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DEVELOPMENT AND APPLICATION OF AN INTEGRATED INFORMATION MODEL FOR OPTIMIZING LAND USE AND FORECASTING YIELDS IN AGRICULTURAL PRODUCTION

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The paper presents the development of a conceptual information model for optimizing land use and crop forecasting in agriculture, implemented using the PHP programming language, Javascript and the MYSQL database management system. The model is designed to solve optimization problems in various fields such as logistics, manufacturing, finance, etc.

As part of the work, an information model was developed, which is a set of data, algorithms and software modules designed to solve optimization problems. The model is implemented based on PHP, Javascript, and MYSQL technologies.

The model allows you to solve optimization problems of varying complexity using various optimization methods such as linear programming, nonlinear programming, artificial intelligence methods, etc.

The model can be applied to solve optimization problems in various fields. In addition, the model allows you to solve optimization problems with a high degree of accuracy and in a short time, and also has a user-friendly interface that allows users to easily and quickly set optimization tasks.

The current optimization problems and forecasting problems are not covered in the work. How this will be implemented is not indicated in the resulting information model.

The relevance of scientific research – Every year farmers face the task of how to use the land. And they face many factors, including transportation costs, seed quality, cattle grazing and many other options for using the land. But using the simulation model or information system proposed by us, it is important to understand not only the actual use of the land, but also the economic profit. The system will indicate (advise) based on historical data as an expert, what kind of crop to plant so that there is maximum benefit. Agrotechnical indicators, allows you to create more accurate models and forecasts, which contributes to making informed decisions. Such a system allows farmers and agronomists to respond quickly to changing conditions, optimize land use and improve the efficiency of agricultural production in general.

An information model has been developed that will make it possible to predict the harvest taking into account data on weather, soil, crops and historical yield data, as well as optimize land use taking into account data on soil type, climate, crop rotation and financial indicators. The developed information model can improve the efficiency and sustainability of agricultural production. The model can be used by agronomists and farmers to make more informed decisions. The model takes into account data on soil type, climate, crop rotation and financial indicators to optimize land use.

Keywords: information model, optimization, PHP, Javascript, MYSQL, optimization tasks, logistics, production, economic profit.

ЖЕРДІ ПАЙДАЛАНУДЫ ОҢТАЙЛАНДЫРУ ЖӘНЕ АУЫЛ ШАРУАШЫЛЫҒЫ ӨНДІРІСІНДЕГІ ӨНІМДІЛІКТІ БОЛЖАУ ҮШІН ИНТЕГРАЦИЯЛАНҒАН АҚПАРАТТЫҚ МОДЕЛЬДІ ӘЗІРЛЕУ ЖӘНЕ ҚОЛДАНУ

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Жұмыста PHP бағдарламалау тілі, Javascript және MySQL дерекқорды басқару жүйесі арқылы жүзеге асырылатын жерді пайдалануды оңтайландыру және ауыл шаруашылығындағы егінді болжау үшін тұжырымдамалық ақпараттық модель әзірлеу ұсынылған. Модель логистика, өндіріс, қаржы және т.б. сияқты әртүрлі салалардағы оңтайландыру мәселелерін шешуге арналған.

Жұмыс аясында оңтайландыру мәселелерін шешуге арналған мәліметтер, алгоритмдер мен бағдарламалық модульдер жиынтығы болып табылатын ақпараттық модель жасалды. Модель PHP, Javascript, MySQL технологиялары негізінде жүзеге асырылады.

Модель сызықтық бағдарламалау, сызықтық емес бағдарламалау, Жасанды интеллект әдістері және т.б. сияқты әр түрлі оңтайландыру әдістерін қолдана отырып, әр түрлі күрделілікті оңтайландыру мәселелерін шешуге мүмкіндік береді.

Модельді әр түрлі салалардағы оңтайландыру мәселелерін шешу үшін қолдануға болады. Сонымен қатар, модель оңтайландыру мәселелерін жоғары дәлдікпен және қысқа мерзімде шешуге мүмкіндік береді, сонымен қатар, пайдаланушыларға оңтайландыру тапсырмаларын оңай және жылдам орнатуға мүмкіндік беретін ыңғайлы интерфейске ие. Модель жерді пайдалануды оңтайландыру үшін топырақ түрі, климат, ауыспалы егіс және қаржылық көрсеткіштер туралы деректерді ескереді.

