for data communication, cloud computing is responsible for data storage and processing. Data analytics includes big data artificial intelligence and machine learning-based algorithms for data analysis. The decision support system helps provide data visualization, guidance functions, and user interaction.

With the adaptation of technology to the agricultural sector, agricultural fields and agricultural vehicles are equipped with sensors, and thus, agricultural vehicles communicate with each other. Thanks to the sensors used, weather conditions such as temperature and humidity can be measured, plant species can be distinguished by remote sensing, stress conditions such as drought, soil, and plant properties can be monitored, diseases and pests can be detected, planting time, amount of seeds to be planted and fertilizers to be applied, estimated harvest time and yield can be determined. Thus, savings in time, labor, and input costs can be achieved.

Mobile access technology, whose versions and coverage area are constantly expanding, is currently at its latest 5G stage. Meeting the demand for mobile services and applications and providing communication capability to "all objects" by spreading communication technology are among the main purposes of 5G. 5G applications offer advantages such as high speed, low latency, high capacity, energy efficiency, high geographical coverage, and access. It is aimed to keep network delays below 1 ms with 5G technology during remote vehicle communication and real-time mobile-controlled applications. Compared to the 4.5G technology used, 5G technology will cover a unit area with a capacity 1000 times higher and will provide continuous access to 100 billion devices [4].

1.2 Using areas and technical parameters of mobile technologies

1.2.1 Technical parameters and system components

In the smart agricultural production process, mobile technologies become operational through the following basic components:
- Physical or chemical quantities obtained from the field are measured with the help of **sensors** that convert them into electrical quantities.
- This data can be obtained wired and wirelessly.
- The developed **wireless communication technology** offers cost, mobility, ease of installation, and access.
- Wireless sensor networks consist of radio frequency modules, micro control units, sensors, and power supplies. All these sensor networks are IoT technology.
- IoT technology can provide solutions that track the status of objects, receive and analyze meaningful data, and connect to a computer in the cloud via a wireless network.
- Cloud computing is used to collect and analyze agricultural information in a common pool and to develop software that will transfer the collected data to service providers.
- Digital monitoring devices such as cameras, sensors, satellites, etc. Information received from sources is stored based on location, made meaningful with algorithms, reported, and transmitted as instant information with the help of **mobile phones** (Fig. 2).

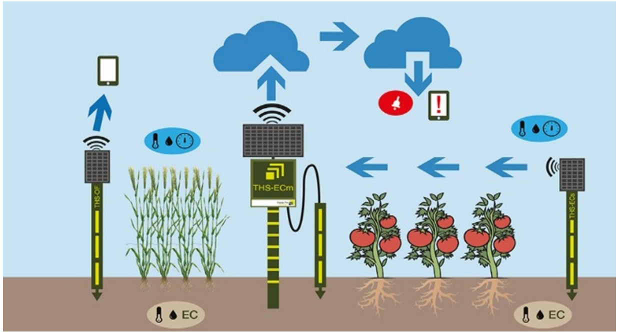

Fig. 2. Transmission of data collected from soil and outdoor conditions to mobile devices [5].

M-apps are software designed to enable the collection and transmission of data for economic or agricultural activities. Most m-apps can be replicated across different mobile interfaces and devices, such as SMS phones, mobile browsers, smartphones, and tablets. M-apps are software that operates on smartphones (such as iPhones, BlackBerries, and Android devices). Moreover, the smartphones brought with them operating systems (such as Apple's iOS and Google's Android) and application stores (such as Apple's App Store) that enabled providers to create m-apps for customers.

Mobile communications technology is a common way of transmitting voice, data, visual displays, and services. This technology could provide for people to reach information, markets, finance, and governance systems. Mob.agr. apps. support farmers for advising agricultural production, marketing, technology, food security, nutrition, etc. In addition, mobile platforms can give opportunity for consumers, companies, or institutions to obtain information about products, market prices, financial services, situation of the production inputs, etc. The most common mobile agricultural application areas are agriculture (including animal husbandry, fisheries, and forestry), resource management, labor, migration, human development, governance and political issues, infrastructure, and information and communication technology.

