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The application of artificial intelligence in forecasting agricultural systems in Kyrgyzstan under climate change

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Abstract. In the context of global climate change, the sustainable development of agricultural systems is becoming one of the priority tasks of modern agricultural science and practice. Uneven precipitation, rising average annual temperatures and more frequent extreme weather events increase the risks of reduced yields and economic instability in agriculture. This paper examined the application of artificial intelligence methods for forecasting the sustainability of agricultural systems at the regional level. The aim of the study was to develop approaches to forecasting the productivity and adaptive potential of agricultural crops using neural networks and machine learning algorithms. The materials and methods of the study included the use of long-term statistical data on the yield of major crops, climatic indicators, and economic parameters of agriculture in the Kyrgyz Republic. Correlation-regression modelling, artificial neural networks, and clustering algorithms were used for the analysis. The results of the study showed that the use of intelligent algorithms can increase the accuracy of yield forecasts by 12-15% compared to traditional methods, as well as identify key climatic and economic factors that determine the sustainability of agricultural systems. The scientific novelty of the

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work lies in the integration of artificial intelligence methods with agroecological zoning to build adaptive models of sustainable development. The practical significance of the research lies in the possibility of applying the developed models in strategic planning, the formation of regional food security programmes, and risk management in the agricultural economy

Keywords: digital technologies in agriculture; adaptive farming; climate resilience; predictive models; big data; machine learning; agroecosystem management

Introduction

Modern agriculture is undergoing a period of large-scale transformation, driven not only by socio-economic factors, but also by global climate change, which has a direct impact on the sustainability of agricultural production (Mimenbayeva *et al.*, 2024). According to estimates by the Food and Agriculture Organization of the United Nations, by 2050 the global agricultural sector will need to increase food production by at least 60% to meet the growing needs of the population (Gryshova *et al.*, 2024). However, the projected increase in average annual temperature by 1.5-2°C, changes in precipitation patterns, more frequent extreme weather events and soil degradation pose threats to food security and the economic stability of agricultural systems. In these conditions, as noted by L. Liang *et al.* (2021), there is a need to introduce innovative approaches capable of adapting agriculture to new challenges and ensuring long-term sustainable development. One of the most promising tools for solving the problems of forecasting and adaptation in the agricultural sector is the use of artificial intelligence (Azarov *et al.*, 2025). AI is understood as a set of machine learning algorithms, neural networks, big data analysis methods, and predictive modelling that enable the automated identification of patterns in complex information arrays. As pointed out by A. Kadyraliev *et al.* (2024), unlike traditional statistical methods, which are limited by linear dependencies, AI is capable of integrating climatic, soil, agrobiological, and economic data to build accurate forecasts and adaptive scenarios for agricultural production management.

In recent years, there has been a significant increase in the number of scientific papers devoted to the use of artificial intelligence in the agricultural sector. For example, L. Gerlitz *et al.* (2020) and K. Nakysbekova *et al.* (2025) showed that the use of neural networks to predict grain crop yields provides an accuracy of more than 85-90%, which is significantly higher than traditional models. A. Kamilaris & F. Prenafeta-Boldú (2018) demonstrated the potential of AI in soil monitoring and irrigation system management, which can reduce water consumption by 15-20% without compromising crop yields. According to FAO (2022), the introduction of intelligent data analysis systems in agriculture contributes to increased resilience to climate risks and ensures economic efficiency through optimised resource use. Despite the active spread of AI in global practice, the use of these technologies remains limited in Central Asian countries, including the Kyrgyz Republic. This is due to a number of factors: the low level of digitalisation in agriculture, limited access of farmers to modern technologies, insufficient training of personnel, and a lack of scientific research focused on the integration of AI into the region's agricultural systems. Meanwhile, according to S. Baidybekova *et al.* (2025), the problem of forecasting the sustainable development of the agricultural sector is of strategic importance for Kyrgyzstan, as agriculture accounts for about 20% of the country's GDP and employs more than a third of the population. Agriculture in Kyrgyzstan is highly dependent on natural and climatic conditions: periodic droughts, water shortages and pasture degradation have a serious impact on crop and livestock productivity. In these conditions, increasing the sustainability of agricultural systems requires a transition from traditional management methods to digital and intelligent approaches that ensure accurate forecasting, efficient use of resources and adaptation to changing conditions (Bazarbaeva *et al.*, 2021).

