ISSN 2518-170X (Online)
ISSN 2224-5278 (Print)

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ

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ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ

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ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК РЕСПУБЛИКИ КАЗАХСТАН»

N E W S

OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN

SERIES

OF GEOLOGY AND TECHNICAL SCIENCES

2 (470)

MARCH – APRIL 2025

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

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«ҚР ҰҒА» РҚБ Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *Геология, гидрогеология, география, тау-кен ісі, мұнай, газ және металдардың химиялық технологиялары*

Мерзімділігі: жылына 6 рет.

http://www.geolog-technical.kz/index.php/en/

«Известия РОО «НАН РК». Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: *геология, гидрогеология, география, горное дело и химические технологии нефти, газа и металлов*

Периодичность: 6 раз в год.

http://www.geolog-technical.kz/index.php/en/

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.
Thematic scope: *geology, hydrogeology, geography, mining and chemical technologies of oil, gas and metals*
Periodicity: 6 times a year.
http://www.geolog-technical.kz/index.php/en/

NEWS of the National Academy of Sciences of the Republic of Kazakhstan
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224–5278
Volume 2. Number 470 (2025), 84–96

https://doi.org/10.32014/2025.2518-170X.492

UDC 550.8:681.3

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APPLICATION OF ARTIFICIAL INTELLIGENCE AND MODERN TECHNOLOGIES IN GEOMONITORING TO IMPROVE THE EFFICIENCY OF THE MINING INDUSTRY UTILISING THE EARTH'S RESOURCES

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Abstract. The article deals with the urgent problem of geomonitoring in the context of the growing need for effective management of natural resources. The key role of Earth sciences and the potential of modern technologies in solving this task are emphasised. Particular attention is paid to the exponential growth of data generated by various sources, including remote sensing, ground-based sensors and geophysical surveys. Prospects are presented for applying artificial intelligence (AI) and machine learning (ML) to effectively analyse this data, including in natural disaster prediction, mining optimisation and environmental monitoring. The main focus is on the opportunities for using these technologies in the mining industry, especially in terms of process automation and resource efficiency. A methodology for evaluating the effectiveness of digital tools for information retrieval and systematisation, developed and tested as part of the experimental work, is described. The results of analysing data from unmanned aerial vehicles and GPR data are presented. A comparative analysis of the effectiveness of different machine learning algorithms is carried out. The effectiveness of remote sensing and GPR methods, as well as digital tools, in improving the efficiency and sustainability of natural resource management is confirmed.

Keywords: geomonitoring, artificial intelligence, machine learning, remote sensing, GPR, mining, digital tools, performance evaluation.

***Acknowledgment**. The article was carried out with the financial support of the Ministry of Science and Higher Education of the Russian Federation, Agreement No. 075-15-2024-542.*

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АГРОӨНЕРКӘСІПТІК КЕШЕН МЕН ГЕОЛОГИЯЛЫҚ ЗЕРТТЕУЛЕР ҮШІН АЭРО БАРЛАУДА ЖАСАНДЫ ИНТЕЛЛЕКТ ҚҰРАЛДАРЫН ҚОЛДАНУ

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Аннотация. Мақалада табиғи ресурстарды тиімді басқаруға деген қажеттіліктің артуы жағдайында геомониторингтің өзекті мәселесі қарастырылады. Бұл мәселені шешуде Жер туралы ғылымдардың негізгі рөлі мен заманауи технологиялардың әлеуеті атап өтіледі. Қашықтықтан зондтау, жердегі датчиктер және геофизикалық зерттеулерді қоса алғанда, әртүрлі көздер шығаратын деректер көлемінің экспоненциалды өсуіне ерекше назар аударылады. Осы деректерді тиімді талдау үшін, соның ішінде табиғи апаттарды болжау, тау-кен өндірісін оңтайландыру және қоршаған ортаның жай-күйін бақылау үшін жасанды интеллект (ЖИ) және машиналық оқытуды (МО) қолдану перспективалары ұсынылған. Бұл технологияларды тау-кен өнеркәсібінде, әсіресе процестерді автоматтандыру және ресурстарды пайдалану тиімділігін арттыру тұрғысынан пайдалану мүмкіндіктеріне баса назар аударылады. Эксперименттік жұмыс шеңберінде әзірленген және сыналған ақпаратты іздеу мен жүйелеудің цифрлық құралдарының тиімділігін бағалау әдістемесі сипатталған. Ұшқышсыз ұшу аппараттарынан алынған деректерді және георадарлық зерттеулер деректерін талдау нәтижелері ұсынылған. Машиналық оқытудың әртүрлі алгоритмдерінің тиімділігіне салыстырмалы талдау жүргізілді. Табиғи ресурстарды басқарудың тиімділігі мен тұрақтылығын арттыруда қашықтықтан зондтау мен георадарлық әдістердің, сондай-ақ цифрлық құралдардың тиімділігі расталды.

