

Software solution for growing crops on an individual land plot

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Abstract. The paper defines the importance of agriculture for the population of the countries that are members of the Eurasian Economic Alliance. The article briefly characterizes the state of the agricultural sector in Russia, the Republics of Tajikistan, Belarus, Kyrgyzstan and Kazakhstan. The level and problems characteristic of crop production on individual land plots to meet their own needs and the sale of products for food and processing industry are established. The aim of the work is to create a software product that provides a high level of crop yields for individual subsidiary plots. The use of system analysis methods made it possible to develop the concept of a digital software product with artificial intelligence functions, which provides the processes of crop rotation, cultivation, care and harvesting of plants in accordance with the set goals. The paper presents a description of the architecture of the corresponding software product and the main screens of the mobile application, realizing the developed functional possibilities. The use of such a software product has important economic, social, cultural and environmental significance for the countries of the alliance, but also provide their food safety.

1 Introduction

Gardening or horticulture is one of the key activities of residents of the countries that are members of the Eurasian Economic Alliance.

According to the results of the microcensus conducted in Russia in 2021, the number of private subsidiary and individual farms has decreased, but at the same time their enlargement has occurred [1]. It is noted that at the same time the effectiveness of agricultural land utilization by agrarians increased, while in private subsidiary farms it slightly decreased [2]. All this is due to the implementation of state programs aimed at supporting agricultural producers, ensuring the involvement of agricultural land in the turnover and re-engineering processes to improve and meet the real needs and food security [3-5].

Analysis of the state of agriculture in Tajikistan shows that its share in the country's GDP is up to 30% [6, 7]. The agrarian component of the economy is provided by the involvement of able-bodied half of the population to work in the industry and land reforms (26% of the total area of the country is occupied by agricultural land). Crop production prevails (Tajikistan is the leader in cotton exports in the world).

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Agriculture in the Kyrgyz Republic is characterized by the predominance of livestock production. The low level of crop production (relative to livestock production) is associated with climatic conditions and, accordingly, the use of about 13% of agricultural land for arable land [8, 9]. However, the reforms have ensured the creation of numerous small peasant farms, which mainly provide food for the country's residents and form export flows of products. At the same time, one of the sources of nutrition for families is their own produce on the homestead [10].

Agricultural production in Belarus meets the internal needs of the population in food products and is also one of the sources of foreign exchange earnings [11]. In the agricultural sector there are about 1.5 thousand organizations and 3.4 thousand peasant farms, which are mainly engaged in the cultivation of cereals, potatoes, vegetables, sugar beets, flax and meat and dairy production [12]. According to statistics, about 362 thousand people are employed in agriculture, wood industry and fisheries [12]. The share of agricultural production by the population of the total production of Belarus is 19%. Incentivizing the population for the production of such products is carried out by paying citizens a premium to the purchase price of products grown and produced by them. In addition, preferential lending is provided to citizens for the realization of private subsidiary farming projects.

There is a period of stagnation in agriculture in Kazakhstan, as there is incomplete and irrational use of labor and natural resources [13]. At the same time, 38% of the budget is formed through the sale of cotton, oilseeds, fruit and berry and grain crops, animal husbandry, wool and leather production, flour [14]. The share of private subsidiary and small peasant farms accounts for up to 80% of the total volume of food production (90% of milk of all kinds, 84% of open ground vegetables, 83% of potatoes and about 70% of meat of all kinds in slaughter weight) [15].

Analysis of literature sources shows that the above countries have a huge agro-industrial potential, which makes it possible to solve the problems of food security and import substitution not only with the help of large agro-industrial complexes or farms, but also due to the effective development of individual gardening and vegetable gardens of the population. Growing plants and breeding of birds, rabbits and other animals makes it possible to provide not only family consumption of products, but also to obtain the possibility of additional income when selling the produced agricultural products [5]. To increase the effectiveness of processes related to the cultivation of crops requires the use of specialized software tools capable of producing a comprehensive analysis of environmental parameters, plant condition and control the results analysis [16]. Agro-industrial complexes and farms have advantages over private subsidiary farms, as they have qualified labor resources, providing organization and management of processes of obtaining agricultural products, as well as the use of high-tech equipment and specialized software for this purpose [17]. The creation of a software tool that provides decision support for growing crops on a personal homestead plot contributes to increasing their yields. All this has high economic, social and environmental significance for the population of these countries.