1.2.2 Sensor types used in mobile agricultural technologies

The information layer (perception) is in charge of processing all data supplied by the set of sensors onboard the tractor, in the soil, or outdoors. All of these sensors detect and transmit the data for agricultural requirements. This process is achieved with the proposed scheme displayed in Fig. 3. It consists of three main modules: sensing, acting, and decision-making. Sensing is in charge of collecting information from the environment through the set of sensors available (imaging, inertial systems, and

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GPS). The information must be appropriate for guidance, weed/crop detection and identification, and mapping. Sensors are adapted according to the tasks to be carried out, and new sensors could be added when required, such as range finders for safety navigation (flexibility). Depending on the agricultural application, each sensor can be replaced by similar sensors with different specifications (scalability). The harsh environmental conditions must be determined by sensors (robustness). All sensors must be able to provide data to be synchronized for real-time implementation (efficiency). The Decision-Making System is in charge of processing the information through specific procedures and algorithms for guidance, weed detection and identification, and mapping [6].

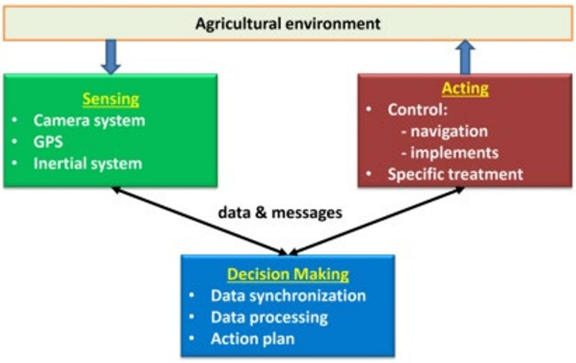

Fig. 3. Architectural design: perception (sensing), actuation, and decision-making [6].

It is possible to give the types of sensors used in agricultural mobile applications as follows:
- Ultrasonic sensors for detection of plant geometry
- Infrared sensor
- LiDAR sensor
- Two-dimensional (2D) or three-dimensional (3D) imaging sensors
- Sensor for measuring crude protein, starch, crude fiber, sugar, and crude ash
- Sensors that determine soil organic matter content, soil moisture, and soil electrical conductivity
- UV sensor
- Wind speed and direction sensor
- Temperature and thermal sensor
- Air humidity sensor
- Solar light intensity sensor
- GPS (Global positioning system)
- Fertilizer nutrient sensor
- Flow and speed measurement sensor.

Sensors are responsible for measuring and monitoring all desired factors in remote sensing smart systems. By using different sensors depending on the intended use, many parameters such as soil moisture level, pH value, control of the irrigation system, plant development, detection of diseases and pests, and weather conditions can be detected. Table 1 below shows the common usage areas of sensors in agricultural smart systems [4].

Table 1. Purposes of use of smart sensors in agricultural production [4].

Soil structure control	Nitrate concentration, phosphate content, soil moisture, soil fertility, land classification
Smart irrigation systems	Water level monitoring, irrigation pump efficiency, irrigation system planning, leakage detection, climate-focused irrigation
Disease and pest detection	Damage due to parasites and observed illness on leaves
Product yield increasing	Early recognition of the crop, estimated amount of fertilizer detection, plant stress identification, crop disease classification, detection of unauthorized entry into land
post-harvest activities	Grain storage, inventory management, intelligent transportation, freshness of the crop (food)

1.3 Mobile technology application examples

Mobile applications are available in a wide range of areas, from crop production to animal husbandry, from greenhouse farming to aquaculture. Within the scope of this study, common practices in plant production processes are discussed. An example of a special mobile application for growing plant products is shown below (Fig. 4). Crop application allows monitoring of the production process from tillage to harvest. Even when offline, you can record your crop production measurements and view them, field maps, and various analyses with great clarity on the go like this application [7].

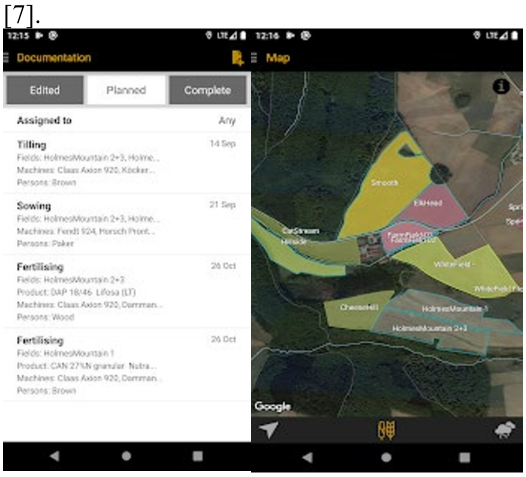

Fig. 4. Mobile recording of crop production measures [7].