Ауа райы, топырақ, дақылдар және тарихи кірістілік деректерін ескере отырып, егінді болжауға, сондай-ақ, топырақ түрі, климат, ауыспалы егіс және қаржылық көрсеткіштер туралы деректерді ескере отырып, жерді пайдалануды оңтайландыруға мүмкіндік беретін ақпараттық модель әзірленді. Әзірленген ақпараттық модель ауыл шаруашылығы өндірісінің тиімділігі мен тұрақтылығын арттыра алады. Модельді агрономдар мен фермерлер неғұрлым негізделген шешімдер қабылдау үшін қолдана алады

Түйін сөздер: ақпараттық модель, оңтайландыру, PHP, Javascript, MYSQL, оңтайландыру міндеттері, логистика, өндіріс, экономикалық пайда.

РАЗРАБОТКА И ПРИМЕНЕНИЕ ИНТЕГРИРОВАННОЙ ИНФОРМАЦИОННОЙ МОДЕЛИ ДЛЯ ОПТИМИЗАЦИИ ЗЕМЛЕПОЛЬЗОВАНИЯ И ПРОГНОЗИРОВАНИЯ УРОЖАЙНОСТИ В СЕЛЬСКОХОЗЯЙСТВЕННОМ ПРОИЗВОДСТВЕ

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В работе представлена разработка концептуальной информационной модели для оптимизации землепользования и прогнозирования урожая в сельском хозяйстве, реализованная с использованием языка про-

граммирования PHP, Javascript и системы управления базами данных MYSQL. Модель предназначена для решения задач оптимизации в различных областях, таких как логистика, производство, финансы и т.д.

В рамках работы была разработана информационная модель, которая представляет собой совокупность данных, алгоритмов и программных модулей, предназначенных для решения задач оптимизации. Модель реализована на базе технологий PHP, Javascript, MYSQL.

Модель позволяет решать задачи оптимизации различной сложности, используя различные методы оптимизации, такие как линейное программирование, нелинейное программирование, методы искусственного интеллекта и т.д.

Модель может быть применена для решения задач оптимизации в различных областях. Кроме этого, модель позволяет решать задачи оптимизации с высокой степенью точности и за короткое врем, а также имеет удобный интерфейс, который позволяет пользователям легко и быстро задавать задачи оптимизации. Модель учитывает данные о типе почвы, климате, севообороте и финансовых показателях для оптимизации использования земель.

Разработана информационная модель, которая позволит прогнозировать урожай с учетом данных о погоде, почве, посевах и исторических данных о урожайности, а также оптимизировать использование земель с учетом данных о типе почвы, климате, севообороте и финансовых показателях. Разработанная информационная модель может повысить эффективность и устойчивость сельскохозяйственного производства. Модель может быть использована агрономами и фермерами для принятия более обоснованных решений

Ключевые слова: информационная модель, оптимизация, PHP, Javascript, MYSQL, задачи оптимизации, логистика, производство, экономическая прибыль.

Introduction. Over the past twenty years, land conflicts among various land users have become more frequent. These conflicts have devastating consequences for society, including the loss of lives and the destruction of property [1].

One of the main reasons for these conflicts is ineffective planning and management of land resources. This can be caused by the use of unsuitable tools and technologies for managing land cadasters [2].

Information and communication technologies (ICT) can help solve this problem. ICT tools such as Land Information Systems (LIS) and Geographic Information Systems (GIS) can improve the planning and management of land resources, thereby reducing the number of land conflicts.

Another factor contributing to land conflicts is the inefficiency in providing land services. According to Mwaikambo and Hagai [3], this leads to delays in the registration of land rights and other problems.

The growth of the population and the increasing cost of land also exacerbate the issue of land conflicts. The demand for land exceeds supply, leading to disputes among various land users.

To address the problem of land conflicts, it is necessary to improve the planning and management of land resources. Using ICT tools for land cadaster management can create optimal conditions for enhancing the efficiency of land service provision, as well as addressing issues related to population growth and the rising cost of land.

Scientific novelty - For the first time an integrated model has been proposed that combines data from agro-climatic conditions, soil characteristics and agrotechnical measures for accurate forecasting of yields and optimal distribution of land resources. New algorithms and methods of big data processing have been developed, which can significantly improve the accuracy of forecasts and the efficiency of agricultural land use.

