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Integration of digital technologies to improve the efficiency of small and medium-sized agricultural enterprises

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Abstract. The purpose of the study was to assess the impact of the introduction of digital technologies on improving the efficiency of small and medium-sized agricultural enterprises in Kazakhstan. To achieve this goal, a set of methods was used, including statistical analysis, a comparative method, and content analysis of respondents' answers through questionnaires. The study results showed that the integration of digital solutions has significantly reduced management and production costs, reducing

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them by 12%. The introduction of digital technologies has helped to increase crop yields by 15% and improve the efficiency of agricultural production. In addition, digitalisation has reduced the time required to make managerial decisions by 20%, which has increased the efficiency of management processes. The use of ERP/CRM systems, agrotechnological platforms and business process automation positively correlated with increased profitability, with correlation coefficients of 0.45, 0.38 and 0.52, respectively, which is statistically significant (significance levels 0.01, 0.05, and 0.02). The ERP system ($r = 0.62$, p -value = 0.01) showed a particularly high correlation with energy efficiency, while automation ($r = 0.55$, p -value = 0.02) and agroanalysis ($r = 0.47$, p -value = 0.03) also made a significant contribution. Analysis of variance showed a statistically significant difference in profitability between enterprises that implement digital technologies (F-statistics 5.62, p -value 0.01) and those that do not use them (F-statistics 2.34, p -value 0.05). This confirmed the importance of digital transformation for improving business financial results. Thus, digital technologies significantly increase the efficiency and competitiveness of agricultural enterprises, which is confirmed by both quantitative and qualitative findings

Keywords: competitiveness; costs; yield; management processes; agrotechnological platforms; automation

INTRODUCTION

The modern agricultural sector is undergoing significant changes under the influence of digitalisation and the introduction of intelligent technologies, which significantly change approaches to managing production processes. The development of data monitoring and analysis technologies opens up new opportunities to increase productivity, reduce costs, and minimise risks associated with natural factors and market uncertainty (Martín & de la Fuente, 2022; Ammann *et al.*, 2022).

In the agricultural sector, the issue of improving the efficiency of small and medium-sized agricultural enterprises is relevant, especially given the global challenges of economic instability, climate change, and growing competition in international markets. Given limited resources and insufficient access to modern technologies, small and medium-sized farms often face difficulties in increasing productivity and ensuring sustainable growth. In response to these challenges, numerous studies highlight the importance of integrating digital technologies such as the Internet of Things (IoT), big data, cloud services, and automated management systems. Thus, P. Katsikouli *et al.* (2020) and R. Finger (2023) demonstrate that implementation of digital solutions can help to optimise production processes, increase yields, and minimise resource costs.

Research by P.V. Méndez-Zambrano *et al.* (2023) points to the successful experience of using intelligent sensors and data analytics to track soil condition, humidity levels, and weather forecasting, which contributes to timely management decision-making. However, most research focuses on large agricultural corporations that have significant financial capabilities, while the capabilities of small businesses remain poorly understood. Research conducted by A. Upadhyaya *et al.* (2021) draws attention to the fact that successful digitalisation of small agricultural farms requires state support that would contribute to the development of appropriate infrastructure, and the financing of technological solutions. In addition, it is particularly important for small businesses to have training programmes

that help to develop employees' digital skills. In particular, J. Trenkle (2020) notes that without proper training of personnel, effective implementation of modern digital tools in small farms is unlikely. In addition to these researchers, other studies also reveal important aspects of digitalisation in agriculture. In particular, the study by F. Saruchera and S. Mpunzi (2023) highlights the importance of precision farming based on innovative approaches to collecting and analysing plant health data. The researchers note that precision farming can significantly reduce the cost of fertilisers and water, and optimise agrotechnical processes, which directly increases the profitability of farms (Rehman *et al.*, 2018; Tandon *et al.*, 2020).

