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SPATIAL ORGANIZATION OF GREEN BELTS FOR LAND PROTECTION WITHIN LAND MANAGEMENT PROJECTS

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Abstract. This article examines the territorial organization of green belts and protective shelterbelts based on land management projects to protect agricultural lands from wind and water erosion, conserve soil fertility, and ensure the sustainable use of land resources. The study analyzes the main spatial configurations of green belts for land protection, including contour-based placement, perpendicular placement relative to the prevailing wind direction, rectangular grid, and checkerboard schemes.

Keywords: land protection, green belt, shelterbelt, wind erosion, water erosion, land management, geoinformation technologies, GIS, agricultural landscape.

Annotatsiya. Ushbu maqolada qishloq xo'jaligi yerlarini shamol va suv eroziyasidan muhofaza qilish, tuproq unumdorligini saqlash hamda yer resurslaridan barqaror foydalanishni ta'minlashda yashil belbog'lar va ihota daraxtzorlarini yer tuzish loyihalari asosida hududiy tashkil etish masalalari tadqiq etilgan. Tadqiqotda yerlarni muhofazalashda yashil belbog'larni joylashtirishning kontur, shamol yo'nalishiga perpendikulyar, to'rtburchak panjara va shaxmat sxemalari tahlil qilingan.

Kalit so'zlar: Yerlarni muhofaza qilish, yashil belbog', ihota polosasi, shamol eroziyasi, suv eroziyasi, yer tuzish, geoaxborot texnologiyalari, GAT, agrolandshaft.

Аннотация. В статье исследуются вопросы территориальной организации зелёных поясов и полезащитных лесных насаждений на основе проектов землеустройства в целях защиты сельскохозяйственных земель от ветровой и водной эрозии, сохранения плодородия почв и обеспечения устойчивого использования земельных ресурсов. В исследовании проанализированы основные схемы размещения зелёных поясов для защиты земель, включая контурную схему, размещение перпендикулярно преобладающему направлению ветра, прямоугольную сетчатую и шахматную схемы.

Ключевые слова: Охрана земель, зелёный пояс, полезащитные лесные полосы, ветровая эрозия, водная эрозия, землеустройство, геоинформационные технологии, ГИС, агроландшафт.

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Introduction. Preserving the productivity of agricultural land and ensuring the sustainable use of land resources have become increasingly important scientific and practical challenges amid the intensification of land degradation. Across many regions of the world, wind erosion causes the loss of the most fertile surface layer of soil, thereby reducing the productive capacity of agricultural land. This problem is particularly pronounced in arid and semi-arid regions, where high wind speeds, uneven precipitation patterns, and declining vegetation cover contribute to the intensification of deflation processes. In Central Asia, climate change, recurrent dust and sand storms, and the degradation of agricultural land have further aggravated this problem. In Uzbekistan, the presence of agricultural areas vulnerable to wind erosion in the Kyzylkum, Ustyurt, Karshi, and Central Fergana regions necessitates the development and improvement of effective land protection mechanisms.

In this context, the spatial organization of shelterbelts and green belts for protecting agricultural land against wind and water erosion is of particular importance. The appropriate integration of shelterbelts into existing land-use systems can reduce wind velocity, limit the displacement of soil particles, and contribute to the conservation of soil moisture. However, the effectiveness of shelterbelts depends on a combination of factors, including their orientation, number of tree rows, width, spacing, terrain characteristics, and prevailing wind regime. Therefore, green belts should be designed and spatially organized within land management projects on a scientifically justified basis. Modern geospatial technologies provide an opportunity to integrate and analyze information on wind direction, terrain, soil properties, land use, and existing shelterbelts, thereby enabling the identification of areas with a high risk of erosion. Accordingly, this study examines the potential application of contour-based, perpendicular-to-prevailing-wind, rectangular-grid, and checkerboard configurations for the spatial organization of green belts and proposes a methodological approach for integrating them into land management projects.

Research aim and objectives. The primary aim of this study is to improve the scientific and methodological foundations for the territorial organization of green belts and protective shelterbelts within land management projects in order to protect agricultural land from wind and water erosion, conserve soil fertility, and promote the efficient and sustainable use of land resources.