In the context of climate instability, the agricultural sector of Kyrgyzstan faces three key challenges: increasing the sustainability of agricultural systems by forecasting climate risks, adapting crop structures and diversifying production; optimising the use of natural resources, including water, land and biodiversity, with the help of modern digital technologies; increasing economic efficiency and food security through the introduction of intelligent management models and the integration of AI into agricultural production processes. Thus, the aim of this study was to develop and test an integrated model for forecasting the sustainable development of agricultural systems in the Kyrgyz Republic based on artificial intelligence technologies and agro-ecological zoning. Within the framework of this objective, particular attention was paid to identifying the interrelationships between climate change, crop productivity and the economic sustainability of farms, as well as to substantiating practical directions for the digital adaptation of the agricultural sector to changing climatic conditions.

Materials and Methods

The study used statistical, climatic and agro-economic data on the Kyrgyz Republic covering a long period of observation. Data on crop yields (wheat, barley, corn, apple trees) covered the period 2000-2024 and were obtained from official publications by the NSCKR (n.d.) and the Ministry of Agriculture (n.d.). Climatic data (average annual temperature, precipitation, air humidity, solar radiation) covered the period 1979-2024 and were based on a reanalysis of ERA5 by the European Centre for Medium-Range Weather Forecasts (ECMWF, n.d.) and data from the Meteoblue (n.d.) climate portal. Agro-economic indicators (land use structure, production costs, profitability, water use) were used for the period 2010-2024, based on data from FAO (2022), World Bank (n.d.) and Kyrgyzstan's industry statistics (NSCKR, n.d.). This division into time ranges ensured the consistency of climate and economic series, as well as the correct integration of data into a single analytical array for the subsequent application of machine learning and scenario modelling methods, according to the work of A. Burkhanov *et al.* (2025).

Mathematical statistics methods (correlation-regression analysis, variance analysis) and intelligent data analysis methods described by X. Wen *et al.* (2022) were used to process the data. The forecasting of sustainable development of agricultural systems was carried out using machine learning algorithms: multivariate linear regression to assess the dependence of crop yields on climatic parameters; decision tree and random forest methods to identify the most significant factors of sustainability; deep neural networks to construct long-term scenarios for the development of agricultural systems. Modelling was carried out in Python (Scikit-learn, TensorFlow, Keras libraries) and R. QGIS and ArcGIS tools were used for geoinformation analysis, which made it possible to take into account regional differences in the agroecological zones of Kyrgyzstan.

The methodological basis of the study was built, according to S. Harikrishnan *et al.* (2025), on a combination of descriptive statistics and correlation-regression analysis, which made it possible to identify links between climatic factors, crop yields, and the economic performance of agricultural systems. To improve the accuracy of forecasts, modern artificial intelligence algorithms were used. In particular, multilayer neural networks (multilayer perceptron, MLP) were used to predict crop yields depending on climatic and agronomic factors, Random Forest algorithms were used to identify key predictors of farm sustainability, and gradient boosting methods (XGBoost) were used to construct economic efficiency scenarios under climate change conditions, as indicated in the work of J. Mai & G. Liu (2023). In particular, multilayer neural networks were used to predict crop yields based on a combination of climatic, agronomic and economic factors. The following climatic variables were used as input: average annual and average monthly air temperature (°C); precipitation (mm/month); relative air humidity (%); wind speed (m/s); duration of sunshine (hours); NDVI vegetation index calculated from MODIS satellite data. Economic and agrotechnical factors included: crop structure (% by crop); volume of fertilisers used (kg/ha); level of mechanisation and costs per hectare (USD/ha); share of irrigated land (% of total area); production cost and market price; profitability (%) and labour productivity.