Thus, the aim of the work is to create a model of a software product that provides support for the processes of growing crops on a personal homestead plot to obtain the maximum possible yield. To do this, we need to perform the objectives to identify the key processes and their subjects, for which digital transformation will be made; to establish their characteristics; based on the results obtained, to create a model that determines the functional possibilities of the software product.

The theoretical significance of the work lies in obtaining a single model that systematizes and synthesizes information about the peculiarities of agricultural plant growth environment depending on climatic and weather conditions, methods and ways of processing, as well as current data obtained by means of objective control (for instance, sensors, photo or video

images). Such a model can be used for research and development related to sustainable agriculture and optimization of agronomic processes.

The practical significance of the work lies in the creation of a tool that provides control and monitoring of the processes of sowing, irrigation, fertilization and harvesting of crops in order to increase their yield and quality. The resulting software product forms a unified digital ecosystem that unites local communities, improving accessibility to topical resources. This contributes to improved livelihoods and social sustainability.

2 Methods

The object of the research is personal plots of citizens, on which the cultivation of crops is carried out. In this case, the form of farm organization is not taken into account, as in accordance with the objective does not affect the results. The subject of research is the processes of crop cultivation and crop rotation.

For the accomplishment of the objectives, the methods included in the system analysis were used. This is due to the fact that the choice in the decision-making process is carried out under conditions of uncertainty due to the presence of characteristics in the subject of research, which cannot be realized with the help of strict quantitative assessment. The problem in this case is considered as a single system with established interrelationships and consequences of decision-making. Using the methods of decomposition, abstraction, generalization, synthesis, observation, analysis of scientific literature related to crop cultivation, made it possible to establish the key characteristics necessary to create a model of software product functional possibilities.

Based on the results obtained, the main users of the software product were established and user scenarios corresponding to them were developed. For this purpose, the wireframing method was used, making it possible to determine the behavior of the software product users in accordance with the elements of its interface.

3 Results

Cultivation of agricultural crops on an individual plot of land is mostly done by amateurs - citizens who have no relevant specialized education. Seed selection, soil preparation, plant care and harvesting are carried out on the basis of their own experience and available reference material, which, most often, is placed in the media. Such materials may have generalized information on solving problems arising in the process of growing crops, not taking into account climatic features, weather and other conditions that characterize a particular land plot (for instance, soil composition and fatigue, location of natural objects and objects of economic activity in relation to the plot). In addition, land plots may be located far from the permanent place of residence of citizens, which affects the timeliness of problem detection and decision-making to eliminate or reduce the negative impact. All this may negatively affect the growth and development of growing plants.

Based on this, the main function of the designed software product is to monitor the condition of the land plot and the crops grown on them. To ensure such a process requires the creation of client-server architecture. The client part is realized in the form of a mobile application, since the availability of smartphones among the population is of a mass character. The server part has a multilink architecture consisting of an application server and a database server. The application server provides business logic for the functional possibilities of the digital system. The database server provides storage of user data and processing of user requests. Such data is necessary for user identification, formation of archive data on current and previously grown plants, growth environment and works performed. Their use provides

automatic formation of recommendations on effective cultivation of crops on a particular land plot.

Here are fragments of images of the user interface of the software product with a description of the possibilities supported by it.

Fig. 1 shows the screen of plots that are available to the user. It is assumed that the user can have several plots located in different places. This means that each of them has different characteristics that have a significant impact on the crop growing process.



Fig. 1. Mobile application screen of land plots available to the user

Possibilities to add site information are available to the user:

1. Location (coordinates). On the basis of data obtained in automatic mode climatic conditions are determined, necessary for determining the most favorable periods for farming; proximity to natural objects (for instance, rivers, forests) and objects of industrial, economic and domestic human activity (for instance, factories, fields, highways); approximate soil composition. All this is necessary to determine the types of crops suitable for cultivation in the specified area, to determine the frequency and composition of work, as well as to select the optimal scheme of fertilizer application.