To achieve this aim, the study focuses on the following objectives: to analyze the natural and climatic conditions, wind regime, soil properties, terrain characteristics, and land-use structure of the study area in an integrated manner; to identify agricultural lands that are highly vulnerable to wind erosion; to assess the current condition and protective functions of existing shelterbelts; to compare alternative spatial configurations for the placement of green belts; to determine optimal shelterbelt locations using geospatial technologies; and to integrate the selected spatial configuration into the land management planning framework. The agricultural lands of Bekabad District were selected as the study area.

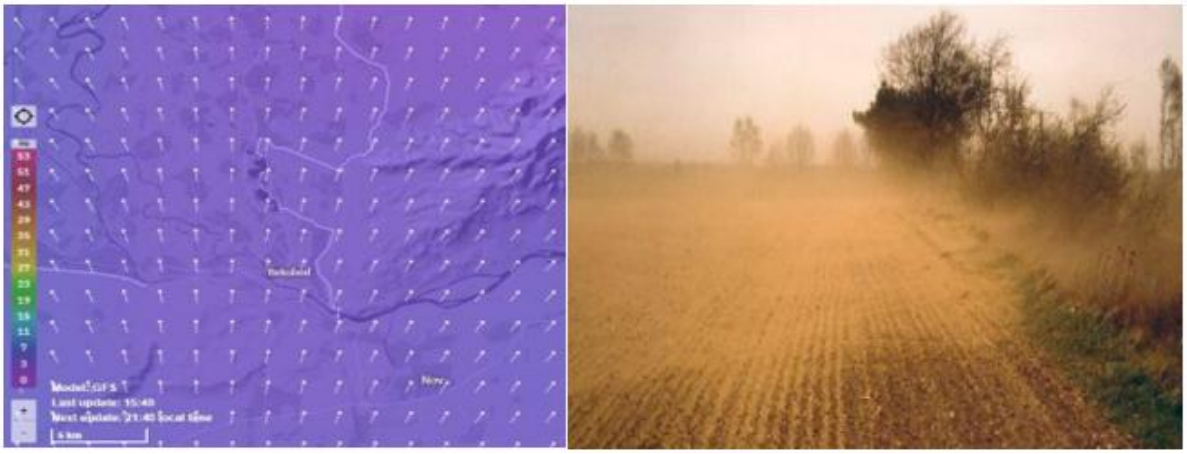
One of the important climatic characteristics of Bekabad District is the occurrence of strong and persistent winds. According to available meteorological information, such winds occur for an average of approximately 52 days per year, generally beginning in November and continuing until March. According to data provided by the Hydrometeorological Service Agency under the National Committee for Ecology and Climate Change of the Republic of Uzbekistan, wind speeds in the area may reach 15–20 m/s; however, observations conducted during the present study indicated that, under certain conditions, wind speeds may reach as high as 42 m/s. The Bekabad wind enters through the Fergana Corridor in the western part of the Fergana Valley and is particularly strong during the winter

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and spring months, with individual episodes lasting from two to five days. Winds blowing from the valley toward Syrdarya Region and the Fergana Valley are locally referred to as the “Bekabad wind” or “Khavosk wind”, whereas winds blowing toward the Fergana Valley are known as the “Kokand wind”. These strong wind events can adversely affect agricultural crops in Syrdarya Region and in the vicinity of Kokand in the Fergana Valley (Figure 1) [5].

Figure 1. ***Map of wind direction and wind flow patterns in Bekabad District.***

Main part. The establishment of protective shelterbelts is one of the long-term agromeliorative measures used to protect agricultural land from wind erosion. However, the mere presence of a shelterbelt does not necessarily ensure a high level of protective effectiveness. Its performance primarily depends on the prevailing wind direction and speed, tree height, shelterbelt width, number of rows, aerodynamic density, and spacing between shelterbelts. In addition, terrain characteristics, soil texture, field configuration, and the existing irrigation infrastructure should be



taken into consideration during the planning and design process.