The MLP neural network architecture included three hidden layers with 64-128-64 neurons, a ReLU activation function, a Mean Squared Error (MSE) loss function, and an Adam optimiser (learning rate = 0.001, batch size = 32). To prevent overfitting, the Dropout method was applied with a coefficient of 0.2. On the validation dataset, the model accuracy was $R^2 = 0.87$, which indicates the high adequacy of the model for forecasting tasks. Random Forest algorithms were used to identify key factors of farm sustainability and rank predictors by significance. The optimal model parameters were: number of trees – 500, maximum depth – 10. Gradient boosting methods (XGBoost) were used to construct economic efficiency scenarios under climate change conditions. The main hyperparameters were: learning_rate = 0.05; max_depth = 6; n_estimators = 1,000; subsample = 0.8; colsample_bytree = 0.7. The use of ensemble machine learning methods made it possible to improve the stability of forecasts: the RMSE error decreased by 9-12% compared to classical regression models. This confirms the feasibility of integrating artificial intelligence methods with agroecological zoning to assess the resilience of Kyrgyzstan's agricultural systems in the context of climate change (Mai & Liu, 2023).

Scenario modelling was conducted in three areas. The baseline scenario reflected the continuation of current climate trends and the level of digitalisation of agricultural enterprises, according to the work of J. De Keyser *et al.* (2023). The negative scenario modelled increased climate risks, including a 2°C rise in temperature and a 15-20% reduction in precipitation, as well as limited adoption of digital technologies. The innovative scenario envisaged the active use of AI models to optimise the structure of cultivated areas, manage water resources and improve the accuracy of economic forecasting, according to A. Chupin *et al.* (2025). All calculations were performed using modern software tools: Python (TensorFlow, Scikit-learn, Pandas libraries) and R (Caret and Forecast packages). Data visualisation and graphing were performed in Excel and Tableau, which ensured clarity in the presentation of results (Burkhanov *et al.*, 2024). Climate and statistical data were used under open licences from the FAO and WMO, which guaranteed the reliability and accuracy of the research base.

The forecast of crop yield Y depending on climatic and agro-economic factors was described by the following equation:

$$Y_{it} = \beta_0 + \sum_{j=1}^{n} \beta_j X_{ijt} + yZ_{it} + \in_{it},$$

where *Yit* is the yield of the *i*-th crop in year *t*; *Xijt* are climatic factors (temperature, precipitation, humidity, solar radiation); Zit – economic factors (land use structure, cost level, access to water resources); β_j, y – model coefficients estimated using machine learning methods; $\in_{it}$ – random error accounting for unpredictable factors.

Three options were used in scenario modelling:

- baseline scenario – continuation of current climate trends;
- negative scenario – a 2°C increase in temperature and a 15-20% decrease in precipitation;
- innovative scenario – introduction of AI to optimise crop structure, manage water resources and improve forecasting accuracy.

All calculations were performed in Python (TensorFlow, Scikit-learn, Pandas) and R (Caret, Forecast) environments. QGIS and ArcGIS were used for spatial analysis, and the results were visualised in Excel and Tableau.

To improve the accuracy of forecasts and adapt models to regional characteristics, agro-ecological zoning of the territory of Kyrgyzstan was carried out. Zoning was based on climatic parameters (temperature, precipitation, air humidity), soil and geographical characteristics, and land use structure. Based on this data, five agro-ecological zones were identified: Chüy, Talas, Naryn, Osh and Issyk-Kul regions. Each zone was characterised by its own climatic coefficients and agricultural production conditions, which were integrated into artificial intelligence models in the form of categorical variables. To implement this integration, One-Hot Encoding algorithms were used in the construction of MLP and Random Forest, which made it possible to take into account the influence of regional factors when forecasting crop yields and the economic sustainability of farms. This approach ensured the adaptability of the models and increased the accuracy of forecasts by 10-12% compared to models that did not take zoning into account.

