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The support and contribution of mobile technologies and applications to agriculture

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A B S T R A C T

Agricultural management is based on information, so information about seeds, water and soil moisture, nutrients, plant protection, market of agricultural products, etc., is critical success factor for agriculture. This information must reach the end users or farmers, in order to use the potential for improving agricultural production and business. In this context, information-intensive and precision agriculture techniques based on knowledge and information and communication technologies (ICTs) are essence of contemporary agriculture. Accordingly, farmers could achieve the benefits of the Internet, mobile technologies and other ICTs that provide information services relevant to the management of agricultural production and business. This paper is a contribution to the research of the use of mobile technologies in agriculture with special reference to mobile applications in agriculture and intelligent agricultural system based on mobile and wireless technologies.

Keywords: Electronic agribusiness, Internet, mobile applications, agriculture web portal, mobile agriculture, intelligent agriculture system

И З В О Д

Управљање пољопривредом се базира на информацијама, тако да су информације о семену, води и влажности земљишта, хранљивим материјама, заштити биља, тржишту пољопривредних производа итд., један од главних фактора успешне пољопривреде. Ове информације морају да стигну до крајњих корисника или фармера, како би се искористили потенцијали за унапређење пољопривредне производње и пословања. У том контексту, информационо-интензивне и прецизне технике пољопривреде засноване на знању и информационо-комуникационим технологијама (ИКТ) су водећи фактори одрживе пољопривредне производње. Сходно томе, пољопривредници треба да буду свесни користи од интернета, мобилних и других ИКТ-а које пружају информационе услуге значајне за управљање пољопривредном производњом и пословањем. Овај рад представља допринос истраживању употребе мобилних технологија у пољопривреди са посебним освртом на мобилне апликације у пољопривреди и интелигентни пољопривредни систем базиран на мобилним и бежичним технологијама.

Кључне речи: Електронски агробизнис, Интернет, мобилне апликације, пољопривредни веб портал, мобилна пољопривреда, интелигентни пољопривредни систем.

1. Introduction

ICT (Information and Communication Technology) has important role in supporting improvement of Agribusiness and contributes to economic and social development of rural regions and its citizens (farmers and their families). However, there is gap between farmers' information requirements and information that the farmers receive. They lack information in form that is understandable for them to effectively manage their agribusiness. Implementation of ICT systems in agriculture improve data gathering, storage and processing and improve decision making in order to achieve greater productivity, competitiveness and income.

There are ICT applications for Farmers that support agricultural production and increase of productivity. These applications assist farmers in decision making on crops, inputs, marketing of agricultural products etc. The applications can be based on web and mobile technologies and may have multimedia elements such as images of plants, video showing animals, audio records with advices etc. The important role in management of agriculture production and business plays mobile technology which is most accessible and available to many farmers even they live and work in poor and remote areas. Advances in mobile and the other information and communication technologies enable farmers to effectively plan agricultural production, cultivate crops and animals, manage agricultural mechanization, organize sale of agricultural products and all these could decrease poverty and increase their quality of life.

Many researchers investigate various aspects of mobile technologies development and use in agriculture, such as relationship between mobile and internet technologies and development of agriculture (Evans, 2018), smart agriculture based on mobile and cloud technologies (Channe et al., 2015), agriculture mobile services based on big data (Nandyala and Kim, 2016), benefits of mobile phone use for farmers (Chhachhar and Md Salleh, 2013), overview of agricultural mobile technologies and applications with case studies (Shah et al., 2014; Costopoulou et al., 2016), model for designing and implementing m-agriculture applications (Gichamba and Lukandu, 2012), adoption of mobile commerce in agriculture (Li et al., 2007), factors affecting the mobile use by farmers (Dissanayeke and Wanigasundera, 2014), and mobile agriculture services and projects (Syngenta Foundation, 2011).

Main aim of the research is to present how mobile technologies and applications can support agriculture and in which agricultural areas and activities contribution of these technologies and applications is manifested. In that context, the paper is organized in six parts. After introduction, in second part, agriculture is viewed from business perspective and information requirements of agribusiness are described. The roles of internet in electronic agribusiness are described in the third part and advantages and contribution of mobile technologies to agriculture are presented in the fourth part. The fifth part of paper is dedicated to mobile applications for support to agriculture production and business. The sixth part presents structure and functions of intelligent agriculture system based on mobile and wireless technologies. The seventh and eighth part are dedicated to the recent researches on application of mobile and wireless technologies in agriculture in world and Serbia. The final part gives concluding remarks.

2. Agriculture from business view and information requirements

Agriculture can be treated as a business that has its own cycle with series of agricultural activities. In one broadest perspective, this business must operate in a complex economic, social and institutional environment, as can be seen in Table 1. This includes the coordination of many stakeholders and actors, such as intermediaries (purchasers, manufacturers, exporters, retailers), supporting organizations (centres for innovation and provision of expert advice and information to farmers, agronomists and government agencies), financial organizations (banks, insurance companies) and consumers.

