Applied Digitalization in Soybean Production

Dautkanov Nurlan Buratovich [1], Dautkanova Dina Rakymkulkyzy [2], Ussembayeva Zhibek Kalievna [3], Kazhymurat Assemay Talgatqyzy [4]

[1] LLP "Kazakh Research Institute of Processing and Food Industry", Almaty, Republic of Kazakhstan. Email: ndautkhanov@gmail.com
[2] LLP "Kazakh Research Institute of Processing and Food Industry", Almaty, Republic of Kazakhstan. Email: dida09@yandex.ru
[3] LLP "Kazakh Research Institute of Processing and Food Industry", Almaty, Republic of Kazakhstan. Email: zh8886707@gmail.com
[4] LLP "Kazakh Research Institute of Processing and Food Industry", Almaty, Republic of Kazakhstan. Email:assemaykazhymurat@gmai.com

KEYWORDS
AI, digitalization, CMM, SPI.

ABSTRACT
There are many sectors of the economy where the use of AI and other digital activity methods is necessary due to the territorial scale and cost of using human participation, this is agriculture, namely crop production. In particular, the production of soybeans for further industrial processing into food ingredients. The widespread use of AI requires the creation of a regulatory framework and its harmonization with existing industry standards. The longest period of full-scale implementation of AI is expected in agriculture, where all processes are long in time and large-scale in territory. If at the stages of industrial processing the use of digital technologies and artificial intelligence is not difficult due to the compactness and intensification of technological processes, then the cultivation of raw materials, harvesting, transportation and storage require a different approach to digitalization.

Considering the stages of soybean cultivation on large areas for monitoring agrotechnical measures, two experimental prototypes of the control mast equipped with video recording devices, thermometers, anemometer, autonomous power supply system, communication channel, lightning rod were used. This completeness of the pilot project is basic, which will be improved in the process of scaling and operation of interested parties. The purpose of the test was to identify the optimal characteristics of the technical equipment for determining the maximum distance of data transmission without distortion, as well as testing control mechanisms throughout the growing season of soybeans for analyzing information flows. A remote-control system for soybean cultivation was created, including a control and measuring mast (CMM). The purpose of the control system for traceability of the quality of soybeans intended for the production of soy protein isolate. Also, monitoring of soybean varieties included in the State Register of Breeding Achievements was conducted, where 64 soybean varieties are registered that are recommended for cultivation in the regions of the country, as well as the predicted gross yields of soybeans.

1. Introduction

With the development of modern information systems and Internet technologies, there is a steady discussion trend among scientists in various sectors of the economy and science about the implementation and development of artificial intelligence (AI) in technological and business processes. Undoubtedly, the use of AI brings significant benefits in many areas of activity, even scientific research and publications are no exception. However, there are many sectors of the economy where the use of AI and other methods of digital activity is necessary due to the territorial scale and cost of using human participation - this is agriculture, namely crop production. In particular, the production of soybeans for further industrial processing into food ingredients. Raushan Gabdualiyeva and a group of researchers [2] note that in order to increase the efficiency of digitalization and modernize the information infrastructure of the agro-industrial complex, the following factors are necessary:

1. Ensuring widespread access to the Internet, automation of production processes, robotics, artificial intelligence, exchange of "big data", etc.
2. Developing the digital competence of farmers and the agro-industrial complex, identifying the need for specialists, providing training and retraining in specialized educational programs using the best world experience in higher educational institutions of the agricultural sector.

3. Adapting production to climate change for the purpose of conscious management of agricultural risks and increasing the productivity of agricultural crops and livestock.
4. Searching for new mechanisms and forms of public-private partnerships to scale up agribusiness.

Despite the obvious benefits of digitalization and the practical application of AI, not all sectors are covered by these technologies, and challenges arise in agriculture, especially in small farms. In their work, Challenges in Implementing AI Technology Smart Farming in Agricultural Sector, Anusha S. Rai A. and R. Srinivasa Rao Kunte [3] focused their model on small and medium farmers. They report that AI tools and machine learning (ML) are making a significant contribution to the agricultural sector. Many tools help farmers find various reports such as machinery, weather forecast, soil culture, etc. However, referring to various journals, articles, and papers, it can be seen that these tools do not reach the end users, i.e. farmers. Methods

This work used field and analytical research methods, extrapolated the conclusions from the review of the studied material from available sources, and also used empirical methods in the form of experiments and observations. Consultations in related sectors of the economy and types of economic activity, as well as radio engineers and IT specialists, were essential.