Undoubtedly, the issues discussed in this article are hypothetical, but it is necessary to keep in mind that with the help of a conceptual information model of land optimization and information flows, the needs reflecting all sides of farmers' professional activities can be identified. In our view, the basis of the conceptual information model for agronomists should primarily lie in the objective factors that influence the formation of their thematic structure.

These include the essence and tasks of the economic and social development of the country, as well as agricultural policy, which involves reorienting industry workers towards developing market relations, increasing responsibility, and direct interest in the rational use of production resources for necessary socio-economic transformations. It is important to link these general tasks with the specifics of a particular farm.

Information about the thematic structure of the agronomists' information model for decision-making will not be complete without studying the themes of needs of individual peasant farms, conditioned by their private interests, the nature and content of labor, specialization and area of crops, the presence of temporary types of activities (folk crafts and crafts), as well as the zonal characteristics of agricultural production.

To achieve success, a modern agronomist, as well as the head of a peasant farm, must not only know the organizational and technological processes of agricultural production but also be able to understand issues of industry business, financing and accounting, marketing, consumer demand, etc. For this, the most diverse information is needed, presented not only in traditional periodicals and books of various kinds but also in various automated information systems. Farmers, more than other categories of agricultural production workers, are interested in rapidly implementing the latest technologies in their farms. Information modeling of land optimization should include not only objective factors that affect their formation but also subjective factors, which, although auxiliary, are important for organizing the solution.

An information model is an abstract representation of information that describes its structure, connections, and interactions between elements. It can be used to optimize various processes, including logistics, production, and economic profit [4].

Optimization is the process of finding the best solution or setting parameters to achieve optimal results. In the context of the information model, optimization may include improving performance, reducing costs, or enhancing the efficiency of the system.

PHP, JavaScript, and MySQL. PHP is a programming language widely used for developing web applications. It allows for the creation of dynamic and interactive web pages [5, 6].

JavaScript is a programming language used to create interactive elements on web pages. It allows adding functionality, form validation, animation, and other capabilities to web pages.

MySQL is a database management system used for storing and managing data. It allows for the creation, modification, and retrieval of information from the database.

Optimization in logistics and production may involve solving the following tasks:

- Optimization of delivery routes: This task involves finding optimal routes for delivering goods with minimal time and fuel costs.

- Optimization of inventory and warehouse management: This task involves determining the optimal level of goods inventory at the warehouse to minimize storage costs and avoid product shortages.

- Optimization of production processes: This task involves finding the optimal production schedule to maximize resource use, reduce downtime, and increase productivity.

Economic profit is the difference between total revenues and total costs of a business. It is one of the main indicators of business efficiency and success. Profit can be achieved by increasing revenues, reducing costs, or a combination of both factors.

As technology advances, the accuracy and availability of information models will only increase, leading to improved efficiency in agricultural production and sustainable rural development.

Materials and methods. The main research methods included statistical methods, machine learning techniques, and data processing software, as well as data processing software such as Python, R, and MS Excel [7, 8, 9].

The processing and analysis of statistical data include: data collection; data cleaning; data transformation; data analysis; data visualization.

An information model based on statistical data is able to predict crop yields, which makes it possible to optimize the use of resources and reduce risks. Using the model, it is possible to increase profitability by implementing a project to increase profitability and environmental efficiency.

As technology advances, the accuracy and accessibility of these models will only increase, leading to increased agricultural production efficiency and increased sustainability.

Methods of processing and analyzing statistical data involve not only their collection, but also the study, processing and analysis. Like any research, working with an information model begins with defining the research problem and assessing its relevance [10].

Optimizing the use of resources. The model allows not only to predict the harvest, but also to optimize the use of resources such as water, fertilizers, pesticides, and labor resources. This helps to reduce costs, increase profitability and minimize the negative impact on the

environment.

Risk assessment. The model can help farmers assess the risks associated with weather conditions, diseases and pests, as well as price fluctuations in the market. This allows them to make more informed decisions about the management of their farms.

Planning and decision-making. The model can be used to develop long-term and short-term economic development plans. It can also help in making operational decisions, for example, about the timing of sowing, watering and harvesting.

Comparative analysis. The model allows you to compare productivity, profitability and other key indicators of different farms, regions or countries. This can help farmers identify best practices and improve their work efficiency.

In addition to the above, information models based on statistical data can be used for important activities and technological processes in agriculture.

Development of new varieties and hybrids of agricultural crops. Models can help breeders in the search for new varieties and hybrids with higher yields, resistance to diseases and pests, as well as other desirable traits.