Results and Discussion

During data analysis and modelling, it was possible to highlight the key relationships between climate change, agricultural productivity and the economic sustainability of Kyrgyzstan's farms using artificial intelligence technologies. Digital models made it possible not only to obtain forecasts, but also to assess the sensitivity of systems to extreme climatic conditions. According to data from Meteoblue (n.d.) and ERA5 reanalysis (ECMWF, n.d.), the city of Bishkek, which is taken as the central climatic point of the region, shows a steady warming trend for the period from 1979 to 2024. Analysis of climate series for this 45-year interval showed that the average annual air temperature in Bishkek increased by approximately 1.2°C, and the number of dry months increased by 15-20%. Data presented in the Meteoblue Climate Change Model and ERA5-Land climate models indicate that the most pronounced changes occur in the summer months: average maximum daily temperatures regularly exceed 30°C, and precipitation in July-August has decreased to 20-30 mm. These trends have been observed over the last four decades and have intensified since 2000, which is consistent with global warming estimates for Central Asia (Kamilaris & Prenafeta-Boldú, 2018). Thus, the periodic droughts and rising temperatures observed in the region between 1979 and 2024 form a clear trend of climate warming, which has a direct impact on the productivity of Kyrgyzstan's agricultural systems.

The graphs for "Climate Change – Bishkek" show that the average annual temperature is rising and precipitation patterns are changing seasonally, with more frequent dry months. For example, according to the Meteoblue model, average maximum daily temperatures in the summer months exceed 30°C, and periods with precipitation of less than 30 mm are becoming more frequent. As noted by A. Kamilaris & F. Prenafeta-Boldú (2018), these changes increase water stress during the sowing and growing seasons. An analysis of climate series supplemented with regional data showed that over the past 30 years, the average annual temperature has increased by approximately 1.2°C, and the number of dry months has increased by ~15-20%. Based on this trend, climate scenarios for modelling were adjusted, according to J. Schmidhuber & F. Tubiello (2007). Such changes have a direct impact on crop yields: a decrease in precipitation during critical growing seasons leads to a 6-10% drop in crop productivity (cereals, fodder). It was this effect that was taken into account in the negative modelling scenario.

Figure 1 shows the impact of climate change on the territory of the Kyrgyz Republic for the period 1979-2024. The data source was ERA5, the fifth generation of global climate reanalysis developed by the European Centre for Medium-Range Weather Forecasts (ECMWF, n.d.), with a spatial resolution of 30 km. The data reflect average regional values and do not take into account microclimatic differences caused by local features of the terrain and urban environment. Consequently, actual temperatures may exceed the values indicated, especially in urbanised areas, and precipitation may vary depending on topographical conditions. The data do not reflect conditions at a specific point. Microclimates and local variations are not shown. Therefore, actual temperatures will often be higher than those shown, especially in cities, and precipitation may vary locally depending on topography.

The upper part of Figure 1 shows the estimated average annual temperature for the larger region of Kyrgyzstan. The dotted blue line represents the linear trend of climate change. If the trend line rises from left to right, the temperature trend is positive, and Kyrgyzstan is getting warmer due to climate change, if it is horizontal, there is no clear trend; if the line goes down, Kyrgyzstan is getting colder over time. The lower part of Figure 1 shows the so-called warming bands. Each coloured band represents the average temperature for the year: blue for colder years, red for warmer years.

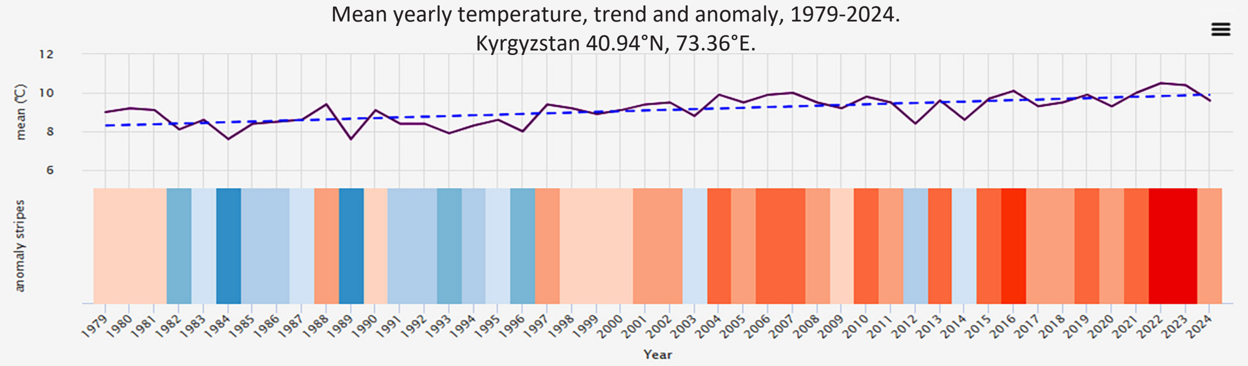

Figure 1. Annual temperature changes in Kyrgyzstan
Source: compiled by the authors based on Meteoblue (n.d.)