2. linear dimensions of the plot. They are used to determine the density of plant distribution on the plot.

3. Mode of operation of the application. All processing data arising in the process of plant cultivation can be obtained in manual or automated modes. For this purpose there are two modes of operation of the digital system: basic and advanced.

The basic mode assumes that the user does not use technical and software means of controlling the condition of the plot. This means that the selection and planting of plants, control over their condition and soil condition is carried out exclusively by a person. Only data obtained from the user on planting and general plant growing techniques are used to form recommendations without taking into account external factors that occur on the plot. The user can manually record in the application the work they have done, so that the list of further recommended objectives can be automatically updated to maximize yields.

The advanced mode of operation of the digital system involves the use of sensors and other means of monitoring the condition of the plot and the plants being grown. Sensors can receive periodic readings of, for instance, soil moisture or acidity, light levels, and ambient

temperature. The use of means that receive video images of the state of plants will make it possible to realize the technology of machine vision to determine the presence of pests or diseases. With the help of these tools, the list of objectives that need to be performed in real time to create favorable conditions that increase plant yields is specified.

Regardless of the selected mode, the user has the possibility to determine the favorable neighborhood of the plants he has planned to sow. Fig. 2 shows the screen that realizes this possibility.

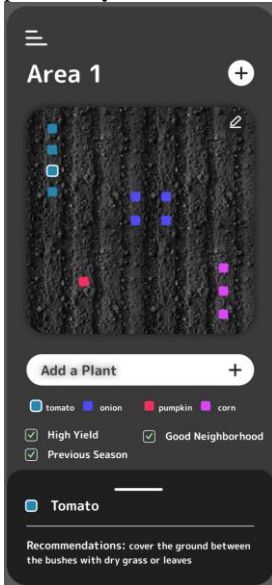


Fig. 2. Mobile application screen for determining the favorable neighborhood of growing plants

The user needs to enter a list of plants into the digital system that they are going to grow and set the goals they want to achieve at the end of the season. This is necessary to determine their compatibility in a given area: different types of plants can create both favorable and negative conditions for their neighbors. For instance, placing carrots and onions nearby protects them from attack by certain insects. Carrot fly cannot tolerate the smell of onions, while onion fly cannot tolerate the smell of carrots. In addition to providing protection from pests, plants may, because of their structure, shade out their neighbors, have different nutrient requirements, release toxins that inhibit the development of their neighbors, and have different maturity dates.

In the presence of archive data (information about the plants grown on the plot in previous seasons), the digital system realizes the function of crop rotation. It is known that growing plants (vegetables, flowers or medicinal herbs) in the same place for several years in a row negatively affects their yield. Using the crop rotation function makes it possible for the user to offset this effect, thereby improving the soil. At the same time, there is no universal scheme of crop rotation, so to get the result requires not only a list of plants and their predecessors, but also information about the type of soil, previously used fertilizers and work done on the site. For instance, cucumber, pepper, carrot, horseradish, cabbage, sunflower and numerous weeds left in the beds can release toxins into the soil.

Once the user has added information about the plants to be sown and defined the targets, the system will automatically generate a layout of the plants in relation to each other. To generate further recommendations for cultivation, the user will need to confirm the scheme or make manual changes. Subsequently, the user can modify the plant layout in accordance with the current status of the plot (for instance, destroying plants, sowing new targets,

harvesting). All information about the grown plants is available for viewing on the screen shown in Fig. 3.