Modeling of various scenarios. The models can be used to simulate various scenarios of the future, for example, climate change, changes in prices for agricultural products, and the introduction of new technologies. This allows farmers to be prepared for possible changes and plan their actions in advance.

Training and advising farmers. The models can be used to create training materials and farmer counseling programs. This will help them improve their knowledge and skills in using data to make better informed decisions.

In general, statistical-based information models are a valuable tool for improving the efficiency and sustainability of agricultural production.

The issues facing peasant farming include low productivity, inefficient resource use, high risks, and food security, which is clearly demonstrated in Figure 1.

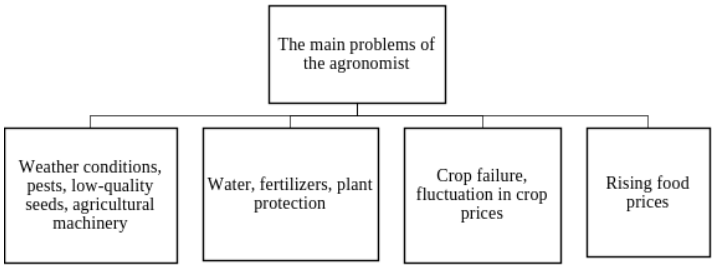

Figure 1 - The main problems of an agronomist (peasant economy)

All of the above factors influence the optimal use of land to build an information model.

The materials are based on statistical data on the state of agricultural lands on the example of the Ayyrtau district of the North Kazakhstan region.

Table 1 shows data on weather conditions during the sowing period, which shows the frequency of 15 days, which are divided into two columns, that is, the dates 01.05 - 15.05 and 16.05 - 30.05.

Table 1 - Statistical agrometeorological data for the last 5 years (data from the weather station of the village of Saumalkol in the Ayyrtau district of the North Kazakhstan region)

№	Indicators	2019		2020		2021		2022		2023	
		01.05-15.05	16.05-30.045	01.05-15.05	16.05-30.045	01.05-15.05	16.05-30.045	01.05-15.05	16.05-30.045	01.05-15.05	16.05-30.045
1	Temperature, 0C	12	13	18	20	21	22	20	17	17	20
2	Precipitation, мм	0,4	0,3	0,8	0	0	0,2	1	0	0,1	0
3	Air humidity, %	36	40	43,5	27,6	37,8	39	36	23	27	30
4	Wind speed, m/s	2,6	3	7,3	4,6	6,1	5,5	5,2	4	7	5,5

It is during these dates that crops such as wheat, barley, corn and alfalfa are actively sown in the area. We will not focus on any culture, but data is important to us for further decision-making of the information model. From Table 1, we see the average daily temperature, humidity, etc. for favorable sowing.

Table 2 - Statistical data on spring wheat crops in the Ayyrtau district of North Kazakhstan region over the past 5 years

№	Indicators	Sown area of spring wheat				
		2019	2020	2021	2022	2023
1	Date of sowing	05.05-15.05	05.05-25.05	10.05-15.05	05.05-20.05	05.05-20.05
2	Variety	Omsk 36 Akmola 2 Astana	Omsk 36 Shortandinskaya 95 improved	Omsk 36 Timas Asyl Sapa	Omsk 36 Akmola 2	Omsk 36 Virgin land 60
4	The area of sowing, thousand hectares	276,4	282,1	290,3	295,7	301,2

As we can see from Table 2, it takes a lot of time to process digital data. The analysis of the table leads to the fact that there are several varieties of spring wheat, and sowing proceeds in a chaotic, in our opinion, random, unpredictable way.

But, experts in the field of agriculture, from table 1, analyze and decide which variety to plant on a particular piece of land. Managing such a complex process as farming, a decision that will lead to considerable losses and losses, pushes us to develop an information model for optimizing both costs and land use. Given the amount of information for processing the model, we will divide it into subsystems: crop programming and land optimization.

If the same crop is grown in the same field for many years in a row, the harvest will get worse every year. In addition, plants will be overcome by diseases and pests, and the soil will be depleted. Crop rotation of crops involves the alternation of plants, and it is necessary to alternate competently.

The information model of crop planning takes into account data on weather, soil, crops and historical yield data, which allows us to visually see the result in the form of yield values in tons [11, 12]. The general type of information flows is considered on the example of a farm, in other cases, information flows occur according to the same principle. A preview is shown in Figure 2.