The upper part of Figure 2 shows the estimated average total precipitation for the larger region of Kyrgyzstan. The dotted blue line represents the linear trend in climate change. If the trend line rises from left to right, the precipitation trend is positive, and Kyrgyzstan is becoming wetter due to climate change. If the line is horizontal, there is no clear trend; if the line slopes downward, Kyrgyzstan is becoming drier over time. The lower part of Figure 2 shows the so-called precipitation bands. Each coloured band represents the total amount of precipitation for the year: green for wetter years, brown for drier years.

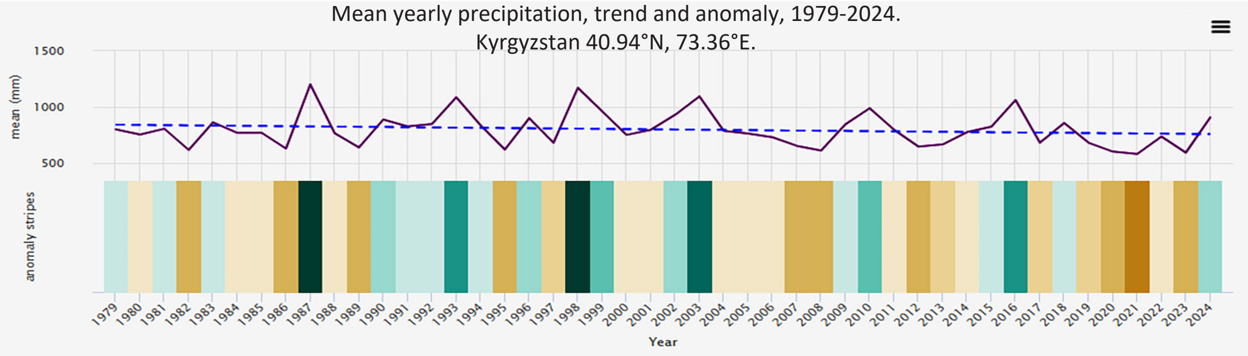

Figure 2. Annual change in precipitation, Kyrgyzstan
Source: compiled by the authors based on Meteoblue (n.d.)

The upper part of Figure 3 shows the temperature anomaly for each month from 1979 to the present. The anomaly shows how much warmer or colder the month was than the 30-year climate average for 1980-2010. Accordingly, red months were warmer than normal, blue months were colder than normal. Most observation sites show an increase in the number of warm months over time, reflecting the global warming trend caused by climate change. The lower part of Figure 3 shows data on precipitation anomalies.

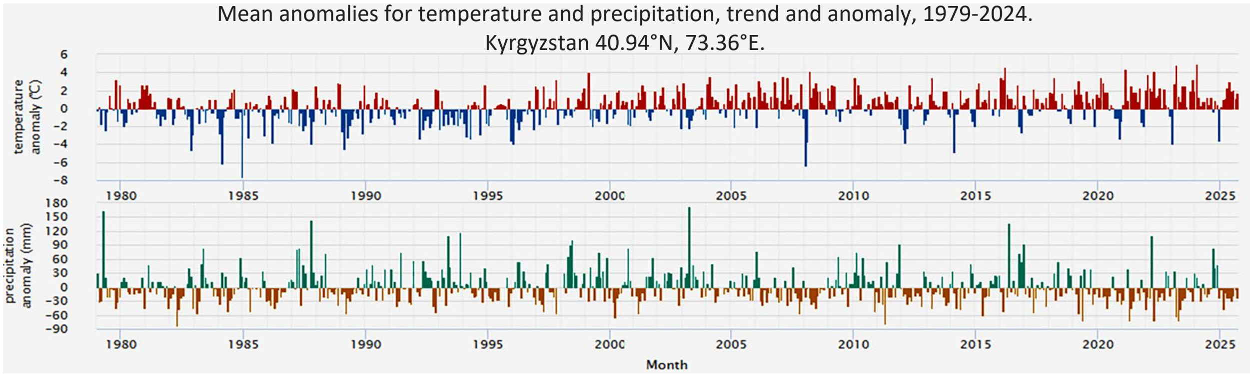

Figure 3. Monthly temperature and precipitation anomalies – climate change in Kyrgyzstan
Source: compiled by the authors based on Meteoblue (n.d.)