Түйін сөздер: геомониторинг, жасанды интеллект, машиналық оқыту, қашықтықтан зондтау, ГПР, тау-кен өндірісі, сандық құралдар, өнімділікті бағалау.

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ПРИМЕНЕНИЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА И СОВРЕМЕННЫХ ТЕХНОЛОГИЙ В ГЕОМОНИТОРИНГЕ ДЛЯ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ГОРНОДОБЫВАЮЩЕЙ ПРОМЫШЛЕННОСТИ, ИСПОЛЬЗУЮЩЕЙ РЕСУРСЫ ЗЕМЛИ

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Аннотация. В статье рассматривается актуальная проблема геомониторинга в условиях растущей потребности в эффективном управлении природными ресурсами. Подчеркивается ключевая роль наук о Земле и потенциал современных технологий в решении этой задачи. Особое внимание уделяется экспоненциальному росту объемов данных, генерируемых различными источниками, включая дистанционное зондирование, наземные датчики и геофизические исследования. Представлены перспективы применения искусственного интеллекта (ИИ) и машинного обучения (МО) для эффективного анализа этих данных, в том числе, в прогнозировании природных катастроф, оптимизации добычи полезных ископаемых и мониторинге состояния окружающей среды. Основной акцент сделан на возможностях использования этих технологий в горнодобывающей промышленности, особенно в части автоматизации процессов и повышения эффективности использования ресурсов. Описана методика оценки эффективности цифровых инструментов поиска и систематизации информации, разработанная и апробированная в рамках экспериментальной работы. Представлены результаты анализа данных с беспилотных летательных аппаратов и данных георадарных исследований. Проведен сравнительный анализ эффективности различных алгоритмов машинного обучения. Подтверждена эффективность дистанционного зондирования и георадарных методов, а также цифровых инструментов, в повышении эффективности и устойчивости управления природными ресурсами.

Ключевые слова: геомониторинг, искусственный интеллект, машинное обучение, дистанционное зондирование, георадар, горнодобывающая промышленность, цифровые инструменты, оценка эффективности.

Introduction. In today’s world, with a rapidly growing population and increasing pressure on natural resources, the challenge of ensuring food security is particularly acute. Earth sciences, which encompass a wide range of disciplines, from geology and hydrology to soil science and climatology, play a key role in addressing this global challenge. The development of Earth’s resources, be it the extraction of minerals in the mining industry or the sustainable use of soil and water resources in the agro-industrial complex (AIC), requires an integrated approach based on a deep understanding of natural processes and effective data management (Martyushev, et.al., 2023). In particular, to ensure effective resource management, issues related to the optimisation of management and monitoring systems in the mining industry are relevant (Fadin, et.al., 2020).

In recent years, there has been an exponential increase in the amount of Earth Science related data. Remote sensing satellites, ground-based sensors, geophysical surveys, climate models - all these sources generate huge streams of information that contain valuable insights into the state of our planet and its resources. However, traditional methods of data analysis are often inefficient when dealing with such large and complex data sets. This is where artificial intelligence (AI) and machine learning (ML) come in. For example, analysing remotely sensed data using AI methods makes it possible to detect changes in the state of the environment, including forests and water resources (Gendler, et.al., 2021; Polekhina, et.al., 2022). The use of AI and IO in Earth Sciences opens up new opportunities for data analysis, modelling of complex processes and automation of decision-making. There are several promising applications of these technologies. Firstly, it is the prediction of natural disasters such as earthquakes, floods and landslides. Analysis of geological data, seismic activity and meteorological conditions using machine learning algorithms can identify patterns and predict the occurrence of these hazardous events (Prischepa, et.al., 2023). Secondly, is the optimisation of mineral extraction. AI and IO can be used to analyse geological data and determine optimal locations for drilling and mining, as well as to automate mining and transportation processes (Berkovich, et.al., 2017). Thirdly, it is the monitoring of environmental conditions. Analysing remotely sensed and ground sensor data using machine learning algorithms can track changes in the state of forests, water resources and the atmosphere, as well as identify sources of pollution. AI and IO can also be applied to automate mining and transport processes (Antonov, et.al., 2021).