Table 1.
A comprehensive view of agriculture as a business

Agricultural inputs	Agriculture	Outputs - effects	Environment
Input and technology (machinery, materials, etc.)	Crop planning	*Economic* (income, poverty reduction, etc.)	Legal and institutional environment (agro-policy)
	Purchasing inputs		
Knowledge and information (skills, geo-climatic info.)	Planting		Research and development (inputs, technologies)
	Growing and maturing	*Social* (food security and quality, poverty reduction)	
Access to capital (loans, leasing, etc.)	Harvesting, sowing		Market environment (market access, demand, supply)
	Warehousing and packaging		
Risk management (insurance)	Transport	*Ecologic* (water and soil quality, biodiversity, etc.)	Infrastructure (transport, processing)
	Marketing and sales		

The most smaller farms have lower productivity and income because they lack access to inputs and credit and cannot bear the high risk that accompanies agricultural production. In addition, these farms lack adequate information and skills, which limits effects of ICT implementation. Agriculture has become an information-intensive business, so farmers need to get timely information in the right place. The costs of information, from the decision on planting and sowing, to the sale of agricultural products, significantly contribute to the total production costs. Information asymmetry also increases total transaction costs (De Silva and Ratnadivakara, 2008).

Farmers need many various information in several areas in order to be successful in management of agricultural production and business. These areas are following:

Land with crops (for example, kind of crops that should be cultivated in specific field and size of field, planting and harvesting time, yields of specific crops etc.).

Techniques of agriculture production (sources of this information are agricultural research institutes and centres for agricultural advices)

Agricultural equipment and inputs (information from this area farmers can obtain from companies manufacturing and selling agricultural equipment and companies selling seed, fertilizer, pesticide and the other inputs).

Market of agriculture products (information from market assist farmers to achieve highest prices for their products, decide when and how to sell their products and which crops should be cultivated in next season).

ICT has high potential to meet these information needs and give relevant information to farmers and the other stakeholders in agriculture. Mobile technologies and communications are the most efficient tools for collection, processing and distribution information, affordable for almost every farmer even in underdeveloped regions.

3. The role of Internet in electronic agribusiness

Electronic agriculture (E-agriculture or E-agribusiness) is the provision of information and services relevant for agriculture through information and communication technologies. The use of this type of services requires the possession of computer and other devices for data processing and Internet access. E-agriculture may also include the use of technologies such as geographic information systems (GISs), remote sensors and various wireless devices. (Kaaya, 1999)

On the other side, mobile agriculture (M-agriculture) is a part of electronic agriculture, which refers to the provision of services related to agriculture through mobile information and communication technologies. Mobile ICTs include various mobile devices such as tablets, mobile and smartphones, as well as mobile telecommunications networks for the transmission of information and the provision of mobile services. M-agriculture may also include the collection of relevant data via automatic weather stations or field data sensors. (Thiam, 2013)

The Internet as a market space for agricultural products and source of information can be effectively used by farmers and the other stakeholders in agribusiness (Manouselis et al., 2009). In order to support agriculture business and participation of farmers on electronic markets, many internet applications are developed. The applications can be oriented to:

- ***Agriculture inputs and the other factors relevant for agriculture production*** (for example, land, seed, equipment and machinery, pesticides, fertilizers etc.).
- ***Services*** (for example, legal, financial and insurance services and services related to logistics and the other activities in agricultural supply chain management).
- ***Products as a agricultural outputs*** (for example, electronic auctions in form of auction web sites support commerce transactions when farmers sell their products such as cattle, hay, fish, vine etc.) (Chung et al., 2021)

Agricultural products are very often perishable and usually can be sold on auctions by bid and demand principle but services, agricultural inputs and production factors have fixed prices and can be purchased on Internet. (Chang and Hsiao, 2017)

To support farmers and agribusiness, a web portal can be created based on the concept of "all in one place" which refers to the integration of information and services into a single point of access from the point of view of users-farmers (Karetsos et al., 2014). Agriculture enterprises and farmers can access this portal via a computer connected to the Internet, so information and government services related to agriculture are enabled. It is also possible to send and receive SMS messages on a mobile phone in order to request information or submit a request for a public service. The main advantage is the ability of farmers to use their mobile phones for web portal services in the field of agriculture, such as:

♣ Information services. These services aim to provide users with relevant information in the field of agriculture that is of interest to farmers-users.

♣ Public administration and government services. Electronic government and mobile government services enable: (a) electronic submission of requests by users; (b) processing requests from the appropriate public authority; and (c) forwarding the response to the user.

♣ Communication services. These services aim to enable communication between farmers and civil servants, agronomists, researchers and other agricultural professionals.

The web portal in the field of agriculture is presented in Figure 1. Farmers are able to exchange informative SMS messages about agricultural problems they face, and the web portal is available with mobile and smart phones, as well as tablets. (Simek et al., 2017).

