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DEVELOPMENT OF A MATHEMATICAL MODEL OF THE SPREAD OF DUST AND SALT PARTICLES FROM ECOLOGICALLY DAMAGED SOIL SOURCES

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Abstract. *The growing focus on ecological issues has led to extensive research on the dispersion of harmful particles. Numerical modeling is used to simulate these particles and track their concentration changes. Key indicators, such as soil physical and chemical properties, are considered in the modeling process. This simplifies the process, allowing for more accurate mathematical models that predict harmful particle behavior. This approach enhances understanding of ecological processes and supports strategies for mitigating harmful particle effects and improving environmental management practices.*

Keywords: *mathematical model, distribution of harmful soils and salts, agricultural production, optimality, Aral Sea region.*

РАЗРАБОТКА МАТЕМАТИЧЕСКОЙ МОДЕЛИ РАСПРОСТРАНЕНИЯ ПЫЛЕВЫХ И СОЛЕВЫХ ЧАСТИЦ ИЗ ЭКОЛОГИЧЕСКИ ПОВРЕЖДЕННЫХ ПОЧВЕННЫХ ИСТОЧНИКОВ

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Аннотация. *Растущее внимание к экологическим проблемам привело к обширным исследованиям дисперсии вредных частиц. Численное моделирование используется для имитации этих частиц и отслеживания изменений их концентрации. Ключевые показатели, такие как физические и химические свойства почвы, учитываются в процессе моделирования. Это упрощает процесс, позволяя создавать более точные математические модели, которые предсказывают поведение вредных частиц. Такой подход улучшает понимание экологических процессов и поддерживает стратегии смягчения воздействия вредных частиц и улучшения методов управления окружающей средой.*

Ключевые слова: *математическая модель, распространение вредных почв и солей, сельскохозяйственного производства, оптимальность, Приаралья.*

EKOLOGIK JIHATIDAN ZARARLANGAN TUPROQ MANBALARIDAN CHANG VA TUZ ZARRALARI TARQALISHINING MATEMATIK MODELINI ISHLAB CHIQISH

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Annotatsiya. *Ekologiya muammolariga e'tibor kuchayib borayotgani zararli zarrachalarning tarqalishi bo'yicha keng ko'lamli tadqiqotlar olib borildi. Raqamli modellashtirish ushbu zarralarni simulyatsiya qilish va ularning konsentratsiyasi o'zgarishini kuzatish uchun ishlatiladi. Modellashtirish jarayonida tuproqning fizik-kimyoviy xossalari kabi asosiy ko'rsatkichlar hisobga olinadi. Bu jarayonni soddalashtiradi va zararli zarrachalar harakatini bashorat qiluvchi aniqroq matematik modellarni yaratishga imkon beradi. Ushbu yondashuv ekologik jarayonlarni tushunishni kuchaytiradi va zararli zarrachalar ta'sirini yumshatish va atrof-muhitni boshqarish amaliyotini takomillashtirish strategiyalarini qo'llab-quvvatlaydi.*

Kalit so'zlar: *matematik modeli, zararli tuproq va tuzlarning tarqalishi, qishloq xo'jaligi ishlab chiqarishi, optimalligi, Orolbo'yi.*

Introduction. In the Republic of Uzbekistan, special attention is paid to the rational use of natural resources on irrigated lands. The Action Strategy for the Development of the Republic of Uzbekistan for 2017-2021 sets the task of "Modernization and advanced development of agriculture" Further optimization of arable land through the placement of agricultural products.

In our country, the need for rational use of water resources is becoming increasingly urgent. In conditions of limited water resources, a modern approach to their efficient use is required.

Optimizing the specialization and strategic placement of agricultural production based on the principles of rational natural resource utilization is a challenge that encompasses a broad spectrum of interconnected factors. This challenge is not only intricate but also demands a comprehensive understanding of the various environmental, economic, and social dimensions involved. As such, the pursuit of effective strategies to optimize agricultural production holds paramount importance in ensuring the sustainability and efficiency of agricultural practices.

The integration of advanced methodologies, such as mathematical modeling, systematic analysis, and other quantitative techniques, plays a pivotal role in tackling this complex issue. These methodologies enable the identification of optimal solutions by simulating various scenarios, analyzing potential outcomes, and guiding informed decision-making. The positive impact of these approaches has been well-documented, as they facilitate the alignment of agricultural practices with environmental sustainability and economic viability.