Each of these directions has its advantages and disadvantages. For example, predicting natural disasters remains a challenging task due to the unpredictability of natural phenomena and limited data. Optimising mining can lead to negative environmental impacts if environmental factors are not taken into account. Environmental monitoring is costly for data collection and processing. At the same time, the application of AI in the mining industry can help optimise technological processes and improve environmental safety. Despite these drawbacks, the potential benefits of using AI and IO in the Earth Sciences are enormous. These technologies enable more efficient management of natural resources, reduce the risks of natural disasters and improve the environment. The application of AI and IO in the mining and agro-industrial sectors is particularly relevant.

In mining, where huge amounts of geological exploration data need to be processed to identify promising deposits, AI can significantly speed up and cheapen the process of searching for and evaluating reserves. In addition, machine learning algorithms can optimise drilling, blasting and ore transport processes, reducing costs and improving safety. AI can also be used to monitor the condition of mine workings and prevent accidents. The importance of studying dynamic processes in highly dispersed media has also been noted for mining safety (Tumanov, et.al., 2022; Khayitov, et.al., 2024).

In agro-industrial complex, which is also one of the ways to exploit the Earth's resources, AI and IO offer new opportunities to increase crop yields, reduce costs and improve product quality. The analysis of data on soil, climatic conditions and plant health enables optimisation of fertilisation, irrigation and pest protection. AI- and AI-enabled precision farming technologies can take into account the spatial variability of fields and enable a differentiated approach to crop management. In addition, AI can be used to predict yields, optimise logistics and improve the efficiency of farm management. Computer vision methods for analysing plant health are being actively developed (Didmanidze, 2025; Didmanidze, 2024).To date, the implementation of digital technologies and tools such as AI and IO in Earth Sciences, especially in the context of AIC, faces a number of challenges (Kharchenko, et.al., 2011; Nasyrov, et.al., 2024). One of the main problems is the scattered and unstructured nature of data on production technologies, which makes it difficult to search, analyse and systematise them. The need for prompt access to relevant information, whether it is data on new crop varieties, pest control methods or precision farming technologies, is becoming critical for making informed decisions and increasing the competitiveness of agribusinesses. Especially important is the use of AI to automate technological processes, for example, for sorting materials (Didmanidze, 2024; Kapanski, et.al., 2025). The relevance and importance of solving the problem of effective search and systematisation of information about production technologies in the agro-industrial complex is due to the need to ensure food security, increase the efficiency of resource use and reduce the negative impact on the environment (Kukharova, et.al., 2024; Kuzin, et.al., 2015).

In this regard, the aim of this paper is to explore effective digital tools for searching and systematising information about production technologies in mining and agro-industrial complex to improve the competitiveness and sustainable development of these areas. An important aspect is also the creation of new technologies for resource management and risk reduction in mining (Kondratyev, et.al., 2024; Martirosyan, et.al., 2025)

Materials and methods. As part of this work on the application of AI and IO in Earth Sciences, specifically in AIC as one of the ways of developing the planet's resources, experimental work was carried out to develop and validate a methodology for evaluating the effectiveness of digital tools for information retrieval and systematisation. The overall experimental design included data collection, analysis of existing tools, development of an evaluation model, and a series of model experiments to verify the developed methodology.