E. Ndhlovu and K. Dube (2023) also focus on the impact of climate monitoring technologies and weather forecasting systems. They found that due to the use of these systems, agricultural enterprises can more effectively plan the periods of sowing, harvesting, and carrying out protective treatments. However, the researchers note that such systems require stable access to the Internet and state support to ensure their distribution in remote areas. S. Rolandi *et al.* (2021) highlights the need to integrate digital solutions with sustainability strategies. The researcher notes that digital technologies can become an effective tool for reducing the impact of agriculture on the environment, for example, by reducing greenhouse gas emissions and saving natural resources. D.C. Rose *et al.* (2020) points out the lack of sufficient research on the impact of digitalisation on small producers, especially in developing countries. There are papers that emphasise the importance of an interdisciplinary approach to digitalisation of agriculture. Thus, V. Saiz-Rubio and F. Rovira-Más (2020) note that the involvement of specialists from various fields, such as agronomy, ecology, information technology and economics, is important for the integrated implementation of technologies. The researchers suggest that such interdisciplinary teams can help to develop digital solutions tailored to the

needs of different types of agricultural enterprises, regardless of their size.

A review of modern sources showed that although digitalisation of the agricultural sector as a whole is a promising area for improving production efficiency, there are significant gaps in the coverage of small and medium-sized agricultural enterprises. The purpose of this study was to determine the impact of the introduction of digital technologies on the efficiency and productivity of small and medium-sized agricultural enterprises in Kazakhstan. The research was aimed at filling existing gaps in the scientific substantiation of digital solutions for small agricultural farms and can serve as a basis for developing practical recommendations that will help small and medium-sized enterprises to gain access to modern technologies and increase their competitiveness in the market.

MATERIALS AND METHODS

The study was conducted in the period from 2021 to 2023 in Kazakhstan at 50 small and medium-sized agricultural enterprises engaged in the cultivation of agricultural crops. To conduct the study, a sample consisting of entrepreneurs and managers of small and medium-sized selected agricultural enterprises in Kazakhstan was formed based on criteria that provide experience in using digital technologies in production processes and business management. Respondents were selected from different regions of Kazakhstan to ensure representativeness. Since the study involved the use of mobile applications to collect information, respondents were selected from among those who actively use platforms such as Facebook Messenger, Telegram, Viber, and WhatsApp. 1000 invitations were sent, of which 870 people confirmed their participation in the study. All study participants were warned about the purpose of the study, its methods, and the possibility of refusing to participate at any time. Before participating in the survey, respondents confirmed their consent to the processing of the information provided. Anonymity and confidentiality of participants' data were preserved. All personal data was used only in the framework of this study and will not be disclosed without the consent of respondents.

Data was collected using a structured questionnaire developed through the Google Forms platform. The questionnaire contained closed and open questions related to such aspects as types of digital technologies, results achieved (reducing costs, increasing crop yields and enterprise efficiency, reducing time for making managerial decisions, etc.), and difficulties faced by enterprises. The questionnaires were sent via mobile applications (Facebook Messenger, Telegram, Viber, WhatsApp), which provides access to a wide audience. First of all, economic indicators before and after the introduction of digital technologies were compared, which allowed assessing changes in such aspects as

productivity, production costs, revenues and other important performance indicators. Additionally, the economic feasibility of introducing digital technologies at small and medium-sized agricultural enterprises was assessed. The assessment was carried out by analysing respondents' responses to questions related to cost reduction, improving management processes, and optimising resource use. An important aspect of the analysis was to identify factors that contribute to or hinder the effective implementation of digital solutions in small and medium-sized businesses. A separate content analysis of respondents' responses to open-ended questions was carried out, which allowed investigating their attitude to digital technologies in more detail.

To assess the relationship between the use of digital technologies and the financial performance of enterprises, a t-test was used to compare the average values between two groups of enterprises: those that use digital technologies and those that do not use them. Variance analysis (ANOVA) was used to determine statistically significant differences between groups of enterprises depending on the level of digital integration (low, medium, high). The significance level (p -value) reflects the probability that the results obtained may be random, and determines their statistical significance. This study used significance levels of 0.01, 0.02, and 0.05, which correspond to varying degrees of confidence in the reliability of the results. In particular, a value of $p < 0.01$ indicated a very low probability of randomness of the result, $p < 0.02$ confirmed a sufficiently high confidence, and $p < 0.05$ was the standard threshold indicating an acceptable probability of significance. All the analysed results in this study corresponded to the specified levels, which allowed considering them reliable. The authors adhered to the principles of the American Sociological Association's Code of Ethic (1997).

RESULTS

As a result of the study of the trend in the use of digital technologies among selected small and medium-sized agricultural enterprises, which are important for achieving greater efficiency and competitiveness in the agricultural sector, it was determined that enterprise resource planning (ERP) and customer relationship management (CRM) systems are used in 35% of enterprises. These are the most common digital technologies among respondents, which indicates the need for agricultural enterprises to increase the efficiency of resource management and improve customer interaction. Such systems help to centralise information, improve operations management, and facilitate informed decision-making, which is important for small businesses with limited resources.