Furthermore, the use of optimization models in the creation of comprehensive databases for one-dimensional, multidimensional, and intermediate analyses represents a forward-looking approach in agricultural science. These models not only enhance the precision of data analysis but also contribute significantly to improving the overall quality of agricultural products. By systematically analyzing various factors that influence agricultural production, these models help in refining practices that lead to higher yields, better product quality, and more efficient resource use.

Addressing the ongoing challenge of improving agricultural product quality necessitates a systems approach. This approach involves an in-depth exploration of how agricultural practices interact with the environment and requires a thorough consideration of environmental phenomena. By adopting a holistic view that integrates environmental, economic, and social considerations, the systems approach ensures that agricultural practices contribute positively to the sustainability of ecosystems.

Moreover, the systems approach is intrinsically connected to the need for incorporating diverse methodological principles. These principles are essential for enhancing the effectiveness of intermediate

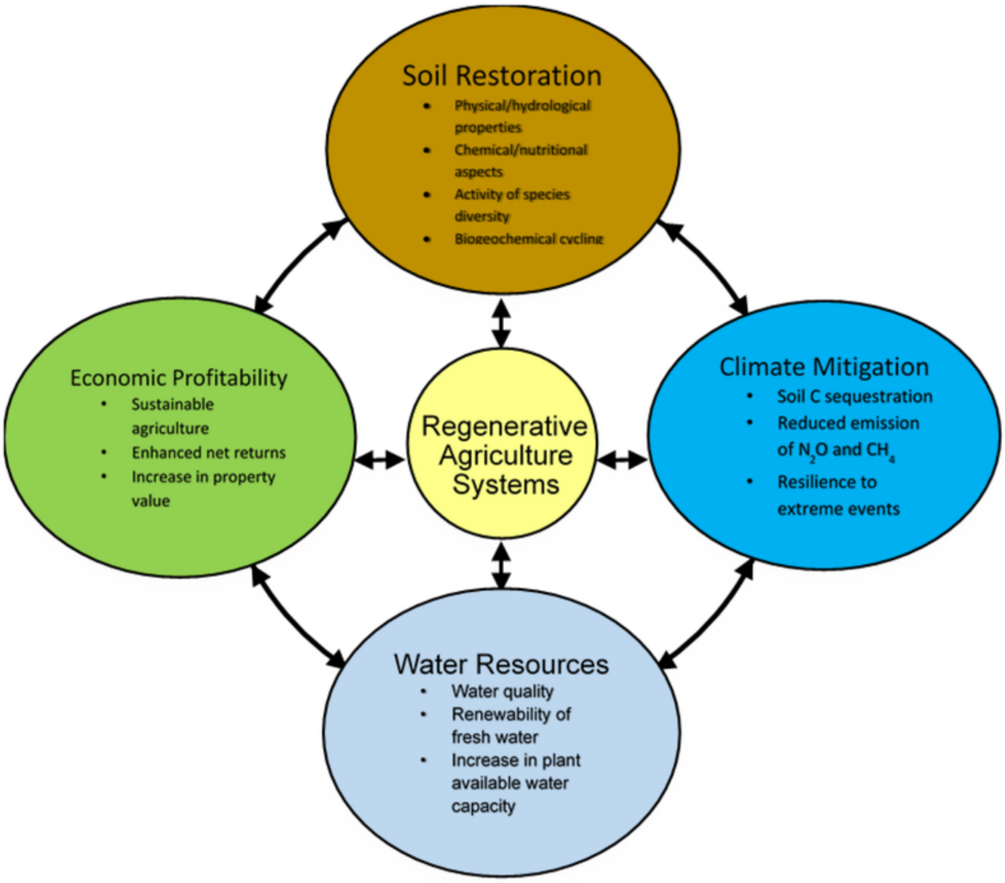

Fig. 1. Basic principles of system analysis of production at an agricultural enterprise.

analyses, which are critical for understanding the complex interactions between different variables in agricultural systems. Optimizing these methodologies during the development process is crucial for achieving more accurate and reliable results. The importance of these principles is extensively discussed in the scientific literature, highlighting their relevance in contemporary agricultural research and practice [1].

In research, the optimization of agricultural production through strategic specialization and placement, supported by advanced analytical techniques and a systems approach, represents a critical area of research with significant implications for sustainable development. The integration of these methods ensures that agricultural practices are not only efficient and productive but also aligned with the broader goals of environmental stewardship and economic resilience.

In this work, the principle of the methodology of the systems approach to the analysis of production of agricultural enterprises and the most important directions are presented as follows (Fig. 1).