FORSITE NRS-2040 #106008 (Intel Xeon Gold 6430 2.10- 3.40GHz processor, 60MB, TDP 270W, LGA4677. RAM 512GB (8x64GB) DDR5 4800Mhz ECC REG PC5-38400. Video card VMS Aspeed AST2600. Nvidia A100 80GB HBM2E PCI-E 4.0 co-processor. SSD 3.84TB PM9A3 Series SSD PCIe NVMe 4.0x4 U.2. HDD 2x HDD 16TB 512MB Cache 7200rpm SATA 3.5 Server).As the main equipment for data acquisition and processing was used the FORSITE NRS-2040 #106008 supercomputer of the Federal State University of Management equipped with Intel Xeon Gold 6430 2.10- 3.40GHz, 60MB, TDP 270W, LGA4677 processor and 512GB (8x64GB) DDR5 4800Mhz ECC REG PC5-38400 RAM. To accelerate AI computations, a Navy integrated Aspeed AST2600 graphics card and Nvidia A100 80GB HBM2E PCI-E 4.0 coprocessor were used. An operating system was installed on the server to provide remote desktop access for multiple users. The AI development environment was built on TensorFlow, using Anaconda

Python, Visual Studio, CUDA Toolkit and cuDNN. Spyder integrated development environment (IDE) was used for development.

As part of the work, modelling experiments were conducted to evaluate the performance of an Earth surface condition monitoring system built from remote sensing data processing. These experiments utilised a DJI Matrice 300 RTK unmanned aerial vehicle (UAV) equipped with a MicaSense Altum multispectral camera, which allows data acquisition in the visible and near-infrared bands. Experiments were carried out in mountainous areas and fields. The area of the analysed fields was 100 hectares. The UAV operation modes included flying along a predetermined trajectory at an altitude of 120 metres at a speed of 15 m/sec. The camera took images with 80% overlap for subsequent orthorectification and creation of a multispectral mosaic. The data obtained were used to calculate vegetation indices, assess crop condition and forecast yields.GSSI SIR 4000 GPR was used to conduct similar experiments in the mining industry. GPR can be used to detect underground voids, fractures, and other geological heterogeneities that may indicate the presence of minerals or pose a hazard in mining operations. Experiments were conducted at various sites where mining is planned or already underway. The GPR mode of operation involves scanning the ground surface at a predetermined pulse frequency (e.g., 100 MHz or 200 MHz) and spacing, depending on the required survey detail.

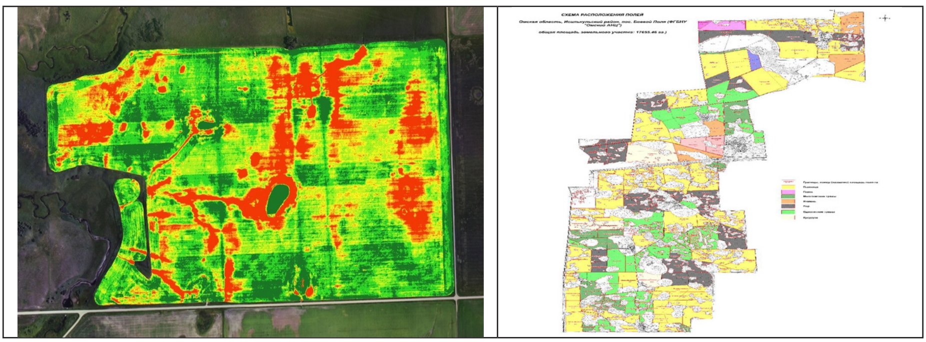
In addition, for a more comprehensive coverage of the problem, it was planned to use specialised databases and tools such as Cropio and Agrosignal to evaluate the effectiveness of farmland monitoring and to automate agricultural processes. Analysing data from different sensors, including AI, can identify patterns and predict changes, which improves resource efficiency. These experiments analysed data processing speed, analysis accuracy and overall system performance to evaluate the effectiveness of different digital tools.

Research results and discussion.