Digital solutions for automating business processes are used by 26% of enterprises, which is an important step to optimise daily operations. Automation allows reducing the time required to complete routine tasks,

increasing productivity, and reducing the human factor in business processes (Gulaliyev *et al.*, 2023). Enterprises that use automation can improve internal processes, which is especially important for small agricultural enterprises with a limited staff. Agrotechnological platforms are used by 23% of enterprises and help farmers to plan sowing and harvesting operations, optimise the use of resources, and monitor the state of crops in real time (Potryvaieva *et al.*, 2024). This indicates that agrotechnological platforms are gradually being integrated into the agricultural sector, although they are not yet widespread, due to a lack of access to high-tech equipment or a lack of understanding of the benefits of digitalisation. Only 15% of the selected enterprises actively use platforms for agricultural analytics, which involves analysing data on yield, weather conditions, soil condition, and other factors that affect agricultural production. This indicates limited access of small and medium-sized enterprises to such analytical tools, or a lack of awareness of their capabilities. Analytics in the agricultural sector helps to optimise the use of resources and make informed decisions, which is key to increasing yields and reducing costs (Fig. 1).

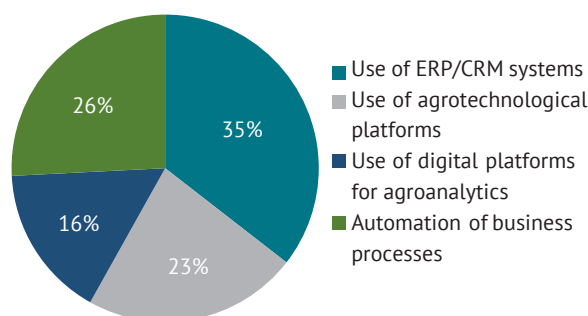


Figure 1. Use of digital technologies in small and medium-sized agricultural enterprises

Source: compiled by the authors

In general, the data show that ERP/CRM systems and business process automation are the most common among the selected small and medium-sized agricultural enterprises. This indicates the priority of such areas of digitalisation, which are aimed at improving the management and efficiency of enterprises. However, the use of agrotechnological platforms and agroanalytics remains less widespread, which may require additional efforts on the part of the state or private investors to improve access to these technologies. The assessment of the achieved results from the introduction of digital technologies in small and medium-sized agricultural enterprises shows significant improvements in key business indicators. First, the cost reduction after the introduction of digital technologies was 12%, which indicates the ability of these technologies to optimise enterprise costs for operational processes. This can be the result of automating certain processes, reducing the need for manual labour, and optimising resources. A 15% increase in crop yields indicates that digital solutions have a positive impact on the productivity of the agricultural sector. Intelligent platforms for agricultural analytics and automation help businesses better manage crops, control resources, and respond in time to changes in growing conditions.

The efficiency of management decision-making has increased by 20%, which is a sign of an improvement in the efficiency and accuracy of decision-making processes due to the use of ERP/CRM systems and agricultural technology platforms. Such systems provide businesses with up-to-date information for better planning and monitoring. A 20% reduction in decision-making time confirms the effectiveness of digital tools in speeding up operational processes. Appropriate platforms allow businesses to access the necessary information faster, which minimises delays in decision-making and improves the overall reactivity of companies to change (Table 1).

Table 1. Results achieved from the introduction of digital technologies

Indicator	Before implementation	After implementation	Change (%)
Cost reduction	100%	88%	-12
Increase in yields	100%	115%	+15
Improvement of the effectiveness of management decisions	100%	120%	+20
Reduction in decision-making time	100%	80%	-20

Source: compiled by the authors

In general, the results of the introduction of digital technologies demonstrate a significant positive effect on the productivity and efficiency of small and medium-sized agricultural enterprises, confirming that these innovations help to optimise resources, increase yields, and reduce operating costs. It is worth noting that the introduction of digital technologies faces several significant problems that may limit the effectiveness of their application. The main problem, according to the survey

results, is the high cost of implementing technologies, which is noted by 60% of respondents. This suggests that the cost of launching and integrating new technologies can be significant for entrepreneurs, which is often a barrier to initial investment. 55% of respondents report a lack of investment to scale technologies, which highlights the difficulties in expanding and distributing implemented solutions, even if they are successful at the initial stage.

