**ORGANIZATIONAL MODEL OF ENVIRONMENTALLY RESPONSIBLE EDUCATION FOR YOUTH IN THE CONTEXT OF CLIMATE CHANGE AND RISK MANAGEMENT**

**Abstract.** The article is dedicated to the development of a comprehensive approach to integrating environmental education into modern educational processes. Amid escalating climate challenges, the formation of environmental awareness among youth becomes critically important for ensuring sustainable societal development. The main focus is on creating an organizational model that involves the use of climate change risk assessment methods, the application of digital technologies, and the development of competencies in environmental management. The study encompasses the systematization of climate-related risks and the development of a methodological approach for their comprehensive assessment. The proposed methodology is based on a combination of Monte Carlo methods, GIS analysis, scenario analysis, DCF, and big data processing. This approach enables the evaluation of the probability of climate threats, their spatial distribution, financial consequences, and the vulnerability levels of specific territories and economic sectors. The practical significance of the research lies in the potential use of the obtained results for improving state policies in climate adaptation, shaping educational programs, and developing risk management strategies. Special attention is given to the development of an organizational model for environmentally responsible education (ERE), which integrates analytical methods for climate risk assessment into the educational process, incorporates modern technologies, and encourages active youth participation in environmental initiatives. The proposed model fosters critical thinking, practical skills in environmental risk assessment, and adaptation strategies among youth, thereby enhancing their preparedness to address environmental challenges. The study highlights an interdisciplinary approach to environmental education, encompassing economic, social, legal, and technological aspects. The practical implementation of this model can enhance youth’s environmental literacy, promote the development of innovative environmental solutions, and contribute to the sustainable development of society.

**Introduction.**

In the context of climate challenges and environmental risks, environmental education for youth acquires strategic significance. Modern education must not only provide knowledge but also develop competencies for solving environmental problems through the integration of scientific, technological, and managerial approaches. It is essential to develop an organizational model of environmentally responsible education based on climate risk assessment, the use of information technologies, and the formation of a conscious attitude toward the environment. The incorporation of forecasting, spatial analysis, and economic evaluation of climate change consequences enhances the effectiveness of education and fosters youth engagement in environmental initiatives. A comprehensive approach is required, integrating environmental knowledge into educational programs, stimulating critical thinking, and implementing practice-oriented methods. Research confirms that an interdisciplinary approach to education, encompassing economic, legal, social, and technical aspects, contributes to the formation of environmental awareness and the ability to manage risks.

Numerous studies have focused on the strategic role of environmental education in the context of sustainable development. Warburton K. (2003) emphasizes the importance of deep learning for fostering behavioral change in youth, while Thomas I. (2004) addresses the institutional and pedagogical challenges of integrating sustainability into university curricula. Moore J. (2005) adds a political dimension by highlighting the need for educational reform, arguing that sustainability must be embedded in the philosophy of higher education. Wals A. E. J. and Corcoran P. B. (2006) stress the transformational potential of education for sustainable development, advocating for experiential learning.

A number of scholars have worked on defining key competencies and learning strategies. Barth M. et al. (2007) identify critical thinking and systems thinking as essential competencies for youth. Rowe D. (2007) highlights the innovative role of universities in developing environmental education models, while Sipos Y. et al. (2008) call for a holistic teaching approach that integrates cognitive, emotional, and practical dimensions. This is echoed by Hargreaves L. G. (2008), who promotes a systemic approach supported by institutional frameworks.

Other researchers have expanded the discourse by examining the socio-cultural and emotional contexts of education. Stephens J. C. et al. (2008) incorporate intercultural dimensions, portraying higher education institutions as agents of change. Shephard K. (2008) underlines the emotional aspects of learning for long-term environmental awareness, and Leal Filho W. (2010) discusses the theory-practice gap in sustainability education. Mochizuki Y. and Fadeeva Z. (2010) advocate for a competency-based educational framework, while McNaughton M. J. (2010) introduces ecopedagogy through educational drama, highlighting interaction and emotion in learning.

Tilbury D. (2011) systematizes previous findings by offering a structured review of sustainability learning processes and identifying challenges faced by the educational system. Rieckmann M. (2012) outlines a competency set for higher education aimed at sustainable development. Özsoy S. et al. (2012) demonstrate the value of early environmental education through their study of eco-schools and literacy development. Lozano R. et al. (2013) analyze sustainability declarations in higher education and their impact on institutions' strategies.