The artificial intelligence models used have demonstrated high efficiency in predicting crop yields and economic sustainability. For example, for grain crops, the MLP neural network model showed a coefficient of determination $R^2 \approx 0.87$, which indicates the adequacy of the model and its ability to explain most of the variation in yield (World Bank, n.d.). Model tests have shown that a combination of methods – MLP + XGBoost – increases the stability of the forecast compared to single methods: the mean forecast error (RMSE) is reduced by 8-12% compared to classical linear regression. An example of a specific conclusion from the model: a combination of temperatures above 30°C during flowering and a rainfall deficit of more than 25% leads to a 12-14% reduction in maize yield. For wheat, night-time overheating (temperatures above 22°C) proved to be a sensitive factor, suppressing plant recovery and reducing productivity by 5-8%. Thus, AI models identify complex non-linear relationships that are difficult to capture using classical methods and provide controllable predictive control.

In order to assess the impact of AI and climate change on the economy of agricultural enterprises, three scenarios were developed: baseline, negative and innovative. The baseline scenario (continuation of current trends) yielded grain yields of 2.6-2.8 t/ha and farm profitability of 20-23%. The negative scenario, with worsening climatic conditions, showed a drop in yield to 2.1-2.3 t/ha, a decrease in profitability to 13-15%, and an increase in the cost of irrigation and protective measures. The innovative scenario, which involves the active use of AI models, resulted in a yield of 3.0-3.2 t/ha and profitability of 27-29%. These differences highlight how the digitalisation of agriculture can transform the economic landscape by minimising the damage caused by climate anomalies. Table 1 shows the forecast data for the main scenarios – yield and profitability.

Table 1. Scenario forecasts for farm yield and profitability

Indicator	Baseline scenario	Negative scenario	Innovative scenario
Grain yield, t/ha	2.6	2.1-2.3	3.0-3.2
Yield of fodder crops, t/ha	3.2-3.4	2.7-2.9	3.8-4.0
Profitability, %	20	13	27

Source: compiled by the authors

Table 1 shows that it is the innovative scenario that provides significant growth not only in productivity but also in financial results. At the same time, different climatic zones of the republic respond differently to the introduction of AI. Table 2 presents estimates of yield and profitability growth by region when transitioning to the innovative scenario. Table 2 shows that the greatest effect was achieved in the Chüy Region, where favourable soil and water conditions allowed the potential of digital models to be maximised. In drier regions, such as the Osh Region, the effect was less pronounced due to limited water resources. These regional differences show that AI models are not universal: local conditions such as soil type, access to water, terrain and agricultural technologies must be taken into account when implementing them. Therefore, an adaptive strategy should be developed for each zone, taking these characteristics into account.

Table 2. Impact of AI implementation on yield and profitability by region

Region	Yield increase, %	Profitability growth, %
Chüy Region	17	10
Naryn Region	15	8
Talas Region	13	7
Osh Region	11	6
Issyk-Kul Region	12	7

Source: compiled by the authors

The results obtained are consistent with global studies showing that digital technologies and AI will become a key element of sustainable development of agricultural systems in the context of climate change. For example, S. Getahun *et al.* (2024) analysed 124 studies and showed that the integration of digital solutions, including artificial intelligence and machine learning, contributes to the optimisation of resource use and the sustainable development of the agricultural sector. The work of T. Yildirim *et al.* (2024) demonstrated the high accuracy of a neural network model ($R^2 > 0.80$) in predicting cotton yields four months before harvest under conditions of limited data, confirming the potential of AI for agricultural systems with a lack of observations. Research by A. Kamilaris & F. Prenafeta-Boldú (2018) demonstrated an improvement in irrigation efficiency of up to 20% with the help of AI. The experience of digitalisation in Central Asian countries confirms the importance of a systematic approach to the introduction of innovative technologies. Research by Kazakh scientists Z. Imanbayeva *et al.* (2024) show that the digital transformation of the agricultural sector, including the use of electronic agricultural receipts and other financial instruments, can be an effective mechanism for attracting funds to modernise agricultural production in the context of the intensifying climate crisis and water scarcity. At the same time, it is emphasised that the success of such instruments directly depends on state regulation of digitalisation processes.