Analysis and optimization of the agricultural production system. The development of agricultural production systems requires a multifaceted approach that not only addresses immediate production needs but also considers long-term sustainability and adaptability. The principle of development plays a crucial role in this context, as it emphasizes the importance of thoroughly analyzing the existing agricultural production system to identify areas for optimization. This principle is foundational for creating and refining optimization models that enhance the efficiency, effectiveness, and sustainability of agricultural production processes [3].

By adopting the principle of development, agricultural enterprises can systematically improve their production systems. This involves developing robust optimization models that are tailored to the specific needs and conditions of agricultural production. These models must be dynamic, capable of evolving with changing environmental conditions, market demands, and technological advancements. As the agricultural production system is analyzed and optimized, the methodologies used for modeling these systems will also be continuously refined. This ongoing improvement ensures that the agricultural production system remains responsive to new challenges and opportunities.

The principle of structuring is equally important, as it requires agricultural enterprises to organize and manage data systematically. This principle mandates that initial data be structured in a way that accurately reflects the current state of agricultural production and facilitates the resolution of optimization problems. Structuring involves categorizing information arrays based on their distinct characteristics, functions, and relevance to the optimization process. By following this principle, enterprises can effectively break down complex systems into manageable components, making it easier to analyze and optimize each part of the production process.

Structuring also plays a key role in understanding the object of analysis. By examining the structure of the analysis object and organizing data sequentially, agricultural enterprises can form a coherent structure that aligns with the logical flow of the production system. This structured approach leads to the segmentation of the analysis object into relatively independent components, each of which can be analyzed separately. The insights gained from analyzing these individual components are then synthesized to address the primary objectives of the optimization process. This systematic organization of information arrays ensures that the data is both relevant and actionable, facilitating the development of targeted production optimization models.

The principle of integrity is essential for creating a reliable information base that supports comprehensive analysis and decision-making. Integrity in data management ensures that the agricultural production system is analyzed as a whole, rather than as a collection of isolated components. This principle enables the transition from individual process models to an integrated system of models, allowing for a holistic understanding of the entire agricultural production environment. An integrated model system supports the implementation of predictive models, which are crucial for forecasting future developments and making informed decisions that enhance production sustainability and efficiency.

Furthermore, the principle of flexibility, encompassing adaptation and correction, is critical for ensuring that agricultural production systems can respond effectively to changing conditions. This principle requires the preparation and analysis of data at multiple levels, including one-dimensional, multi-dimensional, and intermediate levels. Data must be aligned not only with the current state of agricultural production but also with future forecasts. Flexibility in data management allows agricultural enterprises to adapt their production strategies to evolving environmental conditions, market trends, and technological innovations. This adaptability is essential for the continuous improvement of production efficiency and the long-term sustainability of agricultural systems.

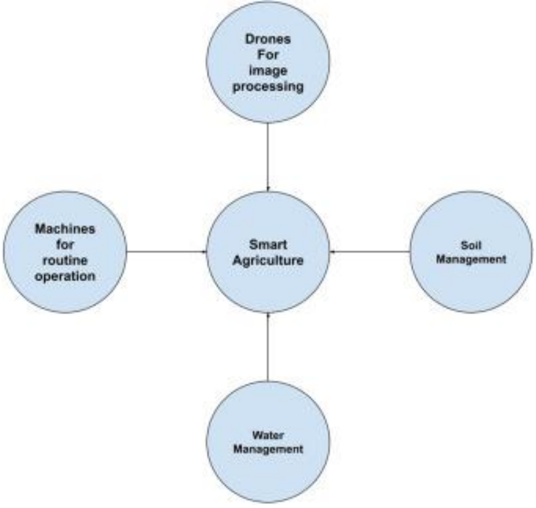

Fig. 2. Monitoring agricultural essentials.

By integrating the principles of development, structuring, integrity, and flexibility, agricultural enterprises can create a more resilient and efficient production system. These principles ensure that optimization efforts are comprehensive, adaptive, and capable of responding to both current demands and future challenges. The systematic application of these principles leads to a more sustainable agricultural production system, one that is better equipped to maintain long-term productivity, protect natural resources, and contribute to environmental sustainability (Figure 2) [5-6].

Moreover, the integration of these principles supports the overall goal of enhancing the quality and sustainability of agricultural products. By employing optimization models, systematic analysis, and strategic decision-making, agricultural enterprises can improve the quality of their products while minimizing environmental impact. This holistic approach not only addresses the immediate needs of agricultural production but also contributes to the broader goal of achieving sustainable development in agriculture. Through the continuous application and refinement of these principles, agricultural production systems can evolve to meet the challenges of the future, ensuring food security, economic viability, and environmental stewardship.