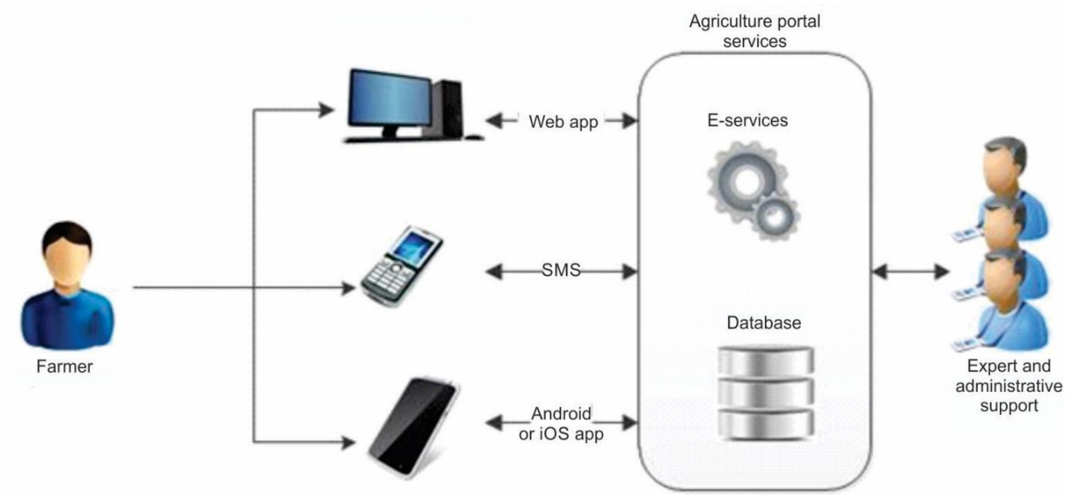

Figure 1. Agriculture web portal
Adapted from: Karetsos et al., 2014, p.5

4. Advantages and contribution of mobile technologies to agriculture

The density of telecommunications is increasing rapidly, and the penetration of mobile information and communication technologies in rural areas of underdeveloped and developing countries is moving in that direction. This created the basis for the development of mobile applications in agriculture, which should primarily help the owners of smaller farms to improve agricultural production, marketing and sales of their products.

Mobile technologies and applications could be a solution to problems related to agricultural information and economic development in rural areas. In this context, the potential benefits that can be obtained by using these technologies in agriculture are: 1) helping farmers to increase income, 2) increasing the efficiency of agricultural marketing, 3) reducing the cost of information and transport, 4) providing agricultural extension services, 5) providing access to various funding alternatives. (Abishek et al., 2016)

1. In some cases, the use of mobile technologies is associated with increased income from agriculture, so that mobile technologies influence better sales and commercialization of agricultural products.

2. Basically, markets are related to the distribution of information, primarily price information, which serves as a single signal enabling coordination between dispersed producers and consumers. Mobile technologies and communications can overcome the problem of market information asymmetry by being able to inform vendors and customers about the prices of agricultural products in different places.

3. The most obvious way the mobile technologies can improve agriculture is to improve access to information and reduce costs of providing information, and on the other hand, mobile phones and other mobile devices can help users communicate with different actors in agribusiness, which can replace travel and reduce transport costs.

4. Many expert advices for effective farming operations can be given by mobile technologies that results in crop yield improvements.

5. Better access to financial and insurance services and payment tools can help in increasing of crop yields and agriculture diversification.

Therefore, the potentials and cited advantages of mobile technologies in agriculture could be achieved on two ways: direct increasing of productivity in production of agricultural outputs and indirect contribution where mobile technologies are used as tools that provide information to farmers in management of their husbandries.

Direct support of mobile technologies to agricultural production implies automation of agricultural production through precise farming based on use of wireless and mobile technologies. It has direct effect to increasing of productivity in cultivating of crops and animals. (Aher et al., 2018; Roy et al., 2017)

Indirect support of mobile technologies to agriculture implies that farmers receive timely and relevant information to make business and marketing decisions.

5. Mobile applications for support to agriculture production and business

There are many mobile applications dedicated for agriculture and they concern crop prices, weather conditions, stock levels of agricultural products and innovative agricultural techniques and machines. For example, in Australia, some applications include livestock tracking, water point management, irrigation management, machine connection, remote grain unloading control, crop sensor monitoring, product marketing, yield estimation and mapping, tool replacement, soil type mapping, etc. However, there are fewer mobile applications specifically designed for agriculture than other types of m-applications. So far, the most dominant applications are those related to weather conditions and applications for access to agricultural news (Karetsos et al., 2014).

Mobile applications can be developed for Android, iOS or some other platform for smartphones and they are called native mobile applications. On the other hand, there are mobile web applications that are based on web standards and run through a web browser on the user's mobile device. There is also a third, hybrid category of mobile applications that combines the features of both native m-applications and web-based m-applications. Regardless of the category, the key functionality of these applications can be focused on different areas of agriculture, such as: horticulture, beekeeping, animal husbandry, farming, forestry, agricultural news, frequently asked questions, forums and weather conditions. Therefore, by combining and integrating different information and communication technologies and knowledge in the field of agriculture, numerous mobile applications have been developed according to the needs of farmers.

Mobile applications can be categorized according to the flow of information in agricultural supply chains that should meet the information and communication needs of participants in these chains. Thus, three categories of mobile applications are distinguished: a) applications that support the information flows needed to coordinate logistic activities in the supply chain, b) applications that support the exchange of knowledge and experience between participants in the supply chain, and with the agriculture experts that service the participants and c) applications that support communication between agriculture producers and consumers. (Jain et al., 2014).

Another classification of mobile applications that is explained here is focused on functions of information and communication in the process of agriculture production and business, as we can see in Table 2.

Table 2.
Agricultural mobile applications

Agriculture	Mobile applications
Crop planning	**1. Applications for knowledge management and decision support** -mobile learning applications -decision support applications **2. Applications for quality control** **3. Applications for financial support** **4. Applications based on market information and interactions**
Purchasing inputs	
Planting	
Growing and maturing	
Harvesting, sowing	
Warehousing and packaging	
Transport	
Marketing and sales	

1. Applications aimed at knowledge management and decision support in the field of agriculture. These applications cover the communication needed to transfer knowledge and skills to farmers, in order to support the distribution of information from research and innovation centres. These applications should solve the problem of skills and knowledge deficit among small farmers and service many more farmers than if only traditional communication channels were used. Mobile applications from this category can be further grouped into:

-*Mobile learning applications*. These applications relate to the transfer of overall knowledge on agricultural techniques, information on crops and their varieties and how to grow them. The applications allow farmers to send their inquiries to a database, enable one-way push communication with farmers, as well as interactive real-time communication to share experiences among farmers.