From this perspective, organizing green belts within the framework of land management projects makes it possible to consider them not merely as tree plantations, but as an integral component of the environmental and productive infrastructure of agricultural landscapes. Under such an approach, shelterbelts are spatially coordinated with field boundaries, internal farm roads, irrigation canals, collector-drainage networks, natural depressions, and other territorial elements. This ensures better compatibility between protective vegetation systems and the existing organization of agricultural land.

The first step in determining the appropriate location of shelterbelts is to establish the prevailing wind regime of the study area. Once the dominant erosive wind direction has been identified, the main shelterbelts should generally be oriented perpendicular to the prevailing wind direction. However, where winds occur from several dominant directions, consideration of only one direction may be insufficient. In such cases, a grid-based protection system consisting of primary and secondary shelterbelts may provide more comprehensive protection.

In areas characterized by complex terrain, protection against wind erosion should be considered together with the risk of water erosion. On sloping land, positioning shelterbelts along contour lines or following approximately contour-based configurations can reduce the velocity of

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surface runoff and limit soil loss caused by water erosion. Consequently, an integrated protection system against both wind and water erosion can be established within the same agricultural landscape.

The application of geospatial technologies is particularly important for the territorial organization of green belts. Within a GIS environment, data on terrain, soil properties, wind characteristics, land use, vegetation cover, and existing shelterbelts can be integrated into a unified spatial database. This enables the identification of areas with a high erosion risk, detection of gaps and discontinuities in existing protective vegetation, and development of alternative spatial configurations for new green belts.

In this regard, the principal function of a land management project should not be limited to allocating land for tree plantations. The project should also specify the spatial position of green belts, row spacing, distances between shelterbelts, the composition of tree and shrub species, irrigation requirements, access routes for maintenance and management, and a system for subsequent monitoring and assessment. Such an integrated approach allows protective vegetation to be incorporated into the overall spatial structure of agricultural land rather than treated as an isolated land-use element.

Research results and discussion. The analysis demonstrates that there is no single universal configuration suitable for the placement of green belts under all environmental and agricultural conditions. The most appropriate configuration for a particular area should be selected based on the combined influence of natural and climatic conditions, wind regime, terrain, soil characteristics, and existing land-use structure.

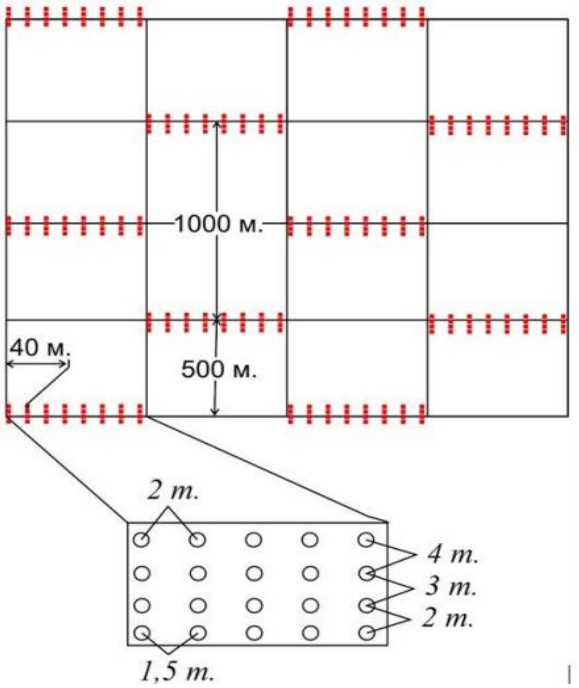
In relatively flat agricultural areas where wind erosion represents the predominant degradation process, the placement of primary shelterbelts perpendicular to the prevailing wind direction is considered an effective approach. In such cases, the spacing between protective shelterbelts should be determined in relation to the expected mature height of the vegetation, prevailing wind speed, and the susceptibility of the soil to deflation. Rather than applying a uniform spacing value to all areas, relating shelterbelt spacing to vegetation height can improve the accuracy and ecological justification of the design.