The principle of variability is fundamentally crucial in the strategic planning and forecasting of agricultural systems. Given the unpredictability and uncertainty surrounding the influence of various external factors—such as climate change, market fluctuations, and technological advancements—on the future development of agricultural systems, it becomes imperative to construct scenario-based plans that anticipate the potential impacts of these variables. The unwavering importance of this principle lies in its ability to provide a flexible and adaptive planning framework that is akin to the rigorous planning required in agricultural production. By crafting scenario plans that incorporate both optimal and adverse conditions, agricultural planners can categorize these plans based on their qualitative characteristics. For example, a scenario plan developed under the assumption of ideal conditions might be considered reliable and robust, whereas a plan that takes into account unfavorable conditions might be classified as less dependable or contingent [2-3].

Moreover, the principle of dynamism emphasizes the necessity of conducting real-time analyses of the agricultural production system within a dynamic and evolving context. This principle asserts that the analysis should not only reflect the current state of agricultural production but should also project future trends and developments over a specified reporting period. A critical aspect of this principle is the requirement for dynamic interim forecasting, which extends its predictive capabilities to cover upcoming years or specific future intervals, thereby ensuring that planning remains responsive to changing circumstances (Figure 3). The successful implementation of this principle is facilitated by the deployment of a dynamic interim forecasting system, which continuously updates and refines predictions in response to new data and emerging trends [4].

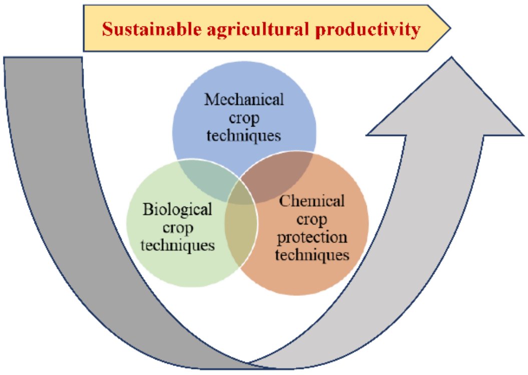

Fig. 3. Critical Aspects of Agricultural Production.

The principle of optimality is paramount in the enhancement of agricultural production processes. It calls for the comprehensive application of optimal planning strategies, which are designed to achieve specific objectives while being flexible enough to accommodate varying scenarios based on changing environmental, economic, and social conditions. Optimality requires the development of plans that maximize the objective functions, which serve as the benchmarks for the optimization process. Implementing this principle involves a meticulous process of selecting and justifying optimization criteria, a task that is complicated by the complex and interconnected nature of agricultural systems. The need to balance diverse performance indicators—such as yield, resource efficiency, and environmental sustainability—requires a thorough and integrated assessment. An inadequate or inappropriate selection of optimization criteria can lead to suboptimal outcomes, particularly in terms of the system’s ability to adapt to real-world conditions [5-6].

The principle of optimization is intricately connected to the development and application of ecological-economic models, which are essential tools for the strategic planning and optimization of agricultural systems. These models are designed to create optimal plans based on a wide range of criteria, thereby ensuring that all relevant efficiency metrics are systematically considered. The optimization process is not merely about achieving the best possible outcome in isolation but about creating a balanced and sustainable approach that integrates ecological, economic, and social dimensions of agricultural production.

Equally significant is the principle of efficiency, which focuses on the analysis and optimization of production processes within agricultural enterprises. This principle is centered on improving the overall functioning and productivity of the enterprise by ensuring that resources are utilized in the most effective and sustainable manner. Adhering to the efficiency principle enables the creation of comprehensive and integrated databases that are suitable for various levels of analysis—whether one-dimensional, multidimensional, or intermediate. These databases serve as the foundation for informed decision-making and strategic planning in agricultural production. Furthermore, by applying the efficiency principle in the analysis and optimization of experimental calculations, agricultural enterprises can achieve significant reductions in the time and material costs associated with information processing, as well as the mathematical, software, and technical support needed to implement these processes [7].

To further elevate the quality and effectiveness of analysis and production planning within agricultural enterprises, it is essential to fully integrate and operationalize these principles. The successful implementation of these principles, when guided by a systemic approach, will be enabled through the use of advanced systemic mathematical modeling of economic processes. This approach allows for the exploration and understanding of logical, informational, and algorithmically interconnected models of complex agricultural systems. By employing these models, agricultural enterprises can make more informed decisions, develop more effective strategies, and ultimately achieve their long-term goals of sustainable development and increased productivity.