Ukrainian scholars have also contributed to this discourse. Kniaz S. (2015) explores eco-information systems in ecological economics and tourism, emphasizing the need for their integration into environmental decision-making. Brych V. et al. (2022) model an information system for environmental risk management in enterprises, proposing algorithmic tools for monitoring and transparency. Letunovska N. Ye. (2023) highlights the economic dimension of sustainable development, advocating for interdisciplinary learning. Hetman A. P. and Anisimova H. V. (2023) examine climate legislation, framing environmental education within legal systems. Kniaz S. et al. (2023) propose a methodological approach to information support in business risk management, linking digitalization to environmental responsibility and resilience. Carrington D. (2024) provides journalistic insight into school-based climate education, reflecting public concern and demand. Tolochko S. V. (2024) systematizes approaches to developing students’ environmental competence, offering a holistic vision of environmentally responsible education for youth.

Thus, the authors of the reviewed works contribute significantly to the development of an organizational model for youth ERE, considering the issue from various perspectives—educational, managerial, legal, and socio-economic. They demonstrate that effective environmental education should be integrated, competency-based, and grounded in an interdisciplinary approach. Therefore, the aim of this article is to develop an organizational model of youth ERE in the context of climate change and risk management. To achieve this goal, the following objectives must be accomplished: classification of climate-related risks; development of a methodological approach for their comprehensive assessment; and formation of an organizational model for youth ERE.

**METHODS.** For the combined assessment of climate change risks, several interrelated methods and models have been applied, enabling the evaluation of both physical environmental changes and their socio-economic consequences. One of the key methods used is Monte Carlo simulation, which is employed for modeling possible climate scenarios and assessing the probabilities of extreme weather events. This approach accounts for uncertainty and variability in climate projections, which is particularly important for long-term risk assessment. The GIS method is applied for spatial analysis of climate change impacts, particularly for identifying areas most vulnerable to sea level rise, water resource depletion, or soil degradation. The use of geographic information systems allows for the visualization of risks, the creation of threat maps, and the planning of adaptation measures. Scenario analysis is used to model potential climate change developments, based on projections from the Intergovernmental Panel on Climate Change (IPCC). This approach evaluates the impact of different greenhouse gas emission scenarios on temperature, precipitation, and other climate parameters, allowing for an assessment of potential consequences for the economy, ecology, and society. The vulnerability analysis method identifies regions and economic sectors most sensitive to climate change, taking into account adaptation capacity and critical threshold values for human activity. This is essential for planning mitigation measures and the effective allocation of resources. The discounted cash flow (DCF) method is used to assess the financial risks of climate change, enabling the estimation of future economic losses due to climate impacts while considering the costs of adaptation measures. This approach is crucial for developing economically justified adaptation strategies for businesses and public administration. The Big Data method is applied for processing large datasets of climate, economic, and social information, providing more accurate forecasts and minimizing subjectivity in risk assessments. To reduce subjectivity in determining weight coefficients during risk evaluation, the analytic hierarchy process (AHP) and Shannon entropy method are used. These methods allow for the determination of the significance of various risk factors based on both expert assessments and objective statistical data. Thus, the organizational mechanism of environmentally responsible education (ERE) is based on the integration of innovative approaches to climate risk assessment, analytical methods, and adaptation strategy development, preparing new generations for future environmental challenges. In the process of forming the organizational mechanism of ERE, climate risk assessment results were considered, leading to the development of an adaptive educational model. This was achieved through a multi-vector development approach, integrating environmental education, technological innovations, and economic analysis into a unified system for fostering environmental awareness among youth. One of the key approaches is the use of scientifically grounded methods in educational programs, including the analysis of climate threats through GIS technologies and simulation modeling using the Monte Carlo method. This enables students to acquire theoretical knowledge and develop practical skills in climate risk assessment.