1.3.1 Mobile applications in some countries

In a study conducted by the World Bank in 2012, mobile agricultural practices in some countries in Asia, Africa, Latin America, and the Caribbean were examined (Fig. 5). In this research, it was reported that there are a total of 92 mobile agricultural applications in these countries. These mobile applications involved price info, market links, extension and support, distribution, resource management, labor, governance, rural finance, and ICT [8].

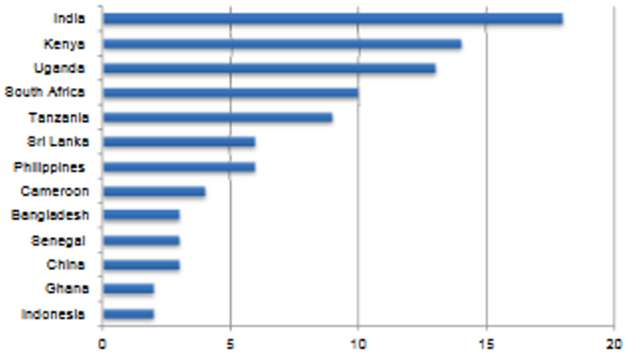

Fig. 5. Number of mobile agricultural applications in some countries [8].

Similarly, in developed countries like Australia, F-Track Live is an on-the-go farm management app that lets multiple users record and access all of their farm information in real-time. With the advent of smartphones in the last 5 years, the providers have seen a huge potential in developing applications on Apple, Android, and Microsoft platforms and introducing them worldwide at attractive pricing models [9]. Another example of this issue is the practice in Chile. The Mobile Information Project platform was piloted in the DatAgro project with a cooperative of 346 corn farmers in Chile who now receive details on weather, news, sports, and more via SMS. The information comes from UNESCO, the government agency 'Fund for Agrarian Innovation', and newspapers. There is a different mobile application that provides open-source mobile data collection for farm inspections of agricultural cooperatives in Mexico. It was developed together with a Mexican coffee cooperative to monitor compliance with fair trade requirements [10].

On the other hand, AEF and AgGateway organizations are considered the key players in promoting interoperability in the primary agricultural production chain in European Countries. For decades, ISO-11783 (ISOBUS) has been the de-facto standard between tractors and implements of different brands. The Agricultural Industry Electronics Foundation (AEF) has been founded for the implementation and further enhancement of ISOBUS. But over time its work has expanded to include Electric Drives, Camera Systems, Farm Management Information Systems, high-speed ISOBUS, and Wireless In-field Communication, developing guidelines and transferring the gained knowledge to ISO level. Currently over 190 members support and actively collaborate within the AEF. Besides the exchange of agricultural-specific data concerning field and crop operations, there also is a need for standardizing more transaction-related data exchange with other actors in the supply chain. AgGateway is a recognized international organization for enabling the use of information and communication technologies for agriculture [11].

1.3.2 Mobile applications in Turkiye

In this study, practices in Turkiye were also examined, and in the following section, an attempt is made to analyze the current situation. Current smart mobile agricultural applications in Turkiye are provided by the Ministries level, private sector, financial banks, some municipalities, and communication companies. The main implementing institution at the ministerial level in Turkiye is the Ministry of Agriculture and Forestry. Relevant applications are summarized below (Fig. 6) The Ministry of Agriculture and Forestry has 20 different mobile agriculture applications for sector stakeholders in this country. 19 of these applications (Fig. 6) are for institutional inquiry and control purposes; a mobile agriculture application called 'Agriculture in My Pocket' (Fig. 7) was developed directly for farmers. The transactions that the Ministry of Agriculture can do from the Provincial and District Directorates of the Ministry such as birth, death, falling earring notifications, and obtaining the Farmer Registration System Certificate related to animals can be carried out through **the smartmobile phone** application [12].