-*Mobile applications to support decision making*. These applications are part of the decision support system in area of agricultural production and business. They are based on localized contextual information, i.e. the provision of spatial data on the microclimate, soil and water during the crop development, to make the right decisions on agricultural technics to support crop growth. It is about creating main components of "precision agriculture" suitable to small farmers, that needs remote crop monitoring tools and GIS based on wireless sensor networks. In addition, mobile decision support applications may include advisory systems, such as remote plant disease diagnostics performed by agricultural experts.

2. Mobile quality control applications. These applications support communication between vendors and customers, agricultural producers and consumers to assist in the sharing of product quality information; product certification; product origin verification; adherence to quality standards, etc.

3. Financial mobile applications. These applications support communication and financial service delivery processes, such as mobile banking, payment or farm-related insurance.

4. Mobile applications focused on market information and interactions. This category of applications groups the information needed to coordinate logistic and distribution activities in agricultural the supply chain. The use of these mobile applications should improve the transparency and efficiency of the market and make better position of farmers in market of agricultural products. In addition to applications that primarily deal with market information, and especially prices, platforms have been developed to facilitate trade (e.g. identifying opportunities for best sales/purchases and enabling product exchange).

6. Intelligent agriculture system based on mobile and wireless technologies

In order to improve agriculture production and business, the information system based on mobile, wireless and cloud technologies can be developed. Primary aim of the system is real time monitoring environmental data, controlling the growth of crops in a farm to help in the increase of the crops yield. This information system supports implementation of precision farming and farm automation.

The system can automatically gather data relevant for crop growth (for example, air humidity and temperature, soil moisture, light etc.) by wireless sensor network. Therefore, there are various types of sensors (for example some sensors measure temperature and the others humidity and moisture) by which the system collects and then processes data, makes decisions or recommends some actions on the field.

The system illustrated on figure 2 automatically estimates the parameters and presents graphical reports to computer and mobile devices of users and enables the farmers to manage sensors and the other devices using the mobile application. Many sensors can be placed around the field and farmers receive information where in the field soil moisture is low and where to run the irrigation system, the motor pumps and other devices in order to maintain the parameters in appropriate span.

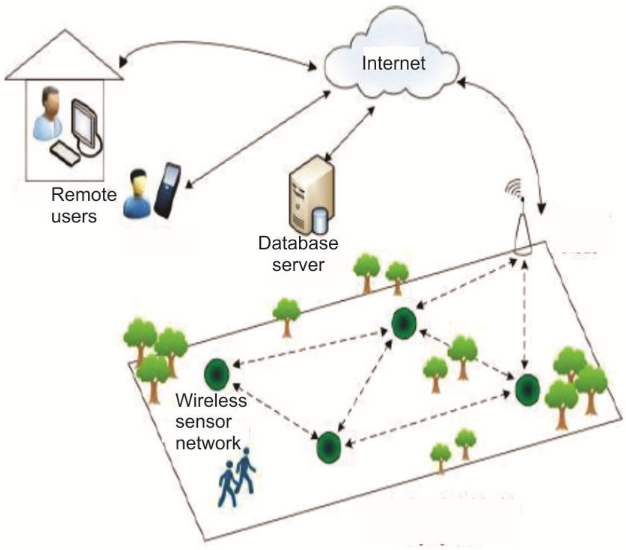

Figure 2. Intelligent agriculture system
Adapted from: Aher et al. 2018, pp.

The system applies the Internet-of-Things (IoT) technology where sensors are embedded in various objects that send and receive data. The system may include and integrate almost all IoT devices, encompassing weather stations, cameras, sensors, etc. that cover a large agriculture field and send and store their data in the cloud. Data from all these IoT devices is transferred to the cloud database that can be accessed by mobile application of farmer and processed for performance analysis and recommendations. With their mobile phones, the farmers can monitor many types of devices and receive the data from the sensors. (Roy et al., 2017)

Therefore, agriculture field covered by smart sensors creates base for intelligent agriculture information system with purpose of centralized monitoring of fields with crops. The farmers can monitor the condition of crops by a mobile phones and access the data stored in a cloud database. Also the farmers can monitor the gathering of data from agriculture field (data on crops, soil, fertilization, irrigation etc.) and correlate such data to estimate crop growth and make forecasts for future crop growth.

7. Recent researches on application of mobile and wireless technologies in agriculture

This section discusses recent research on application of mobile and wireless technologies in agriculture, in order to identify recent trends and challenges in the use of these technologies. Articles in the period from 2018-2022 were searched through the Google Scholar search engine, using the keywords mobile agriculture. Seventeen (17) articles were found which explicitly deal with this topic and which can be divided into two groups. The first group of articles (10) investigates the application of mobile phones, applications and services in agriculture, while the second group (7) studies the application of wireless technologies in implementation of precision or smart agriculture. In the following text, we present the most important results of those investigations.

7.1. Use of mobile applications and services in agriculture - recent trends

As mentioned earlier, to be successful in agricultural production, farmers need many types of information such as information on soil, seeds, crop, weather, fertilizer etc. They get this information from various sources, such as input producers and sellers, agricultural advisors, other farmers etc. However, due to the inefficiency of these offline sources of information, mobile applications have been developed that provide easy access and exchange of information, enabling effective management and communication with farmers.

In recent years, several new mobile applications have been developed in response to new demands and challenges in agriculture (Mandi and Madhav, 2019). As the number of these m-applications grows, a good selection of applications should be made and the applications should give reliable and timely information and meets other requirements. Agricultural production depends primarily on the geographical context, so it is possible to adapt an m-application developed for one context to suit other crops, countries or regions. Therefore, mobile applications should aim at all-round rural development, establishing closer links between farmers and consumers, training and developing the competence of farmers to use technology and information.