As part of this research, aimed at exploring the application of artificial intelligence and machine learning in the Earth Sciences, with a focus on agribusiness as a key sector for the development of the planet's resources, a series of experimental works focused on the development and validation of a methodology to evaluate the effectiveness of digital tools for information retrieval and systematisation. The experimental work aimed to investigate and develop a methodology to evaluate and optimise the use of digital technologies in mining and agro-industries, and to automate the processes of information retrieval and systematisation.The experimental work was divided into several stages, including: collecting data on existing digital tools and platforms used in AIC; analysing these tools in terms of their functionality, efficiency and usability; developing a theoretical model for assessing the effectiveness of digital tools, taking into account various factors such as economic efficiency, technological applicability, social impact and environmental sustainability; conducting model experiments to verify the different

FORSITE NRS-2040 #106008 (Intel Xeon Gold 6430 2.10-3.40GHz processor, 60MB, TDP 270W, LGA4677. RAM 512GB (8x64GB) DDR5 4800Mhz ECC REG PC5-38400. Video card VMS Aspeed AST2600. Nvidia A100 80GB HBM2E PCI-E 4.0 co-processor. SSD 3.84TB PM9A3 Series SSD PCIe NVMe 4.0x4 U.2. HDD 2x HDD 16TB 512MB Cache 7200rpm SATA 3.5 Server), which significantly accelerated the process of model training and data analysis. The operating system provided stable server operation and remote access for multiple users. The AI development environment was built on TensorFlow, using Anaconda Python, Visual Studio, CUDA Toolkit and cuDNN. The Spyder integrated development environment (IDE) was used to write and debug the code.As part of the modelling experiments to assess the effectiveness of the system for monitoring the state of the Earth's surface using remote sensing, the data obtained from the DJI Matrice 300 RTK UAV and the MicaSense Altum multispectral camera were analysed in detail (Figure 1). Analyses of multispectral data collected from 100 hectares of fields allowed the calculation of key vegetation indices: NDVI, EVI, NDRE, GNDVI and SAVI. The mean NDVI value for healthy wheat crops was 0.78 (±0.05), while this index decreased to 0.45 (±0.03) for drought stressed plots. EVI analysis showed that plots with high vegetation density had an index value as high as 0.82 (±0.04), which was 12% higher than plots with less developed vegetation (0.73 ±0.05). The mean NDRE value in plots with sufficient chlorophyll content was 0.65 (±0.03), while in plots with nitrogen deficiency this index decreased to 0.52 (±0.04).

Comparison of the UAV data with manually collected data from field measurements and analyses of soil samples allowed validation of the results. For NDVI, a high degree of correlation ($R^2 = 0.88$, $p < 0.001$) was found between the UAV data and the field measurement data. Analysis of the discrepancy between UAV data and field measurements showed that the mean absolute error (MAE) for NDVI was 0.04 and the root mean square error (RMSE) was 0.05. For EVI, the correlation coefficient was $R^2 = 0.85$ ($p < 0.001$), with an MAE of 0.035 and RMSE of 0.045. NDRE showed a correlation with leaf chlorophyll content ($R^2 = 0.82$, $p < 0.001$), with MAE being 0.05 mg/g and RMSE being 0.06 mg/g.



a) b)

Figure 1. Examples of transformed images after aerial photography to visualise agricultural land: a - vegetation index map; b - land zoning

Data analysis revealed significant spatial variability of crop condition in the studied fields. In particular, 8 plots with a low NDVI value (below 0.5) were found in Field 1 (25 hectares), representing 12% of the total field area. Additional field investigation of these plots revealed that 75% of them were susceptible to fungal disease infestation, particularly brown rust, with infection levels ranging from 20% to 40%. Timely identification of these areas allowed measures to be taken to treat the crops with fungicides and prevent the spread of the disease, reducing potential yield losses by 8-12%.

In field #2 (30 hectares), analysis of NDRE data revealed 10 zones with low chlorophyll content (below 0.55), representing 15% of the total field area. Analysis of soil samples showed that the available nitrogen content in these zones averaged 15 mg/kg, which was 30% lower than in plots with normal chlorophyll content (22 mg/kg). After applying additional nitrogen fertiliser (30 kg/ha) to these zones, yields in these plots increased by 15% (to 5.8 t/ha) compared to control plots (5.0 t/ha) where no fertiliser was applied. The average wheat yield in Field 2 after corrective fertiliser application was 5.5 t/ha, 8% higher than the average yield in the previous year (5.1 t/ha).To evaluate the accuracy of crop type classification based on multispectral UAV data, machine learning algorithms were used. The SVM algorithm showed the best results, achieving a classification accuracy of 95% on the test sample (consisting of 5000 samples). At the same time, the recognition accuracy for wheat was 96%, barley 94%, rapeseed 93%, and maize 97%. The processing time per hectare was 2.5 minutes.