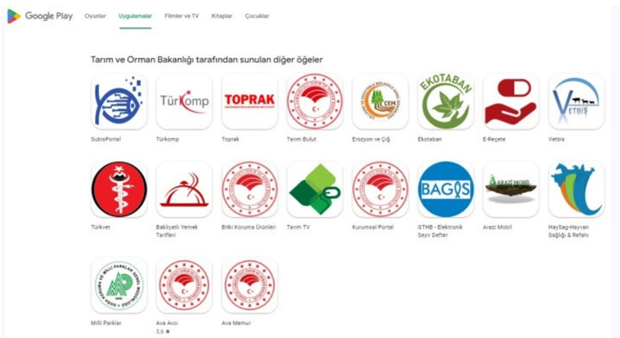

Fig. 6. The Ministry of Agriculture and Forestry practices in Turkiye [12].

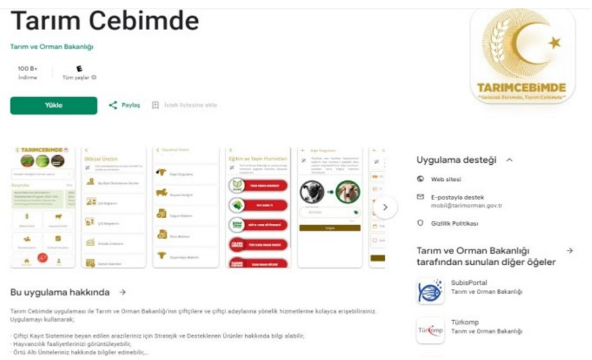

Fig. 7. Screenshot of the 'Agriculture in My Pocket Mobile Application' in Turkiye [12].

Some examples of mobile applications for farmers at the private sector level in Turkiye are shown in Fig. 8 [13] and Fig. 9 [14].

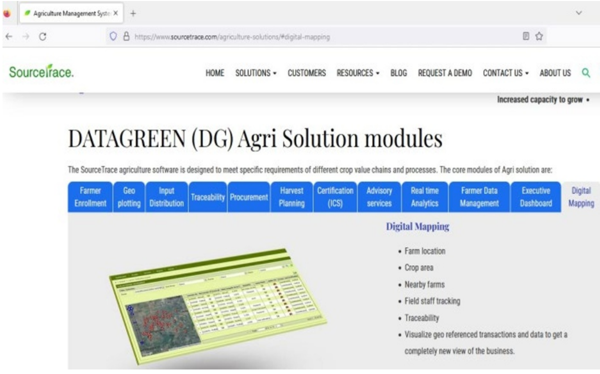

Fig. 8. One of the mobile agriculture application examples of the private sector in Turkiye (digital mapping) [13].

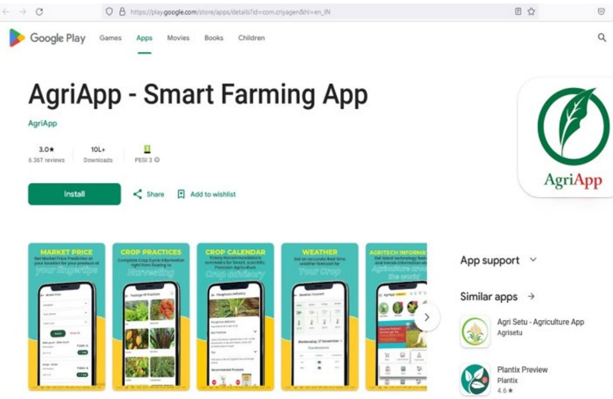

Fig. 9. Mobile agriculture application examples of the private sector in Turkiye (smart farming application) [14].

2 Results and discussion

Most mobile agriculture applications focus on improving agriculture supply chain integration and have a wide range of functions, such as providing market information, increasing access to extension services, and facilitating market links. Users are also diverse, including farmers, produce buyers, cooperatives, input suppliers, content providers, and other stakeholders who demand useful, affordable services. These supply chain integration applications could provide significant economic and social benefits—among them, creating jobs, adding value, reducing product losses, and making developing countries more globally competitive (Fig. 10) [8].