In order farmers to gather data in real time, they can use mobile phone, so a m-application has been developed for that purpose and presented in a research (Dauma et al., 2018). With this application, the accuracy of collecting sociological, economic and agronomic data is increased. In addition, the application can be used to analyse the benefits of using mechanization in agricultural production within the household. The experience with this application called Time-Tracker shows that such m-applications can be effectively implemented in agricultural regions of countries with low income, where the computer and general literacy is not satisfied and the skill of using smartphones is low. This research (Dauma et al., 2018) proves that smartphone m-applications, if well developed, can be efficient tool for collecting data on smallholder farms.

New mobile applications must be adapted to farmers not only from the point of view of providing agrometeorological information, but should also provide advisory and educational services. In addition, m-agriculture applications should provide information on new government policies related to agriculture, on scholarship for those interested in agricultural education, on rural life, etc. One research (Aravindh Kumar and Karthikeyan, 2019) examines current mobile farming applications in the global mobile ecosystem. The study further indicates that educational and extension m-applications for agriculture must include an interactive learning section, 24/7 availability, portability, e-books and e-journals, agricultural vocabulary and instant update capability. These m-applications should be designed to support all mobile operating systems and be available across all platforms that work online and offline. All these facts need to be taken into account by developers and agricultural experts, so new mobile applications must be user-friendly and relevant to farmers, students and other stakeholders in agriculture.

Smart or precision agriculture is a good framework for the application of artificial intelligence techniques integrated with modern cloud infrastructure, with the aim of eliminating pests in agricultural fields and increasing the productivity of crops in those fields. In this context, a research was conducted (Karar et al., 2021) which presents a new mobile application for automatic pest classification, using deep learning technique to support agricultural experts and farmers. The developed m-application uses a neural network whose task is recognition of pests and which is executed in a cloud environment. In addition, information on available pesticides is linked to detected pests, so that farmers can immediately receive advice on how to combat detected pests. The presented neural network showed the most correct recognition results of 99,0% for all pest images tested (Karar et al., 2021). This deep learning technique proved to be more efficient and outperformed other previous recognition methods, such as traditional back propagation (BP) neural networks.

One research (Eichler Inwood and Dale, 2019) provides an overview of m-applications for agriculture in the context of the impact on the sustainability of production and business. In essence, the shortcomings of these applications in providing information and knowledge to decision makers that affect the sustainability of agricultural production are identified here. In this sense, agricultural m-applications can be categorized into applications for compliance with regulations, equipment optimization, agricultural simulation, agroclimatic information management, product tracking, pest identification, and agricultural marketing management applications. Many applications have been created to relate IT products for individual solutions, such as monitoring crop based on GPS technology or sensors connected through the Internet of Things. This research (Eichler Inwood and Dale, 2019) shows that pilot and prototype applications are developed for both Apple and Android mobile platforms, but public mobile applications for agriculture, which would support knowledge sharing, are few and not well documented. This means that there is a great need for applications that emphasize knowledge sharing, rather than just information distribution. If these applications were provided to farmers, they would be able to identify and apply practices that encourage the achievement of sustainability goals. The development of agricultural m-applications for support in business decision making requires early and constant interaction with end users in order to understand their information needs, determine the goals of the application and improve the user experience. In the development of agricultural m-applications, there have been efforts to link big data technology with mobile technologies to support farm management decision-making, but these are mostly one-sided and treat only one agronomic or environmental topic. There is still a need for m-applications that give information to farmers, agricultural advisors and other stakeholders with aim of a sustainable development and management of farms.

Other authors (Emeana et al., 2020) talk about the revolution of services provided to farmers via mobile and smart phones in the function of agricultural development in Africa from the aspect of sustainability. In order to improve the sustainability of m-agriculture services, they recommend designers who need to design and develop these services to involve users in the earlier stages of development and to carefully analyse and understand the target environment and long-term information needs of users. User privacy and security should be ensured, as well as exploring the possibility of reusing or improving existing initiatives, and projects should be open source. However, there are various strategies for m-agriculture services in solving some issues such as affordable service fees, online messages that do not use the Internet for distribution, introducing third party between service providers and users to upgrade user knowledge and skills. At the end of this research (Emeana et al., 2020) it is concluded that policy makers can ensure favourable policies for both users and providers of these services, in order to achieve long-term benefits from m-agriculture services.

M-services distributed to farmers, primarily through the delivery of agrometeorological information, can significantly transform agricultural production and even the rural life of small farmers. In order to better understand the features of m-services for farmers, how farmers use that features, and the factors that influence the use of m-services, a survey (Krell et al., 2021) of small farms in central Kenya was conducted. Factors influencing the adoption of mobile services by Kenyan farmers were examined. These services are specifically related to agricultural production, animal husbandry, purchase and sale of products and warnings about agricultural or animal husbandry activities. It was concluded that age and income level has not relevant impact on the use of m-services. However, a higher level of education of farmers, membership in agricultural organizations and possession of a smartphone have a positive influence on the use of m-services. Owning a smartphone encourages the use of m-services, but m-service providers should also design basic m-services for regular mobile phone users for more efficient delivery of agrometeorological information.