In summary, the integration of variability, dynamism, optimality, and efficiency principles into the planning and analysis processes of agricultural production systems is not only beneficial but necessary for achieving sustainable and resilient agricultural practices. These principles provide a robust framework for navigating the complexities of modern agriculture, enabling enterprises to adapt to changing conditions, optimize their operations, and contribute to the overall sustainability of the agricultural sector. Through the comprehensive application of these principles, agricultural enterprises can enhance their production processes, improve resource efficiency, and achieve a balance between economic growth and environmental stewardship.

Results. The dried bed of the Aral Sea in Central Asia, now an arid expanse dotted with salt flats, stands as a stark example of environmental degradation and its far-reaching impacts. This once-vast body of water has shrunk dramatically, leaving behind exposed land that has become one of the primary sources of toxic salts, pesticide residues, and dust particles that are now routinely swept into the atmosphere by the region's winds. The environmental consequences of this transformation are severe, contributing to a broad array of ecological and public health challenges, not just within the immediate vicinity but also across vast distances as airborne pollutants travel far from their point of origin.

In addressing these pressing issues, this section presents a detailed mathematical model specifically developed to describe the propagation of dust and salt particles emanating from these ground-based sources of heavy and light aerosols. The model is sophisticated, taking into account the complex interplay of meteorological conditions—such as wind speed and direction, temperature, and humidity—that influence the dispersal patterns of these particles. By simulating different weather scenarios, the model provides critical insights into how and where these particles are likely to travel, settle, and impact the environment.

Moreover, to tackle the ongoing challenges of monitoring and forecasting the region's ecological state, a robust suite of mathematical and software tools has been developed. These tools are integral to making informed management decisions, particularly in the context of environmental remediation and protection efforts. The software system is designed to consider a comprehensive range of factors, including the rate of soil erosion, prevailing weather and climate conditions, and the specific physical and chemical properties of the aerosol particles being studied. This multifaceted approach allows for a more accurate and nuanced understanding of the environmental dynamics at play.

Additionally, the software's predictive capabilities enable stakeholders to anticipate potential environmental crises and develop proactive strategies to mitigate their impact. For instance, by identifying areas at greatest risk of contamination or degradation, resources can be allocated more effectively to safeguard vulnerable ecosystems and communities. This proactive stance is crucial not only for addressing the current environmental challenges but also for preventing further degradation and ensuring the long-term sustainability of the region’s natural resources.

In essence, the integration of mathematical modeling and advanced software tools represents a critical step forward in the management of the Aral Sea region’s environmental crisis. By providing a detailed and predictive understanding of how harmful particles spread and interact with the environment, these tools are essential for crafting effective interventions aimed at restoring and protecting the region's ecological balance. This holistic approach underscores the importance of combining scientific innovation with strategic environmental management to address one of the most significant ecological challenges of our time.

To forecast the spread of aerosols in the environment, determine their concentration in the area under consideration $D$and assess the amount of aerosols deposited on the underlying surface, the corresponding mathematical model will be used [8-15]:

$$\frac{\partial\theta}{\partial t}+u\frac{\partial\theta}{\partial x}+v\frac{\partial\theta}{\partial y}+\left(w-w_g\right)\frac{\partial\theta}{\partial z}+\sigma\theta=\mu\Delta\theta+\frac{\partial}{\partial z}\left(k\frac{\partial\theta}{\partial z}\right)+Q\delta(x,y,z); \quad (1)$$

$$\theta(x,y,z,0)=\theta_0(x,y,z); \quad (2)$$

$$-\mu\frac{\partial\theta}{\partial x}\bigg|_{x=0}=\gamma(\theta-\theta_a);\ \mu\frac{\partial\theta}{\partial x}\bigg|_{x=L_x}=\gamma(\theta-\theta_a); \quad (3)$$

$$-\mu\frac{\partial\theta}{\partial y}\bigg|_{y=0}=\gamma(\theta-\theta_a);\ \mu\frac{\partial\theta}{\partial y}\bigg|_{y=L_y}=\gamma(\theta-\theta_a); \quad (4)$$

$$-k\frac{\partial\theta}{\partial z}\bigg|_{z=0}=\gamma(\beta\theta-F_0); \quad (5)$$

$$-k\frac{\partial\theta}{\partial z}\bigg|_{z=H}=\gamma(\theta-\theta_a). \quad (6)$$

When $H=0$ we have an elevated source at the level $z=H$ $(F_0=0)$. of ground sources$F_0\neq 0$ $(Q=0)$.