An equally important problem is the lack of qualification of personnel, which is indicated by 45% of entrepreneurs. This reflects the need to educate and retrain employees to effectively use new digital and environmental technologies. Admittedly, for the successful implementation of such innovations, it is important that the staff has a sufficient level of knowledge and skills. Another problem is the low level of access to technology, which was reported by 50% of respondents. This may be conditioned by technical limitations, lack of infrastructure, or high costs for licenses and equipment. Therefore, enterprises face difficulties in gaining access to the latest technologies, which limits their ability to modernise and improve efficiency (Fig. 2).

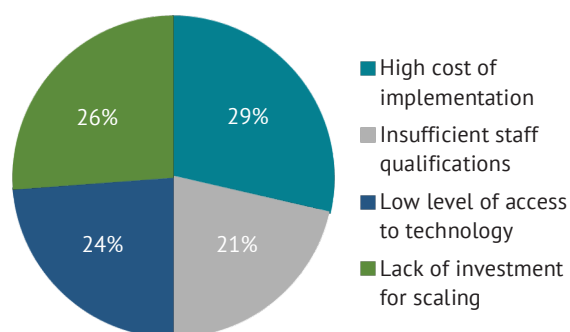


Figure 2. Main problems of implementing digital technologies

Source: compiled by the authors

To overcome the challenges that arise when implementing digital technologies, businesses can implement several strategies that will help to reduce financial barriers and ensure the effective use of new technologies. One of the most important ways is to attract state support, in particular, through subsidies, grants or tax incentives that reduce the initial costs of implementing new technologies. This allows enterprises to reduce the financial burden at the project launch stage. In addition, it is possible to use a step-by-step implementation strategy to reduce the cost of launching innovations. Enterprises should start with small, less costly projects and then gradually expand the use of technology.

Another important strategy is to find strategic investors to scale innovative solutions. Businesses can turn to private investors or venture capitalists who are interested in supporting new technologies. However, the creation of joint ventures with other companies allows attracting additional resources for faster development of technologies that have already been successfully tested. However, in order for innovation to have a real impact, it is necessary to consider the problem of insufficient skills of personnel. To do this, it is necessary to organise training and advanced training programmes for employees. Cooperation with educational institutions and the creation of specialised training courses would allow employees to quickly master new

technologies and apply them in their work. In addition, mentoring programmes and exchange of experience with experts can significantly speed up the adaptation of staff to new conditions. To overcome the problem of limited access to advanced technologies, which is associated with high costs for licenses and equipment, it is important to invest in the development of digital infrastructure, in particular, in broadband Internet coverage and the availability of necessary equipment for small and medium-sized enterprises. Technological hubs or innovation centres can also be created where companies can access the latest developments and test them in their processes.

The correlation analysis performed to assess the relationship between the level of use of digital technologies and the financial performance of enterprises showed a significant positive correlation between the implementation of ERP/CRM systems and profitability. The results show that technologies that have a positive correlation with the effectiveness of business processes can significantly improve them; in particular, ERP/CRM systems, agrotechnological platforms, and business process automation. The implementation of ERP systems has a correlation of $r = 0.45$, which is statistically significant at the level of $p\text{-value} = 0.01$, indicating their significant impact on business processes. Agrotechnological platforms show a weaker relationship with efficiency, but their impact also has statistical significance ($r = 0.38$, $p\text{-value} = 0.05$). Business process automation shows a strong positive impact ($r = 0.52$, $p\text{-value} = 0.02$), which confirms its effectiveness in improving management processes.

As for the impact of digital technologies on energy efficiency, the results show that the introduction of ERP systems and agricultural analytics has a significant positive effect. The correlation between ERP uses and energy efficiency is $r = 0.62$, which indicates a high level of impact on the energy consumption of the enterprise, while $p\text{-value} = 0.01$ confirms the statistical significance of this result. Similarly, agroanalysis has a correlation of $r = 0.47$ with energy efficiency, which is also statistically significant ($p\text{-value} = 0.03$). Process automation provides a correlation of $r = 0.55$ with energy efficiency, which once again highlights the importance of automation to reduce energy consumption. In addition, environmental innovations also have a significant impact on the financial results of enterprises. In particular, energy efficiency has a positive correlation ($r = 0.48$, $p\text{-value} = 0.01$) with financial indicators, which indicates the importance of energy saving for increasing profitability. The use of renewable energy also appears to be correlated with financial results ($r = 0.41$, $p\text{-value} = 0.04$), and recycling of organic waste has the least impact, but is still statistically significant ($r = 0.35$, $p\text{-value} = 0.05$).