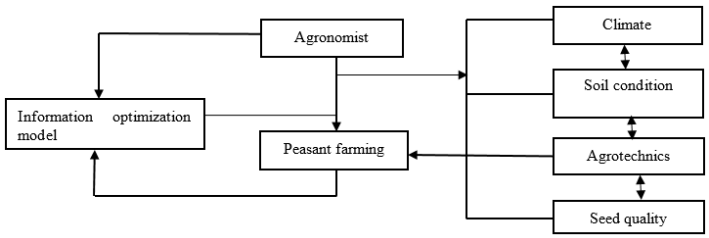

Figure 2 - General view of information flows

When developing an information model for optimizing agricultural land, it is possible to identify the main factors affecting the efficiency and economic profit of each site. 10 tables have been developed that provide information on the storage of crop data, soil and climatic indicators. The Laravel framework and Composer package manager are used to develop the server part of the program, while the React library and npm package manager are used for the client part of the program.

INSERT INTO Area (areaid, userid, arename, area) VALUES (NULL, '1', '111', '101');

INSERT INTO User (userid, username, email,

password) VALUES (NULL, 'Assemgul', 'qwerty').

Cannolly and Begg (2005) define conceptual database design as the creation of an information model reflecting the activities of an enterprise. This model does not depend on technical details, but it is understandable to both end users and developers [13]. The authors emphasize that the conceptual design stage begins with the development of a conceptual data model that is completely separate from the implementation details. This means that the model does not depend on the target DBMS, application programs, programming languages, hardware platform, performance issues and other technical aspects [14]. The conceptual data model is documented using ER diagrams and a data dictionary. Figure 3 shows an ER diagram of the LIS database data, which shows entities, attributes, and relationships.

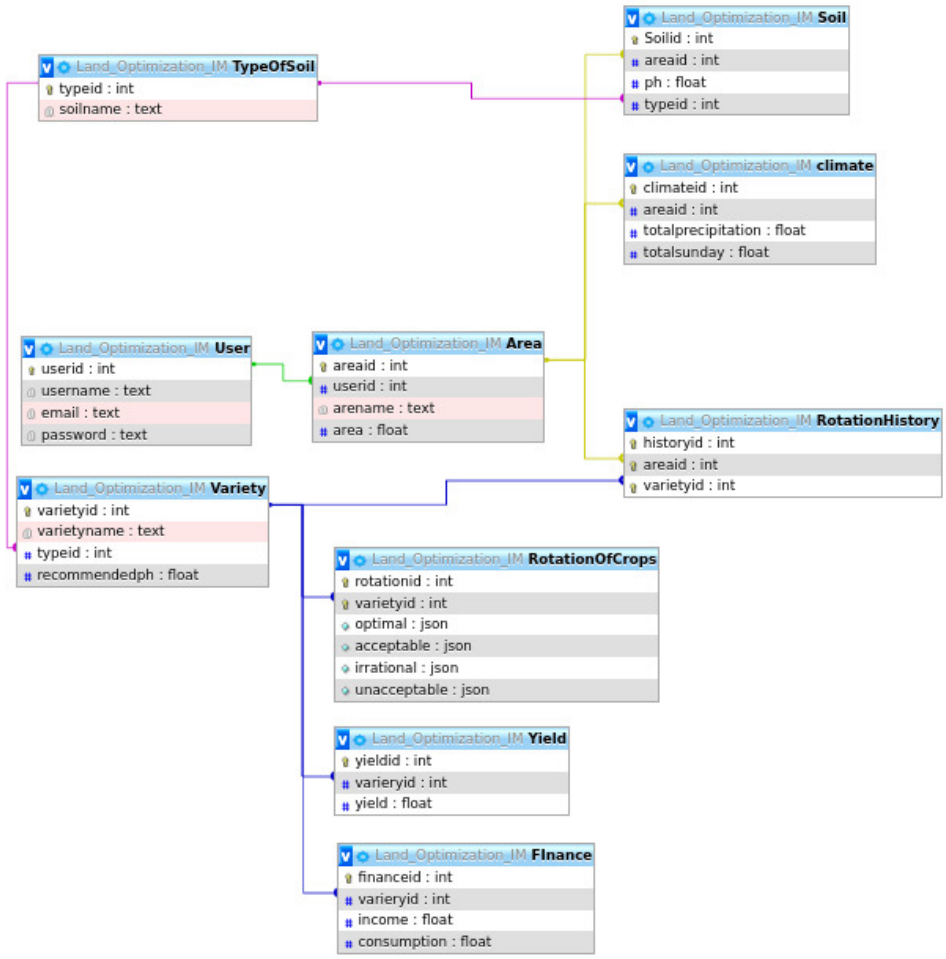

Figure 3 - LIS database schema

Figure 3 illustrates the relationships between the tables of the system. The research presented in the paper was aimed at studying user requirements and developing the architecture of the proposed Land management Information System (LIS). The study presents two contributions. Firstly, the identified user requirements will help LIS developers create systems that meet the real needs of users described in [15, 16].