The expression (1)- (6) in the region $D=(0<x<a, 0<y<b, 0<z<H)$, when the source is located in the ground layer (Fig. 4). In Fig. 4, the “crosses” indicate above-ground sources of atmospheric pollution [1-5].

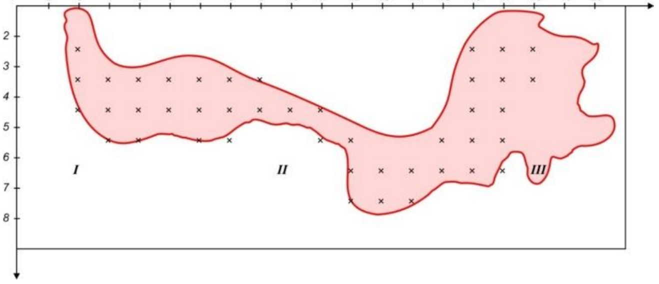

Fig. 4. Location of sources on the surface of the dried-out region of the Aral Sea region.

The value F_0 is a function of x,y,z,t and must be determined from experimental data depending on meteorological conditions, properties of the underlying surface, size and density of dust particles.

To determine this, k let's consider the following models:

1. $k=const, u,v,w$ - $const$;
2. $$k=\begin{cases} v+k_1\cdot\frac{z}{z_1}, z\leq h,\\ v+k_1\cdot\frac{h}{z_1}, z>h,\end{cases} \quad v=|v|\cdot z^n;$$
3. $k=k(z), v=v(z), w=w(z)$,

where h is the height of the surface layer, v is the turbulent viscosity.

Data analysis conducted to assess the influence of various meteorological and climatic conditions on particle transport from the earth's surface has highlighted that the key factor driving soil erosion is the velocity of the incoming air flow. In contrast, soil moisture is identified as the principal element influencing the intensity of the erosion process. While it is true that other parameters can also affect the progression or prevention of erosion, their impact is often complex and difficult to predict with precision due to the variability of environmental conditions.

To address these challenges, it is essential to incorporate a range of parameters into mathematical models that simulate the spread of harmful particles and their concentration changes over time. Such models must account for the velocity of air flows, soil moisture levels, and additional meteorological factors that can influence particle transport. Given that physical and chemical properties of the soil, such as texture, composition, and cohesion, are relatively stable, they can be treated as constant values in the computational formulas.

Incorporating these factors into the mathematical modeling process allows for a more comprehensive understanding of how soil erosion and particle dispersion evolve under varying conditions. This approach not only aids in predicting the potential impact of erosion but also supports the development of effective strategies for managing and mitigating its effects. Accurate modeling can inform the design of interventions aimed at controlling soil erosion and improving environmental quality by providing insights into how different factors interact and contribute to the overall erosion dynamics.

Furthermore, by leveraging advanced mathematical and computational techniques, such as numerical simulations and scenario analysis, researchers and practitioners can explore a wide range of potential outcomes based on different combinations of meteorological and soil conditions. This level of analysis helps in refining predictions and making more informed decisions regarding soil conservation practices and environmental management strategies.

Ultimately, the goal is to enhance our ability to predict and manage soil erosion and particle transport in a way that minimizes environmental degradation and promotes sustainable land use practices. By continuously refining and validating mathematical models with empirical data, we can improve our understanding of these complex processes and develop more effective solutions to address the challenges posed by soil erosion and its associated impacts.

Discussion. The dispersion of harmful particles in the atmosphere and the dynamics of soil erosion are significantly influenced by wind speed and soil moisture, though these factors impact the processes in distinct ways. Specifically, an increase in wind speed is known to exacerbate erosion processes by enhancing the transport of particles from the soil surface. Conversely, an increase in soil moisture acts to mitigate these processes by improving soil cohesion and reducing the likelihood of particle detachment.

According to the research outlined in study [8], the overall relationship between wind speed and soil moisture with respect to soil erosion can be expressed through a general mathematical framework. This framework captures the interplay between these parameters and their combined effect on the erosion dynamics. The model can be formulated as follows:

$$F_0 = f(u, w). \tag{7}$$

Here F_0 is the volumetric flow rate of particles carried away by the atmospheric front, m^3/s.