Regarding the impact of technology on the financial performance of enterprises, profitability is one of the main indicators that positively correlates with the

introduction of digital and environmental innovations ($r = 0.58$, p -value = 0.01). However, energy efficiency has a correlation of $r = 0.47$, which also indicates the importance of energy saving for financial results (Table 2).

Thus, the analysis shows that digital technologies have a significant impact on improving the efficiency of small and medium-sized agricultural enterprises, reducing energy consumption and increasing profitability.

Table 2. Correlation coefficients between digital technology adoption and enterprise performance

Technology/Innovation	Correlation coefficient (r)	p-value
Impact on business process efficiency		
ERP/CRM systems	0.45	0.01
Agrotechnological platforms	0.38	0.05
Business process automation	0.52	0.02
Impact on energy efficiency		
Use of ERP	0.62	0.01
Use of agroanalytics	0.47	0.03
Automation	0.55	0.02
Impact of environmental innovations on financial results		
Energy efficiency	0.48	0.01
Renewable energy sources	0.41	0.04
Recycling of organic waste	0.35	0.05
Impact on financial performance		
Profitability	0.58	0.01
Energy efficiency	0.47	0.03

Source: compiled by the authors

As a result of the analysis of variance (ANOVA), statistically significant differences in profitability were identified between enterprises that actively implement digital technologies and those that do not use them. For a group of companies using digital technologies, the F-statistic is 5.62, and the p-value is 0.01, which indicates a significant difference in profitability. While for the group of enterprises that do not use

technologies, the F-statistic is 2.34, and the p-value is 0.05, which also indicates statistical significance, although at a slightly lower level (Table 3). These results confirm that the introduction of digital technologies has an important impact on the financial performance of enterprises, in particular, on profitability. This highlights the importance of digital transformation to improve business efficiency.

Table 3. Results of variance analysis (ANOVA)

Groups of enterprises	F-statistics	p-value
Using digital technologies	5.62	0.01
Without using digital technologies	2.34	0.05

Source: compiled by the authors

In general, the results of the study show that the introduction of digital technologies significantly improves not only the operational efficiency of small and medium-sized agricultural enterprises, but also their financial results. These innovations help businesses to reduce costs, increase crop yields, improve management decision-making efficiency, and speed up decision-making, which has a significant positive impact on their financial condition.

DISCUSSION

The study results demonstrate a significant impact of digital technologies on the efficiency of small and medium-sized agricultural enterprises in Kazakhstan. Automation systems, such as ERP and CRM, significantly reduce costs and improve management efficiency in agricultural enterprises. The results showed that after the introduction of digital solutions, costs for management

and production processes decreased by 12%, which is a significant indicator for small and medium-sized enterprises in the agricultural sector. This effect was achieved by reducing manual labour, automating routine processes, and facilitating access to information, which allowed businesses to respond faster to changes in market conditions and make more effective management decisions.

According to the results of the study, it was also revealed that investments in digital technologies can reduce the cost of management and production functions from 100% to 88%, which indicates the successful integration of these technologies into the business processes of agricultural enterprises. It is important that these changes not only reduce costs, but also significantly increase the level of managerial transparency and allow enterprises to use their resources more efficiently. With the introduction of modern information technologies, such as platforms for agricultural

analytics, enterprises are able to automate planning and control of production processes, reduce decision-making time, and thereby increase overall production efficiency (Kyfyak *et al.*, 2021). In Kazakhstan, where there is a high level of spending on management functions, the implementation of such solutions can be an important step towards reducing costs and increasing the competitiveness of the agricultural sector.