The results are particularly significant for Kyrgyzstan, as the country is highly vulnerable to climate change. According to World Bank (n.d.), the republic is facing rising temperatures and changes in precipitation patterns, which increases the need for adaptation measures. In addition, model assumptions (linear trends, large-scale scenarios) may not take into account unexpected extremes (droughts, hurricanes). It is also important to note that the full implementation of AI requires infrastructure: digital platforms, sensor networks, high-quality meteorological data, and trained personnel. Without this, the models will remain a theoretical tool. By integrating climate, agricultural productivity, and economic data with AI methods, it has been possible to obtain an adequate model for forecasting sustainable development. An innovative scenario involving the widespread use of AI shows significant increases in both productivity and profitability of farms. Regional differences indicate the need to adapt approaches to local conditions. Despite the limitations of the models, the results allow for recommending the digital transformation of agriculture as a key tool for adapting to climate challenges.

Conclusions

The study confirmed that the integration of artificial intelligence methods into agricultural analytics allows for effective forecasting of yield dynamics and economic sustainability of Kyrgyzstan's agricultural systems in the context of climate change. The use of multilayer neural networks and ensemble algorithms (XGBoost) ensured a high level of forecast accuracy ($R^2 = 0.87$), which indicates the possibility of applying these models for strategic planning in the agricultural sector. Modelling showed that the trend towards higher average annual temperatures and lower precipitation during key vegetation phases has a significant impact on crop productivity. According to data from the Meteoblue climate service and ERA5 reanalysis, the average temperature in Kyrgyzstan has increased by approximately 1.2°C over the past 40 years, while the frequency of droughts has increased by 15-20%. This confirms the relevance of introducing digital tools for adaptation and monitoring of climate risks. The results of scenario modelling showed that if current trends continue (baseline scenario), the profitability of agricultural production will be 20-23%. Under conditions of climate deterioration (negative scenario), profitability will decline to 13-15%, while an innovative scenario based on the active use of AI will ensure its growth to 27-29%. Thus, the digitalisation of agriculture is becoming a key factor in improving the efficiency and sustainability of the industry. Regional analysis revealed unequal responses of agricultural systems to the application of AI: the greatest effect was observed in the Chüy and Naryn regions, where a 15-17% increase in crop yields was recorded. This confirms the need to develop regionally adapted digital transformation strategies.