In each country, the scope of smart agriculture components and mobile applications implemented is primarily shaped in line with the development goals and agricultural policies of that country. In addition, the method of agricultural production and the needs of farmers determine the content and purpose of these practices. Agricultural producers are no longer involved in the production process only with mechanical and labor processes; they have also interacted with digital and information technologies. Moreover, the agricultural sector has increasingly become a multidisciplinary and multi-stakeholder structure. Therefore, farmers are faced with more production parameters; and they have to find solutions to more complex problems.

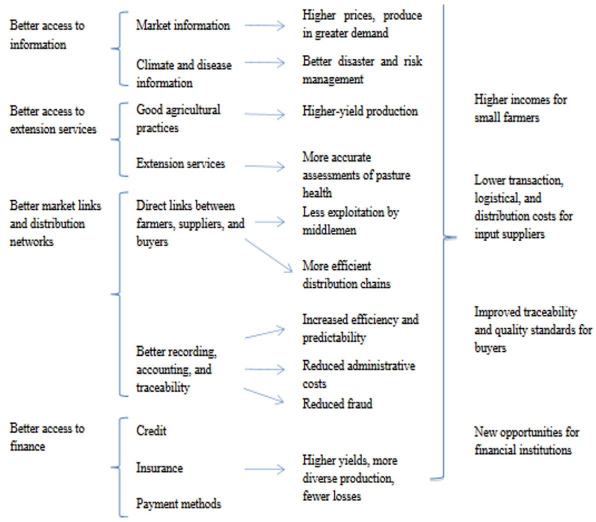

Fig. 10. Benefits of mobile applications for agricultural and rural development [8].

Mobile smart devices have become the greatest technological assistants for agricultural farmers who cannot compete with the speed of technology. Moreover, the agricultural sector has increasingly become a multidisciplinary and multi-stakeholder structure. Therefore, farmers are faced with more production parameters; they have to find solutions to more complex problems. Mobile smart devices have become the greatest technological assistants for agricultural farmers who cannot compete with the speed of technology:

Considering this current situation, it is thought that the following issues will contribute to the solution of possible problems for mobile agricultural applications:
- Use through cooperatives
- Benefiting from smart/precision agricultural financial support
- Joint R&D projects with the Ministry of Industry for domestic replacement circuit elements
-Organizing technology training for agricultural machinery manufacturers and farmers with units of the Ministry of Agriculture
- Making the relevant legal regulations via the Ministry of Agriculture
- Demonstration activities aimed at disseminating these technologies in Research Institutes.
- Mobil application ecosystems in developing countries are fragile and need support from policymakers and development practitioners.
- There are marked differences between the mobile agricultural applications of developed and developing countries, because of the influences of key players and, the existence and sophistication of mobile application platforms.
- Independent local services and support systems are needed.
- Effective regulations and policies are crucial.
- Standardization and certification should be provided in mobile technology tools.

Table 2. Strengths, weakness, opportunities, and threats of mobile agriculture applications *.

Strengths	Weaknesses	Opportunity	Threats
Mobility flexibility	Insufficiency of service and spare parts network	New financial support for smart farming	Necessity of precision components and IT infrastructure
Multiple user access	Lack of expert personnel to analyze data	Competitive advantage	High initial investment costs
Image processing function and photographic analysis	Not included in the undergraduate curriculum at universities in this subject	Even if it is an assembly industry, some entrepreneurs produce these technologies	Monopolistic companies in the external supply chain
Secure recording and storage	Dependency on external suppliers	Export potential	Being a multidisciplinary sector
Saving labor, energy, water, seeds, fertilizer and pesticides	Technological level and purchasing power of farmers	Being included in the priority area in the Top Strategy Documents	Adaptation of imported technologies to country conditions
Scalability, and ability to analyze and report analytically	Small scale plots	Increase in master's and doctoral courses and training in this field	With rapid technological change, the need for software updates
Ability to future projection	Lack of legal basis	Encouraging local circuit designs	Cultural and psychological resilience
Ability to predict risk and yield	Difficulties in accessing financial resources	Collaboration between different actors in the agriculture and food value chain	Insufficiency of educational resources and materials
Communication networks over large areas and long distances	Elderly population in agriculture		
Real-time and lossless, and transmission of data	Inadequate internet infrastructure		
Secure transmission and processing of large-capacity data sets			
Fast and accurate response			
Low power and energy consumption			

* Source: Authors' compilation.

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