The study also highlights that the use of digital solutions can lead to an increase in crop yields by 15% by optimising their cultivation processes and improving the use of resources. In particular, the use of precision farming technologies allows precise regulation of the use of water, fertilisers, and other resources, which reduces costs and increases overall production efficiency (Askaraliev *et al.*, 2024). This was also confirmed in the study by R. Abiri *et al.* (2023), who notes that digital technologies in agriculture reduce the number of resources spent on the production of a unit of production, and this is an important factor in improving the economic efficiency of enterprises. One of the important features of digitalisation in the agricultural sector is also the improvement of environmental efficiency of production (Zadorozhniuk, 2023). Ultimately, the use of precision farming technologies helps to reduce the environmental burden on the environment. In particular, such technologies can significantly reduce water pollution and improve soil structure, which is important for the sustainability of agricultural ecosystems (Bibi & Rahman, 2023).

Analysis of the effectiveness of digital technologies in the agricultural sector using the example of small businesses also confirms the importance of investing in these technologies. According to R.A.A. Madushanki *et al.* (2019), digital solutions such as farm management platforms and big data analytics systems, enable farmers to optimise production processes and significantly reduce resource costs. Thus, automated systems allow controlling each stage of production and quickly adjusting strategies depending on changes in the market or weather conditions. As a result, businesses can increase their productivity and reduce management decision-making time by 20% (Bocean, 2024). M. Amarasiri *et al.* (2019), who analysed the impact of digital solutions on small and medium-sized agribusiness in conditions of limited access to investment, also notes that technologies such as big data analysis and intelligent decision-making systems can significantly improve the efficiency of agricultural enterprises, even in conditions of limited resources. This is confirmed by the results obtained, as even businesses with disabilities have been able to achieve improvements through the introduction of digital technologies.

The results of the study are also confirmed in the practice of other countries. Thus, B.B. Hojnik and I. Huđek (2023) argue that the introduction of ERP systems in US agribusiness has helped to significantly reduce production costs and improve enterprise financial

performance. In particular, it was noted that these systems helped to increase profitability by 10%, which allows enterprises to become more resilient to economic crises and competitive challenges. This shows that digitalisation is a powerful tool for ensuring the economic sustainability of agricultural enterprises, since automation of processes not only reduces costs, but also allows responding more quickly to changes in the market and adapting to new economic conditions. In addition, it is worth noting that one of the main factors for the successful introduction of digital technologies in agriculture is the level of access to these technologies for small and medium-sized enterprises (Lopatynskiy *et al.*, 2023). In Kazakhstan, many agricultural enterprises, especially at the initial stages of development, face difficulties in implementing innovations due to limited access to financial resources and technological tools. As noted by A. Burliai *et al.* (2021), the key challenges are the high cost of investing in digital technologies and the need for specialised knowledge to use them effectively. Therefore, in order to support small and medium-sized enterprises in the agricultural sector, it is necessary to create favourable conditions for access to digital technologies through state support and infrastructure development. In the context of limited resources and difficult economic conditions, the use of digital technologies can become the main factor for increasing the competitiveness of agricultural enterprises (Kovalyshyn *et al.*, 2023). It is important that public authorities and financial institutions support these initiatives by providing small businesses with access to concessional loans and grants for technology adoption, which reduces barriers to innovation and increases their efficiency at all stages of production (Carolan, 2020; Nugraha *et al.*, 2023).

The analysis of the effectiveness of digital solutions in small businesses was also confirmed by X. Zhang and D. Fan (2024), who notes that in China, the introduction of agricultural robots and digital platforms for managing fields has significantly increased yields and reduced labour costs in agricultural enterprises. This also shows a trend where even businesses with limited resources can significantly improve the efficiency of their operations through the introduction of digital technologies. According to L. Klerkx *et al.* (2019), digitalisation allows agricultural enterprises to make more informed management decisions through access to up-to-date and accurate data. In particular, the use of big data analytics platforms helps farmers to predict yields, resource requirements and management needs based on meteorological and agronomic data, which reduces risks and improves operational efficiency. In addition, the use of artificial intelligence systems in the agricultural sector allows automatically adjusting the strategies of tillage, irrigation, and fertilisation in real time, which leads to significant economic and environmental benefits (Chandra & Collis, 2021; Charatsari *et al.*, 2024).

Research R. Gröbli and M. del Pilar (2022) shows that farmers who invested in digital technologies received financial benefits in the form of reducing production costs by 10-15%. An important component is also to increase the availability of financial services, such as lending, through the use of online platforms for farmers. This allows businesses to quickly receive the necessary funds for development, and reduce the financial risks associated with traditional ways of doing business. Thus, the results of the study indicate that digitalisation is an important factor in improving the efficiency of small and medium-sized agricultural enterprises in Kazakhstan. The introduction of modern technologies helps to reduce costs, increase yields, optimise production processes, and reduce the environmental burden. However, to ensure equal access to these technologies for all enterprises, support from the state and financial institutions is required, which will contribute to the development of the agricultural sector based on innovative technologies.