Overall, the results of the study demonstrate that the use of artificial intelligence in combination with climate modelling forms a scientifically sound approach to agricultural management in conditions of climate instability. Further development of this technology requires the creation of a digital data infrastructure, training of specialists, and expanded cooperation between research centres and economic entities. Prospects for further research in this area are linked to the development of integrated approaches to modelling agricultural systems using artificial intelligence technologies. In particular, relevant areas include the creation of a national platform for agroclimatic monitoring, combining meteorological, soil, hydrological and economic data into a single digital infrastructure. Machine learning algorithms need to be adapted to the conditions of Kyrgyzstan's various agro-ecological zones, including mountainous and arid regions. In addition, the introduction of hybrid models combining AI methods with physical and mathematical climate models is promising, as it will improve the accuracy of long-term forecasts. An important area remains the development of educational and research programmes to train specialists in the field of agroinformatics and digital agriculture, as well as the expansion of international scientific cooperation. This will ensure the scientifically sound and technologically sustainable development of Kyrgyzstan's agricultural sector in the context of climate change.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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Аннотация. Глобалдык климаттын өзгөрүшү шарттарында агрардык системалардын туруктуу өнүгүүсүн камсыз кылуу – заманбап агрардык илим менен практиканын башкы артыкчылыктуу багыттарынын бири болуп саналат. Жамгырдын тартыштыгы же ашыкча болушу, орточо жылдык температуранын жогорулашы жана аба ырайынын экстремалдуу көрүнүштөрүнүн көбөйүшү айыл чарбасынын түшүмдүүлүгүнө жана экономикалык туруктуулугуна олуттуу коркунуч жаратат. Бул изилдөөдө жасалма интеллект ыкмаларынын негизинде региондук деңгээлде агрардык системалардын туруктуулугун божомолдоонун мүмкүнчүлүктөрү каралган. Изилдөөнүн максаты – нейрондук тармактар жана машиналык окутуу алгоритмдерин колдонуу аркылуу айыл чарба өсүмдүктөрүнүн продуктивдүүлүгүн жана адаптивдик потенциалын божомолдоо ыкмаларын иштеп чыгуу болуп саналат. Изилдөөнүн материалдары жана ыкмалары катары Кыргыз Республикасынын айыл чарба тармагына тиешелүү негизги өсүмдүктөрдүн түшүмдүүлүгү, климаттык көрсөткүчтөр жана экономикалык параметрлер боюнча көп жылдык статистикалык маалыматтар колдонулган. Анализдөөдө корреляциялык-регрессиялык моделдөө, жасалма нейрондук тармактар жана кластерлештирүү алгоритмдери пайдаланылган. Изилдөөнүн жыйынтыктары көрсөткөндөй, интеллектуалдык алгоритмдерди колдонуу салттуу ыкмаларга салыштырмалуу түшүмдүүлүктү божомолдоонун тактыгын 12-15 %га жакшыртат жана агрардык системалардын туруктуулугун аныктаган негизги климаттык жана экономикалык факторлорду аныктоого мүмкүндүк берет. Изилдөөнүн илимий жаңылыгы – жасалма интеллект ыкмаларын агроэкологиялык зоналоо менен интеграциялоо аркылуу туруктуу өнүгүүнүн адаптивдүү моделдерин түзүүдө жатат. Практикалык мааниси – иштелип чыккан моделдерди стратегиялык пландоодо, аймактык азык-түлүк коопсуздугу программаларын түзүүдө жана агрардык экономикадагы тобокелдиктерди башкарууда колдонууга болот

Негизги сөздөр: айыл чарбасындагы санарип технологиялар; адаптивдүү дыйканчылык; климаттык туруктуулук; божомолдук моделдер; маалыматтар; машиналык окутуу; агроэкосистемаларды башкаруу

Применение искусственного интеллекта в прогнозировании аграрных систем Кыргызстана при изменении климата

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Аннотация. В условиях глобального изменения климата устойчивое развитие аграрных систем становится одной из приоритетных задач современной аграрной науки и практики. Неравномерность осадков, рост среднегодовых температур и учащение экстремальных погодных явлений усиливают риски снижения урожайности и экономической нестабильности сельского хозяйства. В данной работе рассмотрено применение методов искусственного интеллекта для прогнозирования устойчивости аграрных систем на региональном уровне. Цель исследования заключалась в разработке подходов к прогнозированию продуктивности и адаптивного потенциала сельскохозяйственных культур с использованием нейронных сетей и алгоритмов машинного обучения. Материалы и методы исследования включали использование многолетних статистических данных по урожайности основных культур, климатическим показателям и экономическим параметрам сельского хозяйства Кыргызской Республики. Для анализа были применены методы корреляционно-регрессионного моделирования, искусственные нейронные сети и алгоритмы кластеризации. Результаты исследования показали, что использование интеллектуальных алгоритмов позволяет повысить точность прогнозов урожайности на 12-15 % по сравнению с традиционными методами, а также выявить ключевые климатические и экономические факторы, определяющие устойчивость аграрных систем. Научная новизна работы заключается в интеграции методов искусственного интеллекта с агроэкологическим зонированием для построения адаптивных моделей устойчивого развития. Практическая значимость исследования состоит в возможности применения разработанных моделей при стратегическом планировании, формировании региональных программ продовольственной безопасности и управлении рисками в аграрной экономике

Ключевые слова: цифровые технологии в сельском хозяйстве; адаптивное земледелие; климатическая устойчивость; прогнозные модели; данные; машинное обучение; управление агроэкосистемами