2. Goal, Objectives

Against the background of numerous publications on the need for digitalization and the use of artificial intelligence in agriculture, research materials on the use of practical tools and mechanisms are rare. For the food industry, the most important aspect is the quality indicators of commercial products along the entire supply chain from the production of seed material, processing of grown raw materials and its transformation into a food product.

Tests of the control and measuring mast (CMM) were carried out to identify critical points in the quality traceability system along the entire supply chain in the production of soy protein isolate at Agritec LLC. For this purpose, monitoring of soybean varieties included in the State Register of Breeding Achievements was carried out, where 64 soybean varieties are registered. Figure 2 shows the varieties (description of characteristics in the source) that the originators recommend for their cultivation in the regions of the country, as well as the predicted gross yields.

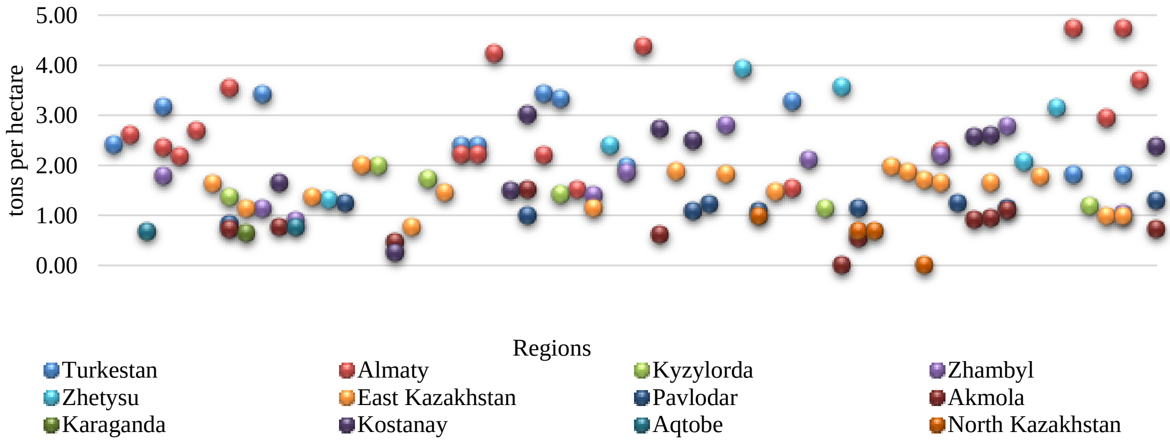

Fig. 1 Yield diagram of soybean varieties recommended by originators by regions of Kazakhstan, tons per hectare [4]

Expectedly high yield rates were demonstrated in the southern and southeastern regions of Kazakhstan. The highest gross rates were in the following regions: Almaty, Turkestan, Zhetysu, where the maximum yield reached 3.92 tons per hectare. In the northern, eastern and central regions of the country, the lowest rates, with rare exceptions in the Kostanay region. Climate features, as well as the intensity of land use, affected this. The distance between the northernmost, eastern and southern regions of soybean cultivation reaches 1.6-2.1 thousand kilometers, it is possible to select the most effective varieties and scale them up to industrial volumes by improving agricultural technology, increasing sown areas and restructuring crop rotation. The highest yield in the northern regions was in the Kostanay region, the largest grain-growing region.