Secondly, the paper presents the architecture of the proposed LIS, which includes two main components: a component of land use allocation and an assessment component. These components provide storage and extraction of land use information, as well as storage, extraction and analysis of estimated information. The purpose of the system is to improve the efficiency and effectiveness of land management in the districts of Tanzania. This is achieved by providing decision

makers with accurate data necessary for their work.

Accurate information and proper valuation of land plots, in turn, contribute to improving revenue collection. After defining the architecture of the platform and the rules of the association, it was necessary to develop the software part of the web platform. The paper presents the implementation of server rules in the Drools engine.

The server consists of three main components:

An application for registering data from external sensors in the system. Devices or applications register as data sources by sending information via a socket to the middleware. This software prepares data according to the type of sensor.

2. The Drools rules module is the core of the server. It accepts the prepared data, applies rules to it, and generates events.

3. Data warehouse – a database that stores all the data used by the system.

The development of a model that helps to use the land correctly takes into account a number of factors. The materials are based on statistical data on the state of the designated lands on the example of the Ayyrtau district of the North Kazakhstan region. Continuous cultivation of one crop in the same field leads to a decrease in yield, diseases and pests, and soil depletion. Therefore, it is necessary to use crop rotation, with the correct alternation of crops. The information model of crop planning takes into account data on climate, soil, vegetation and other factors.

Results and discussion. The presented system is a web application developed in the PHP language. It is designed to optimize agricultural activities by collecting and analyzing data.

Figure 4 shows the structure of the database that is used in the system. It contains information about weather conditions affecting agriculture, the types of crops that can be grown in specific conditions, and the financial situation of agricultural enterprises.

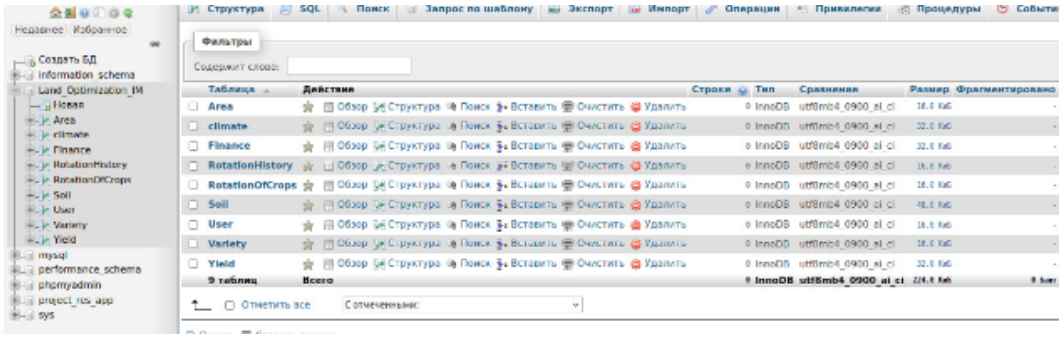

Figure 4 - Sql database

The use of an optimization system makes it possible to increase the efficiency of agricultural production, reduce the risks associated with weather conditions and other factors, as well as increase the profits of agricultural enterprises.

The presented system is a valuable tool for optimizing agriculture. It allows farmers to make more informed decisions, which leads to increased efficiency and profitability of their activities.

In general, the proposed information model will make it possible to soberly assess the potential of agricultural lands, determine the optimal land use options, and possibly increase the efficiency of agricultural production. When developing the information model, such factors as climate, land suitability, soil condition, legal and economic aspects of the land were used. The statistical data used in the information model over the past 5 years are mathematical in nature, which is easy to calculate using mathematical methods.

After authenticating on the site and sending a request to the server. The server calculates which cultures are similar to the sites of our user and outputs them to the client side. According to the results of testing the information model of the system, the following results were recorded.

