WAYS TO PREVENT AND MANAGE WIND EROSION PROCESSES

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Abstract. This article examines the ecological, economic, and agronomic consequences of wind erosion processes in Uzbekistan and the measures for diagnosing and preventing them based on mathematical modeling. In particular, the dynamics of dust storm processes caused by anthropogenic factors in the Aral Sea region, their regional impact, the degradation of soil fertility, and their adverse effects on agricultural production are scientifically analyzed. The main goal of the study is to develop a comprehensive model for managing wind erosion and automated monitoring systems.
Keywords: wind erosion, dust storm, soil protection, mathematical modeling, ecological safety, agro-technology, Aral Sea region.

Introduction. Wind erosion is a soil degradation process in which fine soil particles are blown away by strong winds, leading to a decrease in organic matter content and soil fertility. It mainly occurs in arid and semi-arid zones. Factors such as improper agrotechnical measures, outdated reclamation systems, soil compaction, and destruction of vegetation cover directly contribute to the intensification of wind erosion.

Today, wind erosion is not only an environmental issue for Uzbekistan but also a global problem affecting many countries. Of the 4 million hectares of irrigated land in Uzbekistan, 3 million hectares are exposed to varying degrees of wind erosion. Each year, a significant portion of productive land is degraded due to dust storms. In the Aral Sea basin, this process has intensified due to anthropogenic factors, water scarcity, and secondary salinization of soils.

This issue not only affects soil fertility but also poses serious risks to public health, ecosystem stability, infrastructure, transportation, and energy systems. Therefore, combating wind erosion is one of the key factors in ensuring sustainable agriculture, domestic food security, and ecological protection.

Globally, this problem is also relevant, and countries such as the USA, Canada, Australia, China, and those in the Middle East have implemented national programs to reduce wind erosion and manage agro-ecosystems.

Wind erosion processes cause significant damage to the national economy, especially agriculture and the environment. In Uzbekistan, wind erosion is most widespread in

the western and central parts of the Fergana Valley, as well as the regions of Bukhara, Surkhandarya, and Kashkadarya.

Particularly, the anthropogenic desertification and secondary salinization around the dried Aral Sea — caused by intensive farming and the development of new lands — have intensified wind erosion processes, leading to more frequent and severe dust storms.

The processes of wind erosion and dust storms are also widespread in the United States and Canada, the Mediterranean region, the Middle East, India, Pakistan, China, South Africa, Australia, and several other countries, posing great threats to agriculture.

Therefore, combating wind erosion is a strategically important issue in the development of agriculture.

In order to improve the environmental conditions of the region, it is essential to thoroughly and systematically study the occurrence of dust storms, their forecasting methods, and measures to protect soil and crops in regions where wind erosion is most pronounced. Analysis shows that where an integrated approach to soil protection measures has been applied, dust storms have significantly decreased. These measures, however, are mostly local and based on uniform methodological principles that consider only soil and climate conditions. Therefore, it is urgent to develop theoretical and practical methods for forecasting, diagnosing, and managing wind erosion processes in the desert and steppe zones of Uzbekistan based on generalized concepts. One such approach is mathematical modeling, which makes it possible to deepen knowledge in this field, improve forecasting and management methods, and design protective measures (efficient and soil-conserving technologies).

Based on research, theoretical and practical methods for diagnosing and forecasting dust storms and managing wind erosion processes (effective protection systems) will be developed.

Reforms in agriculture are directly linked to land resources, their ecological-reclamation conditions, and soil fertility. In irrigated lands where agricultural production takes place, several negative processes are currently reducing soil fertility, among which wind erosion remains a significant factor.

It is known that 64.5% of arable land in our republic is subject to wind erosion to varying degrees, in both local (small-scale) and global (dust storm) forms. As a result of wind erosion, the topsoil is partially or completely degraded over hundreds or thousands of hectares. Millions of tons of fertile soil and planted seeds are displaced with soil particles, causing open drainage systems to clog, young seedlings to die, leading to replanting costs and labor. Yield productivity decreases by 20–30%, and fiber quality significantly declines.

The main factors influencing soil degradation during wind erosion are wind regime, soil structure (aggregates), mechanical composition, moisture, surface condition, and human activities.

In addition to improving the implementation of wind erosion control measures developed by scientists, it is important to forecast, prevent, reduce, and eliminate wind erosion processes, protect soil and crops, improve (manage) the microclimate, and develop protective technology measures — which all indicate the relevance of this issue.

Although extensive research has been conducted in Uzbekistan and abroad to study wind erosion processes and develop control measures, these measures often do not fully consider regional soil-climatic conditions and astronomical parameters. Moreover, theoretical criteria for differentiating risk zones have not been developed. Therefore, there is a lack of theoretical efficiency criteria for proper planning and comparing measures.

This study aims to address the following issues through statistical analysis, diagnosis, and forecasting of dust storm conditions, as well as mathematical modeling and management of wind erosion processes:

1. Applying a systems approach and new mathematical and information technologies in analyzing and diagnosing wind erosion processes, including dust storms.
2. Developing mathematical models and geographic information systems (GIS) for forecasting the occurrence and duration (recurrence dynamics) of wind erosion and dust storms based on agrometeorological parameters, seasonal changes, and solar cycles.
3. Studying the spatio-temporal structure of dust storms — i.e., estimating the likelihood of simultaneous occurrence at two geographic points based on their distance — and implementing modeling and zoning (differentiating similar regions). This geographic approach eliminates existing inadequate planning methods for wind erosion control.
4. Evaluating the effectiveness of wind erosion control measures and systems through quantitative criteria and developing efficient ways to apply information technologies in wind erosion management.
5. Developing an automated system for forecasting dust storm conditions and managing wind erosion processes.

Compared to research conducted in Uzbekistan and abroad, this study highlights that many existing mathematical and software tools for analyzing wind erosion are not tailored to local soil–climate conditions, information database methodology and

principles, system-based approaches, automation, technical-economic indicators, or crop quality parameters.

Moreover, many international studies do not consider Uzbekistan's unique soil–climate conditions, crop varieties, irrigation systems, and other characteristics — nor do they use local meteorological data in modeling and forecasting.

Therefore, this theoretical research is highly relevant.

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