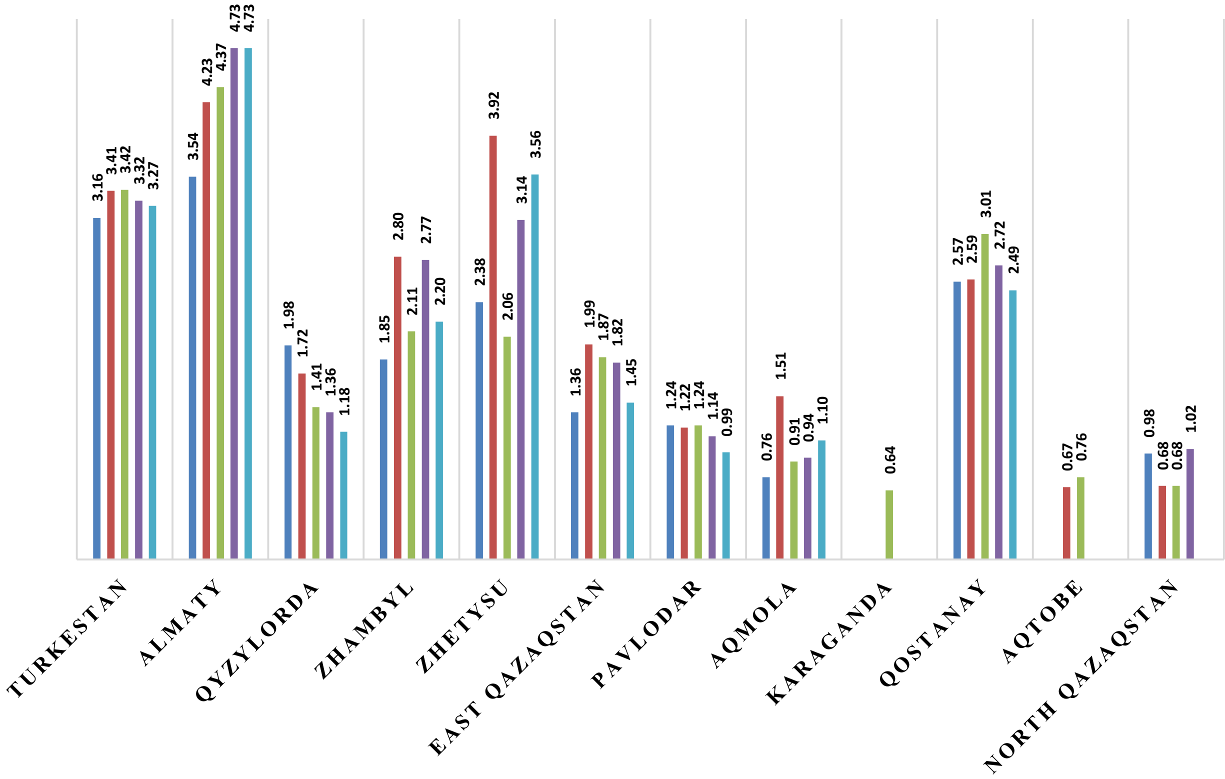

Fig.2 Maximum yield values of varieties by regions of Kazakhstan, tons per hectare [4]

Kostanay region has a sharply continental climate, however, due to the availability of water resources and soil structure, more than two tons were harvested from one hectare.

After scaling the project using a control and measuring mast, an information base will be formed that will allow making analytical conclusions on the selection of the most optimal soybean varieties for cultivation to commercial conditions for processing purposes, at the first stage this is the production of "white petal" with associated derivatives, then enzymatic hydrolysis and isolation of S.P.I. this is the practical part of the application of digitalization in terms of industrial processing of soybeans for food purposes.

To scale the developed SMM system, in the future, it is planned to form a varietal map of soybeans in Kazakhstan, which will be included in the structure of a three-five-field crop rotation, since this legume is the best predecessor of grain, oilseeds and forage crops, enriching the soil with nitrogen. The atmosphere is 78 percent nitrogen in the form of gas. But most plants cannot use this form. However, legumes can convert atmospheric nitrogen into a form they can use. This conversion process is actually a mutual effort called symbiotic nitrogen fixation [5].

3. Results and Discussion

In Kazakhstan, work is also underway to digitalize the agricultural market, with the dairy industry being considered as an example. Yerbol Akhmedyarov in his article explored the possibility of solving the problems of the dairy industry in Kazakhstan by creating information platforms and technological re-equipment with organizational, legal and financial support from the state. It is substantiated that the integrated use of digital technologies in the agricultural market of Kazakhstan along the entire chain of product distribution from raw milk to sale to the end consumer will help reduce costs, improve the quality of milk and dairy products, labor productivity, and transform the industry's personnel. [6].