In areas with complex terrain, contour-based placement becomes increasingly important. Under these conditions, shelterbelts can simultaneously reduce wind flow and regulate the distribution and velocity of surface runoff. Thus, their spatial arrangement can provide complementary protection against both wind and water erosion.

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For large and relatively flat agricultural areas, a rectangular grid system consisting of primary and secondary shelterbelts can be particularly appropriate. Such a configuration divides the agricultural landscape into a series of protected zones, thereby reducing the effective distance over which wind can act across open fields and improving the continuity of the protective vegetation network (Figure 2).

Figure 2. ***Proposed design scheme for the spatial placement of protective shelterbelts.***



In the study, the amount of land occupied by green belts was considered an important criterion for evaluating their overall effectiveness. Excessive expansion of shelterbelts with the sole purpose of increasing the level of protection may reduce the area available for agricultural production. Therefore, the design of green belts should seek an optimal balance between the required level of erosion protection and the efficient use of agricultural land.

The selection of tree species should be based on the specific relief and climatic conditions of the study area. In this regard, species selection should take into account not only the general suitability of a particular species, but also its drought tolerance, resistance to strong winds, adaptability to local soil and moisture conditions, growth characteristics, root-system development, and long-term protective capacity. The appropriate selection and spatial combination of tree and shrub species can substantially improve the stability and longevity of protective shelterbelts. Accordingly, the design process should ensure an appropriate balance between ecological effectiveness and economic efficiency.

The results of GIS-based spatial analysis make it possible to classify the territory according to different levels of erosion risk and to prioritize the establishment of green belts in areas characterized by high erosion vulnerability. Such an approach provides a scientifically grounded basis for preserving

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existing shelterbelts, identifying and eliminating gaps within protective vegetation systems, and locating new shelterbelts in areas where they are most urgently required.

At the same time, the role of green belts should not be assessed solely in terms of their function as windbreak structures. Within agricultural landscapes, they also contribute to the conservation of biological diversity, improvement of the local microclimate, protection of soil moisture, reduction of the adverse effects of wind on soil and crops, and formation of ecological corridors. Therefore, within land management projects, green belts should be regarded as an integrated component of ecological infrastructure designed to ensure long-term land protection and agro-landscape sustainability.

Conclusions, proposals and recommendations. The findings of the study demonstrate that the territorial organization of green belts within land management projects represents an important component of sustainable land management and an effective approach to protecting agricultural land against erosion. The effectiveness of protective shelterbelts is determined not only by the number of tree rows and the width of the shelterbelt, but also by their spatial relationship with prevailing wind directions, terrain characteristics, soil properties, land-use patterns, and the existing green infrastructure.

Based on these findings, it is recommended that the prevailing wind direction and wind speed be systematically incorporated into the design of green belts on agricultural land. Existing shelterbelts should be preserved, rehabilitated, and reconstructed where necessary, while new protective belts should primarily be established in areas characterized by a high risk of erosion. In areas with complex terrain, contour-based and wind-oriented configurations should be combined to provide simultaneous protection against wind and water erosion. In large and relatively flat agricultural areas, grid-based protective systems consisting of primary and secondary shelterbelts are recommended.

The use of GIS and remote sensing data is also recommended for the spatial planning and monitoring of green belts. These technologies make it possible to regularly update erosion-risk maps, remotely assess the condition and continuity of shelterbelts, monitor changes in land cover and wind-exposed areas, and adapt land management projects to changing environmental conditions.

In practical implementation, the spatial arrangement of green belts should be coordinated with agricultural fields, internal farm roads, irrigation and drainage infrastructure, and other elements of the territorial organization of land. The species composition of trees and shrubs should be selected according to local climatic and soil conditions, taking into consideration their ecological adaptability, drought and wind resistance, water requirements, growth characteristics, and protective functions.

Most importantly, green belts should not be regarded merely as isolated tree plantations. They should be planned and established as an integrated territorial system that simultaneously contributes to land protection, agricultural production, ecological stability, and the sustainable management of land resources. Such an approach would allow protective vegetation to become an integral element of land management planning and contribute to the long-term conservation of soil fertility and agricultural productivity.

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