Another paper (Michels et al., 2020) investigates the factors that influence farmers in accepting and adopting smartphones as a tool for managing agricultural production and business. This research was done in Germany and involved German farmers. The relation of farmer demographic characteristics and feature of farm to smartphone adoption was analysed. A sample of 817 German farmers was surveyed, which is representative in sense of farmer age, farm size and diversification, and regional representation in Germany. The research presents that farmer age and education level, and farm size as well are factors influencing smartphone adoption. In addition, this research (Michels et al., 2020) presents data on the use of smartphone operations and the functions that agricultural m-applications have. The results of this research confirmed the assumptions that the farmer's education and the size of the farm have a positive impact on the adoption of smartphones. The age of farmers has a negative impact on smartphone adoption. If a farm is located in the southern part of Germany, there is lower probability for smartphone adoption. Opposite situation is if the farm is in the western and northern regions. Also, the innovativeness and computer literacy of farmers have positively influenced the adoption of smartphones. Finally, there is not impact of farm diversification and farmer gender on smartphone adoption.

It would be of great importance to farmers to make a comprehensive overview of m-applications by category and their characteristics and to somehow make a comparison between them. In this sense, a research was organized (Mendes et al., 2020) which provides an overview and analysis of the characteristics of a large number of mobile applications used in precision agriculture. Most of these applications are offered on the market, but some are created at the research level. This review is useful for farmers and also for researchers and application designers to get information on the shortcomings of the mobile applications and how they can be improved. For now, there are very few applications that help farmers make business decisions and many of them are still in the development phase. On the other hand, there are applications for identification of pests and animal diseases, controlling of crop growth, monitoring of irrigation, planning of yield, management of land and many others.

It was found (Mendes et al. 2020) that there is a great potential of agricultural m-applications in the execution of artificial intelligence algorithms, considering that every modern smartphone can receive high-quality images and has the capacity to analyse and process them. A smartphone can be very useful for obtaining agronomic data. Image processing, among other things, is actually the biggest common denominator among all analysed applications. Photographs of plants and their leaves, as well as the processing of those images to identify diseases and pests, are the focus of most existing applications. Considering the growth in the number of applications in this area, smartphones are significantly contributing to the spread of mobile applications in agriculture.

Finally, in the creation of m-applications for agriculture, the values adopted by the users are important for the optimal use of the applications. Failure to respect these values can make user disappointment and negative socio-economic implication. Therefore, a research was conducted (Shams et al., 2020) that identifies the desired values of users and determines whether or not these values are present in existing mobile applications for agriculture in Bangladesh. Using the Schwartz's theory of basic human values, the researchers came to the conclusion that the users of the selected applications have 21 desired individual values, of which 11 values are present in the applications, and 10 values are not. On a basis of this research, developers can develop applications that take into account the basic human values of users. Such research on mobile applications for agriculture can be conducted in other developing countries, in order to observe cultural differences. In this way, m-applications for agriculture of different countries and their respective values can be compared.

7.2. Application of wireless technologies in agriculture

The quality of products and the preservation of the environment, which is influenced by agricultural activities, are among the priority goals of modern agriculture. Contemporary information technologies, such as the Internet of Things (IoT), cloud technology, data mining and big data can help achieve these goals. Just one research (Liu et al. 2019) studies the information system based on these technologies for which an experimental environment is created. The experiment shows that the development of a contemporary agricultural information system for controlling agricultural production, which offers users a messaging service, the ability to analyse big data in the cloud by data mining tools, has been validated. For the needs of this system, NoSQL database DynamoDB, Oracle relational database and Amazon S3 object storage was designed.

Automation of agricultural production is achieved by wireless sensor network (WSN) and other intelligent devices such as IoT. These hardware resources, together with the software, form a system of precision or smart agriculture, which should provide the best possible conditions for crop development, optimization of agricultural production and sustainability. The system of precision agriculture takes data on the state of the soils and crops and about the weather conditions in the agricultural fields from a wireless sensor network. Through satellite or air-borne platforms, high-resolution crop images are obtained, in order to create information for making crop decisions (irrigation, fertilization, etc.).

Shafi and his colleagues (Shafi et al., 2019) in their research deal with the implementation of wireless communication technologies in the assessment of environmental conditions and describe the platform used to provide and analyse images of crops and parameters of growth. Through a case study, this research shows precision agriculture system based on IoT devices for crop controlling which consists of two modules. Main component of the first module is a wireless sensor network for monitoring the health status of crops in real time. The second module uses a platform for remote acquisition of multispectral images, which are analysed to detect crops with disease.

And other authors (Pathaka et al., 2019) talk about an intelligent system for monitoring agricultural fields that controls the condition of the soil and crops and manages irrigation. Various parameters are collected using an Internet of Things (IoT) and sensors. Sensor data is collected and stored in a cloud environment, to be analysed and displayed using ThingSpeak analytics tools. ThingSpeak is an IoT analytics platform that enables aggregation, visualization, and analysis of data streams in the cloud. Some techniques have also been developed to forecast and model crop yields and predict good harvests, which enable decision making in marketing, logistics and crop storage. In this context, an expert system based on multiple criteria could be designed that allows farmers to take adequate measures under conditions of uncertainty using data collected by the IoT system.

The increasing and intensive use of Internet-connected devices increases the possibilities for the application of wireless communication technologies in agriculture on small farms. Precision agriculture in small-scale households based on the Internet of Things (IoT) has the potential for intensive development. In this context, a research was conducted (Antony et al. 2020) providing insight in IoT technology implementation on small farms, challenges related to the implementation of this technology on small farms, and recommendations for practitioners. Based on the cases of successful implementation of IoT technology in countries with low and middle income, it can be concluded that this technology has perspectives in the future.