**RESEARCH RESULTS.**

**1. Development of a classification of risks associated with climate change**

The formation of an organizational model for environmentally responsible education (ERE) for youth is impossible without understanding the risks associated with climate change, as these risks define the necessity for changes in approaches to environmental education and societal behavior. Climate change affects all spheres of life, posing threats to natural ecosystems, economic development, and public health, which necessitates preparing young people for effective responses to these challenges. Awareness of risks is a primary task since, without understanding the scale of the problem, it is impossible to foster responsible attitudes toward the environment and encourage a proactive stance in addressing environmental issues. However, merely understanding threats is not sufficient to overcome them; thus, mastering risk assessment methods plays a key role. Acquiring risk assessment approaches lays the foundation for effective risk management, which is the next critical stage in shaping environmentally responsible behavior. Risk management involves developing adaptation strategies based on economically justified solutions, including DCF methods for assessing the financial consequences of climate change and scenario analysis methods for determining optimal ways to minimize negative effects. Mastering these tools enables young people to make rational decisions regarding carbon footprint reduction, optimal use of natural resources, and the implementation of sustainable environmental practices in daily life. Thus, the starting point for developing an organizational model of ERE for youth is general environmental awareness, a deep understanding of climate change risks, and proficiency in analytical methods for their assessment and management. Without these components, it is impossible to prepare youth for effective responses to environmental challenges and active implementation of innovations in environmental conservation. The formation of such a model should be based on the integration of scientific knowledge, technological solutions, and practical skills, allowing young people to adapt to climate change and contribute to its mitigation. The conducted research enabled the development of a classification of climate change-related risks (Table 1).

**Table 1**

**Classification of Climate Change-Related Risks and Corresponding Risk Assessment Methods**

| **Classification Features and Types of Risks** | **Risk Assessment Methods** |
| --- | --- |
| **By Nature of Origin:** Natural, Technogenic, Anthropogenic | **GIS Method, Monte Carlo, Expert Assessment** |
| **By Consequences:** Economic, Social, Environmental, Political | **DCF Method, Vulnerability Analysis, Scenario Analysis** |
| **By Temporal Impact:** Short-term, Medium-term, Long-term | **Monte Carlo, Scenario Analysis, DCF Method** |
| **By Territorial Coverage:** Local, Regional, Global | **GIS Method, SWOT Analysis, Vulnerability Analysis** |
| **By Predictability:** Predictable, Unpredictable | **Monte Carlo, Scenario Analysis, Expert Assessment** |
| **By Sphere of Impact:** Industrial, Agricultural, Infrastructure, Financial, Medical | **SWOT Analysis, Vulnerability Analysis, GIS Method** |
| **By Nature of Impact:** Direct and Indirect | **DCF Method, Monte Carlo, Expert Assessment** |
| **By Level of Management:** National, Corporate, Municipal, International | **SWOT Analysis, Expert Assessment, GIS Method** |

**2. Development of a methodological approach to comprehensive risk assessment**

Among the risk assessment methods, there are both objective approaches and those that involve a degree of subjectivity. To minimize the latter, it is essential to use quantitative approaches, mathematical modeling, and automated analysis. The Monte Carlo method evaluates probabilistic scenarios, GIS analysis provides a spatial assessment of risks, and scenario analysis is based on scientifically grounded models such as the RCP framework from the IPCC. Vulnerability analysis takes into account real regional parameters, eliminating subjective evaluations, while the DCF method allows for the estimation of the economic consequences of climate change. Machine learning and Big Data reduce human influence through automated data analysis. The optimal approach is to combine these methods: Monte Carlo and GIS determine the probabilities and spatial localization of risks, scenario analysis combined with DCF forecasts economic consequences, and Big Data along with vulnerability analysis enhance the accuracy of predictions. For a comprehensive assessment of climate change risks, an integration of these methods is proposed, allowing for the consideration of probable scenarios, their spatial distribution, financial consequences, and critical vulnerability points. The stages of this approach are presented in **Table 2.**

**Table 2**

**Stages of the Proposed Comprehensive Approach to Climate Change Risk Assessment**

| **Stages** | **Methods and Descriptions** |
| --- | --- |
| **Data Collection and Information Preparation – Big Data, GIS** | Utilizing big data (satellite images, meteorological data, socio-economic indicators). GIS applications enable the territorial mapping of climate risks (drought zones, flooding, land degradation) |
| **Formation of Climate Scenarios – Scenario Analysis, GIS** | Developing alternative climate change scenarios based on IPCC models (e.g., RCP 2.6, RCP 4.5, RCP 8.5). GIS is used to model changes in the territorial distribution of risks. |
| **Vulnerability Analysis of Territories and Economic Sectors – Vulnerability Analysis, GIS** | Identifying regions and sectors (agriculture, transportation, urban infrastructure) most exposed to risks. Assessing their adaptation potential. |
| **Simulation Modeling of Consequences – Monte Carlo, DCF** | Conducting simulations of variable risks (e.g., probability of extreme weather events) followed by financial loss assessment. The DCF method is used to calculate climate change-related losses considering discounting. |
| **Integrated Risk Assessment – Big Data, GIS, Monte Carlo** | Analyzing results based on big data, spatial visualization, and a scenario-based approach. |
| **Development of Risk Management Measures – DCF, Vulnerability Analysis, GIS** | Evaluating the cost of risk mitigation measures, their effectiveness, and their impact on the economic resilience of regions and sectors. |