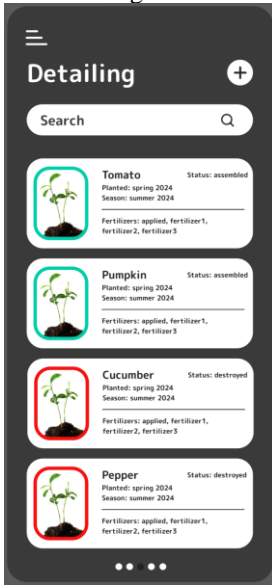


Fig. 3. Mobile app screen on the status of plants growing on the plot

If the user only needs to create a system of notifications about recommended work, he can use the controls to add plants planned for growing in the current season (without taking into account crop rotation and plant neighborhood conditions). In this case, the system will remind him about planting and care dates in accordance with the set list of tasks. For this purpose, a calendar of tasks is formed, which is shown in Fig. 4.

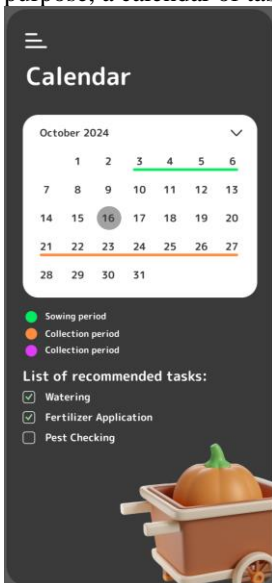


Fig. 4. Cultivation task list mobile application screen

The calendar is interactive and is available to the user regardless of the selected mode of use of the mobile application and sowing conditions. Each number corresponds to a certain

list of objectives, which are recommended for the user to perform in order to obtain a good harvest. The fulfillment of objectives is confirmed in both manual and automatic modes. The basic mode is characterized by manual confirmation only, while the advanced mode is characterized by the hybrid format. In the hybrid format, the confirmation of objective fulfillment is based on data obtained from sensors (if possible) and user interviews. For instance, it is possible to determine watering of plants using the installed soil moisture sensor, while the application of specific fertilizers will not be automatically determined in most cases.

4 Discussion

The main trend of agricultural development at present is the active implementation of Internet of Things technologies, artificial intelligence, robotization and the use of geo-analytics [8, 13, 16]. Manufacturers of software products actively offer solutions for automation and digitalization of agricultural production processes mainly for large farms and agrocomplexes that have labor and economic resources, as well as technological solutions [17, 18]. At the same time, for production on an individual land plot, the choice of software solutions is limited to software products with the functions of selling seeds and seedlings, general recommendations on plant cultivation and related services (for instance, tree pruning, mechanized tillage, pest control). In the works of researchers it is noted that in order to increase the yield and quality of grown products on individual land plots it is necessary to develop software solutions that do not require special knowledge in the field of agriculture from the user and use a simple interface to manage the relevant processes [3, 19, 20]. The created model of the software product meets such requirements and provides the process of monitoring and control, as well as the timely formation of recommendations for the operational management of plant cultivation processes.

The obtained model corresponds to the results of the methods stated in the corresponding section. The analysis of the works shows that for formalization of systems, which include numerous objects and processes, the connections between which have an uncertain or random character, the method of structural analysis, abstraction and synthesis of the obtained results is used to determine the key characteristics of the research object. This approach is typical in research on, for instance, transportation systems [21-23] and ecosystems [19, 24]. Researchers obtain a list of key actors of the processes and their qualitative and quantitative characteristics, based on which parametric models of the description of the research object, functional possibilities of software products, models of object behavior, etc. are formed. Such results correspond to the results obtained during the application of system analysis methods. Thus, the obtained model is complete, adequate to the problem area and reliable.

5 Conclusions

Despite the transformation of modern society, gardening and horticulture are popular among most citizens. It is one of the most accessible and economical ways of obtaining fresh food, as well as cooking and canning. The efficient use of land resources requires the use of modern software tools that make it possible to establish unified approaches to the organization of cultivation processes, control and monitoring of plant conditions to ensure high yields and environmental friendliness.

Organization of organic production using environmentally friendly technologies in crop cultivation is currently a competitive advantage in the food market. Many consumers are ready to refuse to buy products in favor of their own production, if during the cultivation, transportation and storage of products used technologies that have a negative impact on the

environment. In this case, the use of software tools in plant cultivation contributes to increasing the level of citizens' knowledge in the field of agriculture.

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