To establish the type of function (7), it is necessary to analyze the forces that contribute to the destruction of the soil and counteract this destruction. We will denote the destructive forces as F. They are opposed by the resistance forces R, which include such parameters as soil moisture and other physical and mechanical properties.

The process of soil erosion and removal of harmful particles from the surface begins when the force F exceeds the force R. The force of destruction F is determined by the magnitude of the shear stress created by the oncoming air flow. At the same time, with an increase in the number of solid particles in the flow, the total shear stress affecting the soil increases.

To obtain a theoretical dependence, we

consider the process under equilibrium conditions. In a state of dynamic equilibrium, the difference between the forces F and R must be equal to zero, that is:

$$F - R = 0. \tag{8}$$

Let us formulate an expression for these forces. The relationship between the volumetric flow rate F_0 of the entrained particles and the flow velocity is expressed as

$$F = \frac{\partial F_0}{\partial u} \cdot \chi, \tag{9}$$

where χ is the shear stress, kg/m^2.

For the resistance force R, by analogy with F, we take the expression

$$R = c_0 \frac{\mu_c}{l} \frac{\partial F_0}{\partial \zeta}, \tag{10}$$

Where μ_c– viscosity of the mixture (air + soil), kg * s/m^2; l – distance between individual particles, m; c_0 - soil constant.

Substituting (9) and (10) into (8), we have

$$\frac{\partial F_0}{\partial u} \chi - c_0 \frac{\mu_c}{l} \frac{\partial F_0}{\partial \zeta} = 0 \tag{11}$$

or

$$\frac{\partial F_0}{\partial u} - c_0 \frac{\mu_c}{l\chi} \frac{\partial F_0}{\partial \zeta} = 0. \tag{12}$$

Let us consider a separate expression $c_0\mu/(l\chi)$ in equation (12).

If we approximately assume that the shear stress is determined by the value of the external velocity u_∞, i.e. $\chi = u_\infty$, then this expression in equation (12) can be represented as

$$c_0\mu_c/(l\chi) = c_0\mu_c/(lu_\infty). \tag{13}$$

In expression (13), the dynamic viscosity of the mixture is $\mu_c$mainly determined by the soil moisture, which enhances the adhesion between individual particles. Based on expression (13), it can be assumed that the soil constant depends on some function of moisture:

$$c_0\mu_c/(lu_\infty) \cong c_0' f(\zeta). \tag{14}$$

In the future, we replace the function $f(\zeta)$ with a simple dependency

$$f(\zeta) \cong c_0 c_0' \zeta. \tag{15}$$

Finally, dependence (14) takes the form

$$c_0\mu_0/(lu_\infty) \cong c_0 f(\zeta) \cong c_0 c_0' \zeta = k_p w, \tag{16}$$

where k_p is the soil constant, s/m.

Returning to expression (12), we obtain

$$\frac{\partial F_0}{\partial u} - k_p \zeta \frac{\partial F_0}{\partial \zeta} = 0. \tag{17}$$

Thus, an equation has been formulated that makes it possible to calculate the volume of particles carried away from the soil surface, taking into account its humidity and the speed of the approaching air flow. Having determined the value of the volumetric flow rate of particles F_0 and applied the boundary condition (5), it becomes possible to solve the problem of the transfer and diffusion of pollutants in the atmosphere.

Conclusion. Since problems (1)-(6) are represented by multidimensional partial differential equations with prescribed initial and boundary conditions, deriving analytical solutions to these equations is notably intricate. These equations often embody complex interactions and dependencies across multiple dimensions, making exact solutions challenging to obtain. To tackle these challenges, an implicit finite-difference scheme with second-order accuracy in time has been utilized. This numerical method involves discretizing both the spatial and temporal domains, which transforms the continuous partial differential equations into a set of discrete algebraic equations. These discrete equations are then solved iteratively to approximate the solution at specific points in time and space. The implicit finite-difference method is particularly advantageous because it enhances the stability and convergence of the solution, even in the presence of complex boundary conditions and varying initial states. Unlike explicit methods, which can be prone to instability and require small time steps to maintain accuracy, the implicit scheme allows for larger time steps and maintains accuracy through its implicit formulation. This is crucial when dealing with dynamic systems where the behavior changes rapidly over time. In practice, the application of this scheme involves setting up a grid that covers the entire spatial domain and discretizing the time into discrete intervals. At each time step, the implicit scheme updates the state of the system based on the previous time step's information, incorporating the effects of spatial interactions and boundary conditions. This iterative process continues until the solution converges to a stable state that accurately represents the behavior of the system over time. The implementation of this approach allows for effective simulation and analysis of complex systems described by partial differential equations, facilitating insights into the behavior of phenomena such as particle dispersion, soil erosion, and other related processes. The numerical solutions obtained through this method provide valuable data for further analysis and decision-making, contributing to a deeper understanding of the underlying dynamics and aiding in the development of strategies for managing and mitigating related issues.