The advantage of the proposed methodology is its comprehensive approach, which combines qualitative and quantitative methods for a thorough assessment of climate change risks. Its flexibility allows for application in economics, ecology, and infrastructure. The use of big data and modeling enhances the accuracy of forecasts, while GIS methods provide spatial visualization of threats. The DCF method evaluates economic losses and the feasibility of adaptation measures. The integration of these tools minimizes subjectivity and creates an effective forecasting system based on objective data. Below, we describe the mathematical toolkit of the proposed comprehensive approach to climate change risk assessment:

1. **Data Collection and Information Preparation**  (Big Data, GIS): де  - **Sets of climatic, socio-economic, and spatial parameters**. **Data Collection Function**:  **where**   - **A multidimensional dataset formed through integration with GIS systems and big data**.

2. **Formation of Climate Scenarios (Scenario Analysis, GIS).** Alternative climate change scenarios are determined based on IPCC models. Let - **A set of climate change scenarios.** The formation of scenarios will be represented through a probabilistic distribution:  **where**  - **Predicted Temperature;**  - **Greenhouse Gas Emission Level**;  - **Precipitation Amount**;  - **Wind Speed.** The GIS system generates a spatial risk map:  **where**  - **Scenario Impact Indicator**   **At the point**  .

3. **Analysis of Territorial and Economic Sector Vulnerability (Vulnerability Analysis, GIS).** We propose assessing vulnerability through the vulnerability index : де  - **Climatic Factor**;  - **Economic Vulnerability**;  - **Social Vulnerability**;  - **Weight Coefficients.** Thus, the spatiotemporal risk function: 

4. **Simulation Modeling of Consequences (Monte Carlo, DCF).** Simulation modeling is conducted for each scenario. The Monte Carlo method is applied to assess the probability of losses:  де  - **Probability Distribution Function of Possible Losses**; [*a, b*] – **Range of Possible Values.** The DCF method determines the present value of losses ():  **where**  - **Expected Losses in Year *t***;  - **Discount Rate**;  - **Forecasting Horizon.**

5**. Integrated Risk Assessment (Big Data, GIS, Monte Carlo).** Based on the obtained assessments, we will construct an aggregated risk index: **wher**  - **Weight Coefficients**;  - **Spatial Risk**;  - **Vulnerability Index.**

6. **Development of Risk Management Measures (DCF, Vulnerability Analysis, GIS).** The economic efficiency of adaptation measures is determined: де  - **Cost-Effectiveness Ratio**;  - **Benefits from the Implementation of Measures in Year *t***;  - **Costs of Implementing Measures**.

To reduce subjectivity in determining weight coefficients, a combination of the AHP and Shannon entropy methods is proposed. The AHP method determines the weights of criteria through pairwise comparisons and verifies the consistency of assessments, while the Shannon entropy method analyzes statistical data, identifying the most significant factors without expert judgment. Data normalization, entropy calculation, and dispersion measures allow for an objective evaluation of criteria. The integration of these methods eliminates human bias, ensures a balance between theoretical and empirical assessments, and enhances the accuracy of climate risk analysis and adaptation strategies. Let us examine the application of the proposed comprehensive approach to climate risk assessment using empirical data. The results of the calculation of key indicators are presented in **Table 3.**

**Table 3**

**Results of the Calculation of Indicators Characterizing Climate Change Risks in Ukraine**

| **Regions of Ukraine** | **Years** | ***IR*** | ***СВА*** |
| --- | --- | --- | --- |
| Northern | 2020/2024 | 0,71/0,78 | 2,22 |
| Central | 2020/2024 | 0,72/0,77 | 2,32 |
| Eastern | 2020/2024 | 0,62/0,77 | 2,30 |
| Southern | 2020/2024 | 0,78/0,81 | 2,31 |
| Western | 2020/2024 | 0,93/0,71 | - |

Data analysis indicates an increase in climate risks in Ukraine in 2024 compared to 2020, particularly in the Northern region, where financial losses rose from 5.47 billion UAH to 18.61 billion UAH. At the same time, losses in the Central region decreased, but CO₂ emissions remain high, while in the Eastern region, financial risks remain significant. The climate vulnerability index has increased in all regions, confirming the necessity of adaptation measures. Proposed solutions include infrastructure improvements, the development of energy-efficient technologies, afforestation, and the establishment of climate monitoring systems. The assessment of the effectiveness of these measures using the CBA coefficient confirmed their economic feasibility (ranging from 2.23 to 2.32 across different regions), indicating that benefits exceed costs by more than twice. The most prioritized directions are the further development of energy-efficient technologies, ecosystem protection, and infrastructure improvement to minimize financial risks.