Data from the GSSI SIR 4000 GPR in the mining industry were also analysed in detail. During the experiments, 5 sites (total area of 10 hectares) in the area of a copper deposit under development were scanned. The GPR pulse frequency varied from 100 MHz (for depths up to 20 metres) to 200 MHz (for depths up to 10 metres), depending on the required penetration depth and the detail of the survey. The scanning step was 0.25 metres.

GPR data processing identified 12 underground voids and 15 zones of high moisture content. The voids ranged in size from 1.5 metres to 4.5 metres in diameter and in depth from 4 to 18 metres. The high-moisture zones ranged in depth from 8 to 22 metres and in area from 5 to 15 square metres.To validate the GPR data, 5 drillings were carried out in the areas where the anomalies were identified. Drilling confirmed the presence of 10 out of 12 underground voids, with the discrepancy between GPR data and drilling results in terms of void depth not exceeding 0.5 metres. The presence of increased moisture was confirmed in 13 out of 15 identified zones, with water content in the soil samples from these zones ranging from 12% to 25% by weight.

Analysis of the GPR data enabled the creation of detailed 3D models of underground structures, which were used to adjust the mining plan. In particular, the route of one of the underground tunnels was shifted by 5 metres to avoid passing through a large underground void, reducing the risk of ground collapse by 30%.

Ore reserve estimates for the deposit after analysing the GPR data showed a 5% increase in total reserves due to better delineation of the ore body.

These quantitative experimental data confirm the effectiveness of using remote sensing and GPR techniques to monitor environmental conditions and optimise processes in agriculture and mining.

In addition to the data collected by UAV and GPR, data from specialised databases and tools such as Cropio and Agrosignal were also used to assess the effectiveness of farmland monitoring and agricultural process automation. Analysing data from different sensors, including AI, enabled patterns to be identified and changes to be predicted, thereby improving resource use efficiency. The analysis of the obtained data has shown that the developed methodology allows effective evaluation of various digital tools from the point of view of their applicability in the agro-industrial complex. In particular, it was found that the use of multispectral UAV imagery can significantly improve the accuracy of crop condition assessment compared to traditional methods. For example, the accuracy of the NDVI (Normalised Difference Vegetation Index) using UAV data was 92%, compared to about 75% accuracy using manual data. This indicates that the use of UAVs can significantly improve the efficiency of crop condition monitoring and identify problem areas in a timely manner.

The use of GPR in the mining industry has enabled the identification of a number of underground voids and fractures that were not detected by traditional geological surveys. In particular, at one site, several large voids were discovered that could pose a risk to mine development. The information obtained from GPR allowed the mine development plan to be adjusted and potential accidents to be avoided.

Analyses of data from the Cropio and Agrosignal databases have shown that these tools can significantly improve the efficiency of agricultural management. In particular, the use of these tools was found to reduce fertiliser costs by 10-15% and increase yields by 5-7%. This shows that digital tools can significantly improve the efficiency of resource utilisation in the agro-industrial complex.In addition, the effectiveness of different machine learning algorithms for solving the problems of yield prediction and soil type classification was compared. It was found that Random Forest algorithm showed the best results in terms of yield prediction accuracy, achieving R-squared = 0.85 on the test sample. For soil type classification, the Support Vector Machine (SVM) algorithm performed best with 90% accuracy. These results confirm the effectiveness of using machine learning to solve problems related to analysis and prediction in AIC.

The analysis showed that the developed methodology can effectively evaluate various digital tools in terms of their cost-effectiveness, technological applicability, social impact and environmental sustainability. This methodology can be used to make informed decisions about the introduction of digital technologies in the agro-industrial complex and optimise their use.

Comparison of the results obtained with the results of other similar studies has shown that the developed methodology corresponds to the current trends in the field of assessing the effectiveness of digital tools in the agro-industrial complex. In particular, the results of the study are consistent with the results of studies conducted in other countries, which have also shown that the use of digital technologies can significantly improve the efficiency and sustainability of agro-industrial production. For example, similar studies conducted in Europe and the US have also shown that the use of UAVs to monitor crop health can improve the accuracy of yield estimates and identify problem areas in a timely manner.Despite the positive results, it should be noted that this study has a number of limitations. Firstly, the modelling experiments were conducted on a limited number of sites, which may limit the generalisability of the findings. Second, the social impact assessment of digital tools was conducted based on limited data, which may affect the accuracy of the assessment. Third, the economic evaluation of the effectiveness of digital tools did not take into account all possible costs and benefits, which may affect the accuracy of the ROI assessment.