In the work "Artificial Intelligence for Digital Agriculture at Large: Methods, Policies, and Challenges" Somali Chaterji, Nathan D. DeLay from Colorado State University and others found that understanding how agricultural technologies and big data can improve farm productivity could significantly increase global food production by 2050 in the face of limited arable land and declining water levels. Little is known about the economic costs and benefits of these new systems. For example, if an algorithm requires combining data from multiple data owners, this raises questions about data ownership [7].

The closest material to our research in terms of the application of artificial intelligence in agriculture is by Parinita Das and Kaushik Saha, who review the applications of AI and highlight the following: there are computer vision and machine learning techniques to detect plant diseases and deficiencies, recognize weeds, which helps in spraying only those parts of the land where plants are infected with diseases or where weeds are present, and not the entire field. The use of AI in agriculture helps in developing agricultural practices that can increase crop yields and reduce the previously identified problems [8].

In terms of understanding the potential applications of artificial intelligence in the agricultural sector, Mohd Javaid et al. in their study say that AI-based solutions will help farmers produce more with less resources, improve crop quality, and speed up the time to market. AI helps in understanding the properties of the soil. AI can help farmers choose the optimal time to plant seeds. Hyperspectral imaging and 3D laser scanning are leading AI-based technologies that can help ensure crop health. These AI-based technologies collect accurate data on crop health in larger volumes for analysis [9].

Tanha Talavia from the Department of Computer Engineering, Indus University, Ahmedabad, Gujarat, India [10] says productivity can be increased with the help of technology and thus these problems can be solved. It can be improved with the help of various AI-driven techniques such as remote sensors to detect soil moisture content and automated irrigation using GPS. The problem that farmers faced was that precision weeding techniques overcome the high yield loss during the weeding process. These autonomous robots not only increase efficiency, they also reduce the need for unnecessary pesticides and herbicides.

Studying the challenges of implementing AI technologies, Anusha S. Rai A. and R. Srinivasa Rao Kunte [11] focused their model on small and medium farmers and reported that AI and ML tools are making a significant contribution to the agriculture sector. Many tools help farmers to find various reports such as machinery, weather forecast, soil culture, etc. However, referring to various magazines, articles and documents, it can be seen that these tools do not reach the end users, i.e. farmers.

For the production of soy protein isolates (SPI) for food purposes, special methods are used for selecting seed material and processing beans to obtain high-quality raw materials "white petal" for extracting the isolate.

Observing all the measures prescribed by modern agricultural technologies, the collected soybeans are passed through photoseparators for better separation of raw materials. If at the stages of industrial processing the use of digital technologies and artificial intelligence is not difficult due to the compactness and intensification of technological processes, then the cultivation of raw materials, harvesting, transportation and storage require a different approach to digitalization.

Considering the stages of soybean cultivation on large areas, two experimental prototypes of a control mast equipped with video recording devices, thermometers, anemometer, autonomous power supply system, communication channel, lightning rod were used to control agrotechnical measures.

From the entire supply chain of SPI production, we selected the most difficult link in terms of traceability - soybean cultivation. It is in this area that the morphological structure of the beans is formed, which will be processed for maximum SPI extraction, and the quality of the raw material is very important in this aspect. Table 1 lists the main elements of the pilot control and measuring mast (CMM).

Table 1. Technical characteristics of one control and measuring mast

Name	Functionality	Completeness, notes
Autonomous power supply system	Ensuring uninterrupted power supply	Solar panel, 12 Volt battery, controller, vertical wind generator included, power cables, power source switching relay
Communication channel	Data transmission	GSM modem, wi-fi router (5 GHz)
Weather node	Measuring temperature, wind speed	Thermometers 3 units, anemometer, humidity sensor
Video cameras	Visual control	Panoramic video cameras 2 units at least 30x zoom, 16-channel IP video recorder
Mast	Support system for measuring instruments	Metal mast in a concrete base
Information center	Collection, processing of information	Computer, digital algorithm (due to lack of software)
Lightning rod	Grounding of lightning atmospheric discharge	Metal lightning rod, insulated brackets, grounding cable
Quadcopter	Operational control	Drone with a video camera