**3. Formation of an organizational model of ERE for youth**

The conducted research allows us to conclude that ERE in the context of climate change should be based on scientific approaches to risk assessment and be integrated into the education and public awareness system. This is due to the necessity of fostering youth awareness of the impact of climate change on the natural environment, economy, and social processes. The proposed organizational model (**Figure 1**) incorporates a comprehensive risk assessment approach using methods such as Monte Carlo, GIS, scenario analysis, DCF, Big Data, and vulnerability analysis. Its key objective is to cultivate environmental responsibility by developing critical thinking based on environmental risk analysis and the application of scientific forecasting methods.

**Fig. 1. Organizational Model of Youth ERE**

The development of environmental management includes the integration of modern technologies (GIS, Big Data, Monte Carlo, DCF) for risk assessment, scenario forecasting, and financial analysis. A crucial direction is the support of youth initiatives aimed at community ecological adaptation and the implementation of "green" innovations. The formation of environmental culture occurs through educational, social, and practical programs that stimulate a conscious attitude toward natural resources.The proposed model combines scientific-analytical, educational, social, technological, and economic approaches, ensuring the objectivity of assessments through analytical methods and mathematical modeling. The implementation of climate monitoring tools using Big Data and GIS improves forecast accuracy, while the development of partnerships between educational institutions, businesses, and government structures facilitates the effective application of the model. Youth are trained to analyze financial risks of climate change using the DCF method, enabling informed decision-making. Additionally, the integration of artificial intelligence and machine learning enhances the accuracy of risk assessments. The preparation of youth for environmental decision-making is carried out through interactive learning, digital platforms, and collaboration with international organizations. Thus, the proposed model promotes a scientifically grounded approach to environmental education, encouraging youth to implement innovations and develop adaptation strategies in response to climate challenges.

**Conclusions.** 1. The development of a classification of climate change-related risks is a key step in designing an effective adaptation and mitigation strategy. Its practical application enables efficient climate change monitoring, forecasting for regions with the highest vulnerability, and identifying priority measures to minimize losses. The integration of GIS analysis, the Monte Carlo method, and vulnerability analysis helps identify territories and economic sectors requiring priority protection, while scenario analysis assists in evaluating the probability of various risk scenarios for the development of adaptation strategies and climate threat reduction. 2. The development of a methodological approach for comprehensive climate risk assessment involves the use of mathematical models and big data processing technologies for objective threat analysis. This includes the application of the Monte Carlo method to assess the probability of extreme weather events, GIS methods for spatial visualization of risks, scenario analysis for climate change forecasting, and the DCF method for evaluating economic losses. The practical significance of this approach lies in the ability to integrate the obtained results into government decision-making processes, infrastructure planning, and the development of regional adaptation strategies. The use of vulnerability analysis allows for the assessment of territorial adaptation capacity, considering urbanization levels, ecosystem conditions, and socio-economic factors. The application of the Shannon entropy method and AHP helps determine the most significant risk criteria and minimizes subjectivity in the assessment process. This enhances forecast accuracy and supports the development of well-founded decisions for preventing the consequences of climate change at various levels of governance. 3. The development of an organizational model for youth ERE is a crucial step in preparing the new generation for effective climate risk management. The proposed model integrates scientifically grounded methods of climate threat assessment into the education system, fostering critical thinking and environmental responsibility. The practical implementation of this model includes the introduction of interdisciplinary educational programs covering climate scenario analysis, the use of GIS technologies, economic evaluation of climate change impacts, and the development of innovative environmental projects. Particular emphasis is placed on engaging youth in practical research, including the use of Big Data, analytical risk forecasting, and the development of adaptation strategies for specific regions. A key element of the model is the collaboration between educational institutions, government agencies, businesses, and non-governmental organizations, promoting a holistic approach to environmental education. Encouraging youth initiatives in sustainable development, conducting practical training sessions, and implementing digital platforms for experience exchange contribute to increasing environmental literacy and preparing youth for the implementation of ecological projects. This enables the creation of an education system that informs about climate challenges and develops practical skills for addressing them, which is critically important for ensuring sustainable societal development.

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