Smart or precision agriculture is often seen as one of the relevant factors influencing on the elimination of hunger and malnutrition in the world. However, the practical application and adoption of technologies that make up smart agriculture encounter social and economic obstacles. Edge computing as a new data processing concept offers a model for the development of smart agriculture, which is the subject of study in one paper (O'Grady et al., 2019). This paper analyses the application of the Edge computing model in agriculture. The research results present that the Edge model is tested in a many areas of agriculture, but that it is in the prototype phase and that detailed researches are needed. The abilities of this technology has been demonstrated, but some problems must be solved, for a significant influence to occur. It can be said that implementation of the edge technology in agriculture is at the beginning of its application, that the systems based on this technology are in the prototype phase and are only showing certain aspects of solving problems in different agricultural domains. The main problems that need to be investigated and solved in the implementation of this technology are interoperability and scalability.

With the implementation of wireless sensor networks, IoT and similar technologies, the volume of data gathered from farms is growing rapidly. In order to extract relevant information from this large amount of data, machine learning tools are increasingly being used in agriculture. In their work, Mekonnen with his colleagues (Mekonnen et al., 2019) investigate machine learning methods which are often used by researchers in the last two years with data from wireless sensor networks. Various machine learning models implemented in multiple smart agriculture applications, such as yield prediction, weed and plant disease identification are presented. The focus was on precision agriculture based on wireless sensor networks, where machine learning algorithms are used for data mining, prediction and automation. A smartphone application and backend platform for data analysis with aim of predicting crop timing, yield and quality are also described.

Therefore, IoT and wireless sensor technologies are increasingly being used in agriculture to increase yields and the quality of agricultural products, and decrease production costs. In this context, several authors in their work (Muangprathub et al., 2019) propose the development of a system for efficient irrigation of crops based on a wireless sensor network. This is a monitoring system that uses sensors in agricultural fields to control the condition of crops and to manage the information by a smartphone and web application. Data analysis is done through data mining tools to forecast the appropriate soil temperature and humidity for optimal crop growth management. The system has 3 parts: hardware, web application and mobile application. The first part is in the form of a control box connected to sensors to obtain crop data. The second part is a web application that manipulates crop and agricultural field data. The third part of this system is a m-application that is used to monitor crop watering. It enables both automatic and manual monitoring of irrigation.

This system has been developed in Makhamtia district in Thailand, so it has shown its advantages and provided corresponding benefits to farmers (Muangprathub et al., 2019). The moisture of the soil is managed in an appropriate manner for the growth of vegetables so costs are decreased with improvement of productivity. The effects of increasing productivity are illustrated by the graphs in Figure 1. From economic aspect, investment in this system has returned within 2 months, due to increased productivity in crop cultivation.

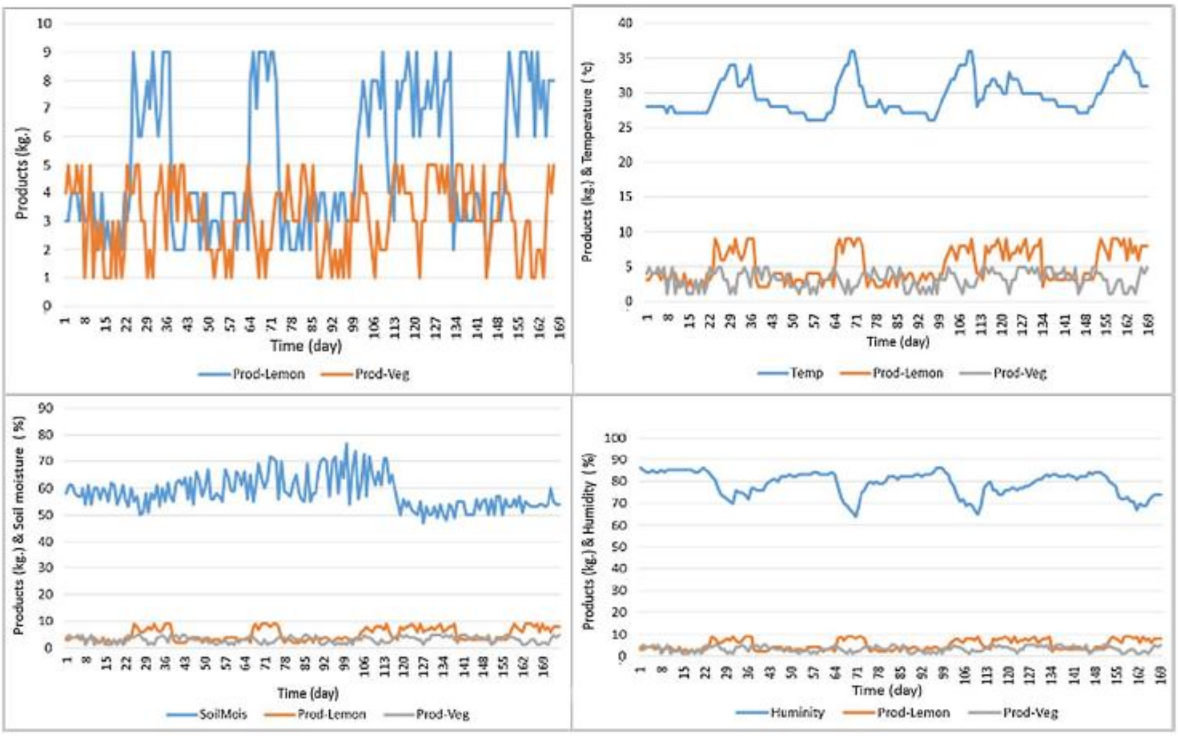

Figure 2. Smart agriculture system and productivity
Source: Muangprathub et al., 2019, p.474

8. Application of mobile and wireless technologies in agriculture – some experiences and researches in Serbia

In the last ten years, the application of mobile and wireless technologies in agriculture has intensified in the Republic of Serbia. This is evidenced by researches published in our reference journals in the field of agricultural production and business. For the purposes of this research, three journals were taken into account: Acta agriculturae Serbica, Contemporary agriculture and Economics of agriculture. All issues of these journals in the last 10 years were analysed with the aim of finding articles that dealt with applications of mobile and wireless technologies in agriculture. Here is an overview of seven articles found in these journals on this topic.