This pilot project complete set is basic, which will be improved in the process of scaling and operation of interested parties. Below are the details of the main CMM units:

1. Autonomous power supply system. This is the main unit for continuous monitoring of agro-technological processes, in this version (in the pilot project) the most expensive.
2. Communication channel. A standard GSM modem of a mobile operator and a router with a data transmission capacity of no more than 1.5 kilometers were used, since longer distances give a blurry image.
3. Weather unit. The importance of measuring temperature during the entire growing season was taken into account, a decision was made to install thermometers at three levels: in the soil at a depth of 10 cm, 50 cm from the surface, 150 cm from the soil surface. The anemometer was installed at a level of 200 cm from the soil surface.
4. Video cameras. Given the variability of weather conditions, and after consultations with operators of open-air video surveillance systems, panoramic video cameras were installed at a height of 300 cm from the ground on a mast.
5. Mast. A metal pole 400 cm high in a round cross-section, with a diameter of 18 cm at the base and 12 cm at the top, and a metal thickness of 1.5 mm. It was installed in a concrete cup, which was buried 70 cm deep.
6. Information center. This is a conditional name for a pilot project; a laptop and a self-developed algorithm were used here, which are quite suitable for testing. A full-fledged information center was planned after scaling the project and developing special software.
7. Lightning rod. Due to the fact that the vertical wind generator is installed at the very top of the mast, the lightning rod was attached to it through a Z-shaped bracket.
8. Quadcopter. A regular drone with a video camera was used to practice force majeure procedures.

These control and measuring masts were tested on the territory of a private farm in the Almaty region in the autumn period in areas not used for sowing purposes. The purpose of the test was to identify the optimal characteristics of the technical equipment for determining the maximum distance of data transmission without distortion, as well as to develop control mechanisms throughout the soybean growing season for analyzing information flows.

The SMM tests showed the following results:

1. The height of the mast provides greater panoramic coverage, but installing a video camera at a height of 300 cm does not allow one to assess the germination of soybeans at the early stages of vegetation using photo/video data.
2. The metal mast material distorts thermometer readings due to its heating in sunny weather.
3. A tent-type bird protection must be installed on a vertical wind turbine.
4. In foggy and rainy weather, the characteristics of the video series deteriorate, and at a certain angle of incidence of light (from the sun), the picture is overexposed.
5. The optimal distance for monitoring the germination and further growth of soybeans to harvesting conditions is no further than 800-950 meters.
6. The communication channel with the GSM modem and wi-fi router (5 GHz) provided a stable connection, the characteristics corresponded to the declared parameters of the equipment supplier.
7. Quadcopter. It demonstrated its effectiveness in the operational plan, but the sample used had weak flight characteristics.
8. The weather node, assembled from different suppliers, functioned correctly, but will be replaced with a compact weather station.

The pilot CMM functioned according to expectations, some aspects of the technical plan were identified, which will be taken into account when scaling the project. For example, the metal mast itself will be replaced with a concrete one, an operator center in a container design will be created.

4. Conclusions

This system for determining key parameters worked within the forecast and expectations. Collection and processing of information on the developed algorithm made it possible to formulate a technical task for the development of special software. To continue the trend of implementing AI, these studies represent an applied base for new research.

All statements on this topic are undoubtedly important and relevant, but the general digitalization of processes, things, phenomena and technologies has another side of the coin, reducing the participation of an industry specialist to the level of an operator of information systems, machines and units. Agriculture and its numerous workers will become not a subject of agribusiness, but a resource in project aggregation. Against the background of a growing population of people, digitalization, AI, the Internet of Things and other technologies will free up more than half of the working population of the planet.

With regard to AI, at the moment, its capabilities are somewhat overestimated, the successes of this direction are due to constantly improving operating systems. A significant breakthrough in AI is expected with the development of quantum computers and other systems of the future.

Acknowledgments:

This research work was carried out on the territory of a private farm in the Almaty region in the autumn period within the framework of the scientific and technical program of the IRN BR22883587 "Improvement and development of science-intensive technologies for deep processing of agricultural raw materials to strengthen food security of the Republic of Kazakhstan" for 2024-2026.

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