REFERENCES

1. Kabulov A., Yarashov I. Mathematical model of Information Processing in the Ecological Monitoring Information System //2021 International Conference on Information Science and Communications Technologies (ICISCT). – IEEE, 2021. – C. 1-4.
2. Yarashov I. Algorithmic Formalization Of User Access To The Ecological Monitoring Information System //2021 International Conference on Information Science and Communications Technologies (ICISCT). – IEEE, 2021. – C. 1-3.
3. Yarashov I., Normatov I., Mamatov A. THE STRUCTURE OF THE ECOLOGICAL INFORMATION PROCESSING DATABASE AND ITS ORGANIZATION //International Conference on Multidimensional Research and Innovative Technological Analyses. – 2022. – C. 114-117.
4. Kabulov A., Kalandarov I., Yarashov I. Problems Of Algorithmization Of Control Of Complex Systems Based On Functioning Tables In Dynamic Control Systems //2021 International Conference on Information Science and Communications Technologies (ICISCT). – IEEE, 2021. – C. 1-4.
5. Yarashov I., Normatov I., Mamatov A. ECOLOGICAL INFORMATION PROCESSING TECHNOLOGIES AND INFORMATION SECURITY //International Conference on Multidimensional Research and Innovative Technological Analyses. – 2022. – C. 73-76.
6. Kabulov, A., Normatov, I., Kalandarov, I., & Yarashov, I. (2021, November). Development of An Algorithmic Model And Methods For Managing Production Systems Based On Algebra Over Functioning Tables. In 2021 International

Conference on Information Science and Communications Technologies (ICISCT) (pp. 1-4). IEEE.

7. Турдымамбетов И.Р., Мамбетуллаева С.М., Бекмуратов Б.М. Современное состояние окружающей среды в регионе Южного Приаралья// технологии социальной работы в различных сферах жизнедеятельности: материалы Международной научно-практической конференции. – Махачкала: Апробация, 2019. – С. 161-164.
8. Тлеумуратова Б.С., Мамбетуллаева С.М. Мустафаева Р. Моделирование выноса солей с обсохшего дна Аральского моря и его последствий// Эффективные исследования современности: сб. научных работ X Международной научной конференции Евразийского Научного Объединения. – Москва: ЕНО, 2015. – 242 с.
9. Батыщев Д.И., Шапошников Д.Е. Многокритериальный выбор с учетом индивидуальных предпочтений// ИПФ РАН. Ниж. Новгород. 1994. 29 с.
10. Гиматудинов Ш.К. Физика нефтяного и газового пласта. Изд. 2, перераб. и доп. М.: Недра, 1971, 312 С.
11. Грандберг А.Г., Суслов В.И., Суспыцин С.А. Многорегиональные системы: экономико-математическое исследование// Новосибирск: Сибирское Научное Издательство, 2007. -371 с.
12. Рафиков А.А. Природные условия осушающегося южного побережья Аральского моря. – Ташкент: Фан, 1982. – 142 с.
13. Ляшенко И.Н., Михалевич М.В., Утеулиев Н.У. Методы эколого-экономического моделирования// Монография Нукус. Билим, 1994. -211 с.
14. Шарипов Д.К, Модели и алгоритмы систем мониторинга и прогнозирования загрязнения атмосферы промышленных регионов: дисс. канд. наук. – Ташкент, 2017. – 137 с.
15. Нахшиниев Б.Р., Сато Т. Численное моделирование распространения пыли с высохшей акватории аральского моря // Доклады Академии наук Республики Таджикистан. – 2009. – Т. 52, №4. – С. 301-307.
16. Акулич И.Л. Математическое программирование в примерах и задачах [Текст]: Учеб. пособие / И.Л. Акулич. - 2-е изд., испр. - Санкт-Петербург; Москва; Краснодар: Лань, 2009. - 347 с.
17. Ногин В.Д. Линейная свертка критериев в многокритериальной оптимизации. «Исскуственный интелект и приниятия решения» // Российская Акамия наук. Вып. 4/2014. 73-82 с.