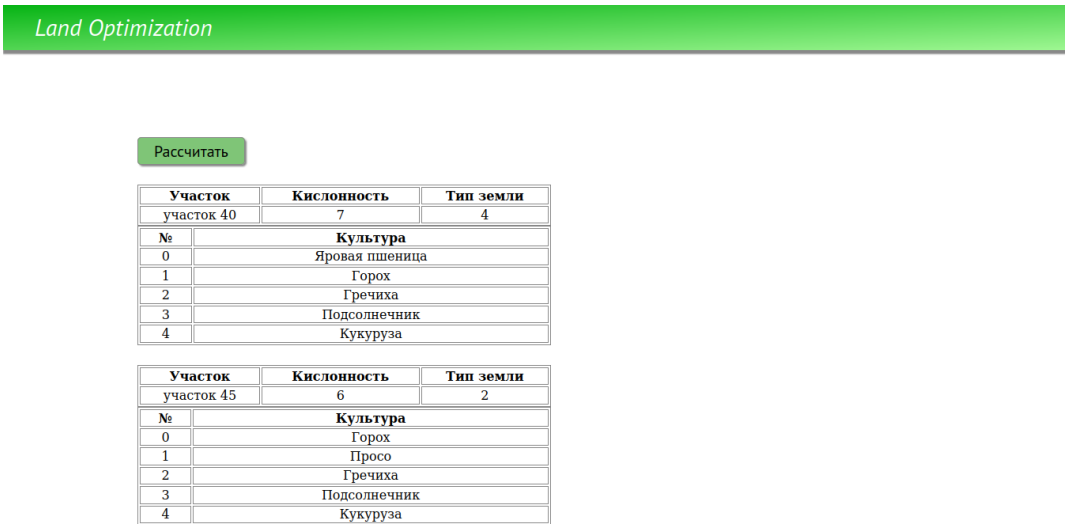

Figure 5 - Scenario on the level of restrictions on sowing

The proposed system is a revolutionary tool that radically simplifies the tasks of land use and assessment. It provides reliable and secure storage for working with huge amounts of land data in real time.

The system's compliance with all of the above criteria, as well as the use of open data on agricultural land and the possibility of involving agricultural experts in the development of the model, open up wide opportunities for further research. This will allow the model to be integrated with other information systems, which will lead to the creation of an even more powerful and versatile tool.

One of the key advantages of the system is its ability to generate graphs and diagrams that clearly demonstrate the dynamics of yields, costs and revenues. This allows users to easily track changes in key indicators and make informed decisions based on reliable data.

The implementation of the proposed system can have far-reaching consequences for various sectors of the economy, including agriculture: increasing yields, optimizing resource use, reducing production costs; forestry: optimizing logging, preserving forest resources; real estate: more accurate assessment of land value, improving the efficiency of land asset management; environmental protection: combating land degradation, conservation of biodiversity.

Thus, the proposed system is a powerful tool that can significantly improve the efficiency of land management and contribute to the sustainable development of the economy.

The implementation of the model is the launch of pilot projects in different agro–climatic zones to test and adapt the system. Organizing training for farmers and agronomists on the use of the system and collecting feedback to improve it. Organizing training for farmers and agronomists on the use of the system and collecting feedback to improve it.

This approach will ensure the integrated and rational use of land resources, increasing their productivity and sustainability of agricultural production.

Conclusion. In the course of our research, an information model on crop rotation and crop optimization was developed for further information processing and machine learning. Databases and the use of SQL queries will make it easier to find the information that the farmer needs. The developed web service, which uses the Django tool, can download data and receive data processing if necessary. As a result, an algorithm of agronomic farming was developed, which contains all the information necessary for its management. But the result of the study was a model that would make a decision when using land, and the best option for its use. We believe that the developed information model of crop rotation and crop optimization has great potential for improving the efficiency of agronomic farming and ensuring food security.

This optimization model is implemented as a web service, which makes it accessible to a wide range of users. It can be supplemented with modules for crop forecasting, risk assessment, and inventory management. In addition, the information model can

be integrated with agricultural enterprise management systems, meteorological services, and must also be adapted to the climatic, soil and economic conditions of specific regions.

The development of information systems to support decision-making in agronomic farming is an urgent task of great importance for ensuring food security. The proposed information model represents the first and most general thematic expression of one of the current areas of activity of automation of agricultural structures by software of the appropriate level when making a decision. The model can be used by farmers to increase the profitability of their farms and optimize the use of resources.

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