CONCLUSIONS

The integration of digital technologies into the activities of small and medium-sized agricultural enterprises in Kazakhstan has a significant potential to increase their efficiency and competitiveness. According to the results of the study, the introduction of digital technologies can significantly reduce costs by 12%. In addition, digitalisation helps to increase crop yields by 15%, which increases the efficiency of agricultural production. This indicates the high potential of digital solutions for improving agricultural productivity. Another important result is an increase in the efficiency of management processes. In particular, the introduction of digital technologies can reduce the time spent on making managerial decisions by 20%, which significantly increases the efficiency of management structures in the agricultural sector.

The results of the study confirm that the introduction of digital technologies significantly increases the operational and financial efficiency of small and medium-sized agricultural enterprises. In particular, ERP/CRM systems, agrotechnological platforms, and automation of business processes show a significant correlation with the increase in profitability of enterprises, with correlation coefficients of 0.45, 0.38, and 0.52, where the statistical significance levels are 0.01, 0.05, and 0.02. Energy efficiency is most positively affected by the use of ERP systems, the correlation coefficient of which is 0.62 at p-value 0.01, while automation shows $r = 0.55$ (p-value = 0.02), and agroanalysis – $r = 0.47$ (p-value = 0.03).

The results of the variance analysis show a statistically significant difference in profitability between enterprises implementing digital technologies, where F-statistics is 5.62 and p-value is 0.01, and those that do not apply them, where F-statistics is 2.34 and p-value is 0.05, emphasising the importance of digital transformation for improving business financial performance. Thus, digital technologies have a significant positive impact on reducing costs, increasing crop yields, improving management processes and financial efficiency of enterprises in the agricultural sector, which is confirmed by both qualitative and quantitative results of the study. The perspective of future research is an in-depth analysis of the impact of digital technologies on various aspects of the agricultural sector, in particular, on sustainable development, adaptation to climate change, and improvement of environmental efficiency.

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CONFLICT OF INTEREST

None.

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Інтеграція цифрових технологій для підвищення ефективності малих та середніх аграрних підприємств

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Анотація. Метою дослідження було оцінити вплив впровадження цифрових технологій на підвищення ефективності діяльності малих і середніх сільськогосподарських підприємств у Казахстані. Для досягнення поставленої мети було використано комплекс методів, включаючи статистичний аналіз, порівняльний метод та контент-аналіз відповідей респондентів за допомогою анкетування. Результати дослідження показують, що інтеграція цифрових рішень дозволила значно скоротити управлінські та виробничі витрати, зменшивши їх на 12 %. Впровадження цифрових технологій сприяло підвищенню врожайності сільськогосподарських культур на 15 % та підвищенню ефективності агровиробництва. Крім того, діджиталізація скоротила час, необхідний для прийняття управлінських рішень, на 20 %, що підвищило ефективність управлінських процесів. Використання ERP/CRM-систем, агротехнологічних платформ та автоматизації бізнес-процесів позитивно корелює зі зростанням прибутковості з коефіцієнтами кореляції 0,45, 0,38 та 0,52 відповідно, що є статистично значущим (рівні значущості 0,01, 0,05 та 0,02). ERP-система ($r = 0,62$, p -значення = 0,01) показала особливо високу кореляцію з енергоефективністю, тоді як автоматизація ($r = 0,55$, p -значення = 0,02) та агроаналіз ($r = 0,47$, p -значення = 0,03) також зробили значний внесок. Дисперсійний аналіз показав статистично значущу різницю в прибутковості між підприємствами, які впроваджують цифрові технології (F-статистика 5,62, p -значення 0,01), і тими, які їх не використовують (F-статистика 2,34, p -значення 0,05). Це підтверджує важливість цифрової трансформації для покращення фінансових результатів бізнесу. Таким чином, цифрові технології значно підвищують ефективність та конкурентоспроможність сільськогосподарських підприємств, що підтверджується як кількісними, так і якісними результатами

Ключові слова: конкурентоспроможність; витрати; врожайність; процеси управління; агротехнологічні платформи; автоматизація