As already emphasized, the challenges to which modern agriculture needs to respond, such as greater food production, can be solved to a some extent by new technologies (Internet of Things, wireless sensor networks, mobile technologies, smart agriculture) that become the driver of changes in agricultural sector (Radić et al., 2022). In his research, Janos Simon (2013) presents a project for the development of a universal microclimate control system based on wireless technologies. Adaptive management of this system in different conditions is technically enabled. A wirelessly controlled mobile measuring station is used to monitor climatic conditions and the condition of crops and land.

Markovic, with his colleagues, was engaged in researches on the application of mobile and wireless technologies in monitoring and controlling agricultural production on the farm (Marković et al., 2015), detection of frost in orchards (Marković et al., 2013), assessment of the intensity of sunlight, which is important for crop development and quality (Marković et al., 2014) and remote control of beehives (Marković et al., 2016; Marković et al., 2019). On the basis of these researches, the benefits that agriculture can achieve and are already achieving through the application of mobile and wireless technologies can be emphasized, namely: increasing the efficiency of the use of agricultural inputs, decreased costs of agricultural production, greater income of households and farms, sustainability of agricultural production and business, food safety and environmental protection.

In monitoring and controlling the agricultural production, IoT technology can be implemented. The technology is implemented on microcontroller platforms and Arduino sensors, as described in the mentioned research (Marković et al. 2015). Autonomous sensor devices collect data from agricultural fields and send signals to actuators. This system with IoT devices provides the possibility of remote monitoring of the conditions in which the agricultural production process takes place.

When we talk about frost detection in orchards, the aforementioned authors (Marković et al., 2013) propose wireless information system that is used for that purpose. At the heart of this system are wireless sensor devices sensitive to temperature changes that send data to a web server via the GPRS network. This data is stored on the server for further analysis and prediction of the possibility of frost, in order to take timely measures to protect the fruit.

If there are other agrometeorological conditions, insufficient intensity of sunlight can be a limiting condition for achieving good crops in agricultural fields. In the aforementioned research (Marković et al., 2014), a mobile application for calculating the intensity of solar radiation at any geographical location was presented. Based on GPS coordinates and the position of the terrain under different meteorological conditions, this application allows determining the intensity of sunlight for a certain period of time.

Finally, two researches (Marković et al., 2016; Marković et al., 2019) deal with remote control and monitoring of beehives with the support of mobile and wireless technologies. A system for remote temperature controlling at different points in the hive is presented. Temperature data is collected using IoT devices, and then transferred to a remote server for processing and analysing by CEP (Complex Event Processing) technology in order to detect important events in the hive and the creation of reports for the beekeeper as a direct decision maker. Wireless sensors in the form of IoT technology can control other parameters in the hive, such as humidity, hive weight, carbon dioxide level, etc.

In the processing of data collected by sensors, machine learning technology is used, which is able to identify critical events without explicit programming by comparing the collected data with reference temperatures. In this way, the time it takes the beekeeper to intervene is significantly shortened, because the critical event in the hive is immediately detected and the beekeeper is informed on it. This increases the chance that the bee colony will overcome some problems with human intervention.

Remote control of hives using IoT devices allows beekeepers to get information about the health of the bee community and to avoid constant disturbance of the bees if they were to manually control the hives. Manual control of hives also causes unnecessary labour costs, as bee communities require frequent inspections for pests or diseases. If a large number of hives are located in remote locations, manual inspection is extremely labour-intensive, which increases costs.

9. Conclusions

Information requirements of agribusiness are various so farmers need information on crops, agricultural equipment and techniques, market, inputs like seed, fertilizers, pesticides etc. Benefits of ICT can be obtained if these requirements are defined well. After comprehensive definition of the information requirements of farmers, developers can implement effective ICT applications. Benefits and advantages of the ICT implementation in agriculture are: the effective utilisation of agricultural inputs like land, fertilizers, seed, pesticides, etc.; decreased costs of agricultural production; greater profitability of households and farms; sustainability of agricultural production and business; food safety and environmental protection. In implementation of the ICT systems, focus should be on incorporation of internet and mobile information and communication technologies.

Development and building of Internet infrastructure in rural areas is precondition for access and use of ICT by farmers. Also building of wireless communication infrastructure enables farmers to use mobile phones and smart phones (with mobile and web applications) in order to process data and access information useful for agricultural production and business. It is expected that dissemination of wireless infrastructure and use of mobile devices in rural regions will continue, particularly in developing countries. This creates opportunity for development of many mobile agribusiness applications for knowledge management and decision support, quality control, financial and marketing support.

The researches in our country and in the world indicates the increasing use of mobile and wireless technologies in agriculture with measurable effects in increasing productivity and reducing production and business costs, while increasing yields. In addition, other technologies are combined with these technologies, such as: cloud and edge computing, artificial intelligence and machine learning, big data analytics and IoT. With the synergistic effect of all these technologies, many farms and businesses are approaching the concept of smart or precision agriculture. At the same time, the number of mobile applications that help farmers obtain and collect information important for managing agricultural production and business is growing.

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