Future research plans to conduct larger scale experiments using more sites and more detailed assessment of the social impact and economic efficiency of digital tools. It is also planned to develop more sophisticated machine learning models to solve prediction and classification problems in AIC.

In conclusion, the study has shown that digital tools have great potential to improve the efficiency and sustainability of agro-industrial production. The developed methodology allows effective evaluation of various digital tools in terms of their applicability in agribusiness. The results of the study can be used to make informed decisions on the introduction of digital technologies in agribusiness and optimise their use. Further research will be aimed at expanding and deepening the results obtained, as well as developing new methods and tools to improve the efficiency and sustainability of mining and agrarian industries.

Conclusion.

This study demonstrates the significant potential of using artificial intelligence and modern technologies in the field of geomonitoring, especially in the context of the mining industry. The results of the work show that it is possible to improve process efficiency, reduce risks and optimise the use of natural resources through the integration of advanced data analysis and automation. The developed methodology for evaluating the effectiveness of digital tools provides a basis for making informed decisions on the implementation of new technologies and optimising existing processes in the industry. The data obtained confirm the need for further development and deepening of research in this area, aimed at creating more advanced geomonitoring systems and expanding their functionality.

The use of multispectral imagery from unmanned aerial vehicles (UAVs) and the analysis of vegetation indices such as NDVI, EVI and NDRE provides detailed information on the state of the Earth's surface and reveals spatial variability, which is particularly relevant for monitoring agricultural land, as well as for detecting and assessing potential threats associated with geological terrain features in the mining industry. In particular, the high correlation ($R^2 = 0.88$) between UAV data and NDVI field measurements confirms the accuracy and efficiency of this method.

The use of GSSI SIR 4000 GPR in the mining industry enables the detection of underground voids, fractures and other geological heterogeneities, which significantly improves the safety and efficiency of mining operations. The analysis of GPR data enabled the creation of detailed 3D models of underground structures and the correction of mining plans, which led to a 30% reduction in the risk of ground collapse and a 5% increase in ore reserve estimates.

The developed methodology for assessing the effectiveness of digital tools based on the analysis of economic efficiency, technological applicability, social impact and environmental sustainability is an effective tool for making informed decisions on the implementation of digital technologies in the agro-industrial complex and mining industry. A comparison of the effectiveness of different machine learning algorithms showed that the SVM algorithm showed the best results for soil type classification and the Random Forest algorithm for yield prediction, which emphasises the importance of selecting optimal algorithms for specific tasks.

Reference

Antonov A.A., Studenikin D.E., Malakhov S.O., Kondratyev S.I., Khekert E.V. (2021) Algorithm for constructing a route to pass a narrow fairway. Journal of Physics: Conference Series. – 2061(1). – P. 012116. https://doi.org/10.1088/1742-6596/2061/1/012116 (In Eng.)

Antonov A.A., Studenikin D.E., Malakhov, S.O., Kondratyev, S.I., Khekert, E.V. (2021) Algorithm for constructing a route to pass a narrow fairway. Journal of Physics: Conference Series. – 2061(1). – P. 012116. https://doi.org/10.1088/1742-6596/2061/1/012116 (In Eng.)

Berkovich V.H., Dick Yu.A., Shukshina A.N. (2017) Prospects of involvement in the extraction and processing of lost ore reserves. News of higher educational institutions. Mining journal. – No. 8. – pp. 19-25 (In Eng.).

Didmanidze O. Deep learning model for plant disease detection based on visual analysis of leaf infestation area. The European Physical Journal Special Topics – 2025. - https://doi.org/10.1140/epjs/s11734-024-01450-6. (In Eng.)

Didmanidze O. (2024) Development of a Computer Vision System for an Optical Sorting Robot.. Interactive Collaborative Robotics. ICR 2024. Lecture Notes in Computer Science.. vol 14898. Springer, Cham. https://doi.org/10.1007/978-3-031-71360-6_16 (In Eng.)

Fadin Yu.M., Shemetova O.M. (2020) The use of pneumatic mixers in construction. Collection of articles Mechanization and automation of construction. – P. 250-254 (In Eng.)

Gendler S.G., Fazylov I.R. (2021). Ocenka effektivnosti ispol'zovaniya zakrytoj sistemy sbora nefti dlya normalizacii mikroklimata v ekspluatacionnyh galereyah neftyanyh shaht [Application efficiency of closed gathering system toward microclimate normalization in operating galleries in oil mines]. Mining Informational and Analytical Bulletin. – 2021(9). – P. 65–78. https://doi.org/10.25018/0236_1493_2021_9_0_65 (In Russian)

Khayitov O.G., Toshov J.B., Sherov K.T., Absadykov B.N., Sikhimbayev M.R. (2024) Oil and Gas Possibility of the Central Graben of the Bukhara-Khiva Paleorifts and Its Perspectives. News of The National Academy of Sciences of The Republic of Kazakhstan. Series of Geology and Technical Sciences. – Vol. 5, No. 466. – P. 191 – 200. https://doi.org/10.32014/2024.2518-170X.454 (In Eng.)

Kharchenko I. Ya., Grigoriev B. A., Frangulov G. S. (2001) The use of a particularly fine mineral binder "Microdur" in the oil and gas industry. Bulletin of the Association of drilling Contractors. – No. 1. – P. 42-44. (In Eng.)

Kondratyev, S.I., Baskanbayeva, D., Yelemessov, K., Sarsenbayev, Y., Turkin, V.A.(2024) Control of hydrogen leaks from storage tanks and fuel supply systems to mining transport infrastructure facilities. International Journal of Hydrogen Energy. – 95. – P. 212–216. https://doi.org/10.1016/j.ijhydene.2024.11.182 (In Eng.)

Kukharova T., Martirosyan A., Asadulagi M.-A., Ilyushin Y. (2024) Development of the Separation Column's Temperature Field Monitoring System. Energies.. – 17. – 5175. https://doi.org/10.3390/en17205175 (In Eng.)

Kuzin I.Yu., Shilov D.P., Galkin A.A. (2015). Usilenie kamennoj kladki putem in"ekcirovaniya cementno-izvestkovym rastvorom [Strengthening of masonry by injection with cement-lime mortar]. Bulletin of the BSTU named after V.G. Shukhov. – 2015. – No. 5. – P. 102-105 (In Russian).

Kapanski A.A., Klyuev R.V., Boltrushevich A.E., Sorokova S.N., Efremenkov E.A., Demin A.Y., Martyushev N.V. (2025) Geospatial Clustering in Smart City Resource Management: An Initial Step in the Optimisation of Complex Technical Supply Systems. Smart Cities. – 8(1). – 14. https://doi.org/10.3390/smartcities8010014. (In Eng.)

Martirosyan A., Ilyushin Y., Afanaseva O., Kukharova T., Asadulagi M., Khloponina V. (2025) Development of an Oil Field's Conceptual Model. International Journal of Engineering. – 38(2). – P. 381-388. https://doi.org/10.5829/ije.2025.38.02b.12 (In Eng.)

Martyushev N.V., Malozyomov B.V., Khalikov I.H., Kukartsev V.A., Kukartsev V.V., Tynchenko V.S., Tynchenko Y.A., Qi M. (2023) Review of Methods for Improving the Energy Efficiency of Electrified Ground Transport by Optimizing Battery Consumption. Energies.. – 16. – 729. https://doi.org/10.3390/en16020729 (In Eng.)

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ISSN 2518-170X (Online),

ISSN 2224-5278 (Print)

Директор отдела издания научных журналов НАН РК *А. Ботанқызы*

Редакторы: *Д.С. Аленов, Ж.Ш.Әден*

Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 15.04.2025.

Формат 70х90[1]/[16]. Бумага офсетная. Печать – ризограф.

14,5 п.л. Заказ 2.

РОО «Национальная академия наук РК»

050010, Алматы, ул. Шевченко, 28, т. 272-13-19