Scientific fundamentals of agricultural landscapes optimization and planning with the use of GIS technologies

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SUMMARY

Economic activity has become and remains a factor significantly affecting the structure of land in Ukraine and causing profound changes in the holocenotic cover. Anthropogenic landscapes, among which agricultural landscapes are dominating, have been created in the place of the natural ones. Violations of the "rule of the limits in natural systems transformation" and ecological balance in the structure of lands, underestimation of reclamation functions of forests and existing functional relationships between landscape components in the process of economic activity have led to the appearance and development of environmental risks intensified by climate change. The possibility of creating conditions that would reduce the negative influence of economic activity on agricultural landscapes with their simultaneous improvement is realized by means of their optimization and planning. The tool used for optimization of agricultural landscapes is landscape planning based on GIS technologies, providing for a substantiation for management decisions (measures) to improve the condition and increase the level of environmental safety of geosystems.

Keywords: agricultural landscapes, optimization, GIS technologies
Introduction

The sphere of human activity is holocoenotic cover - the functional unity of lands of different purposes, on which natural and man-made geosystems function, interacting with each other through intergeosystem relations. Economic activity has become a factor that has been and remains significantly affecting the structure of land, causing profound changes in holocoenotic cover. In the primary holocoenotic cover in the territory of Ukraine 50% were presented by natural forest landscapes, 35% - steppe, 6% - wetlands and 1% - meadow landscapes (Sheliah-Sosonko and Popovych, 2002). Today forests occupy only 15%, wetlands - 1.6% and water covered lands- 4%, in the structure of the land fund.

Anthropogenic landscapes have been created in the place of the natural ones, among which agricultural landscapes predominate (70.9% of the total area). Cropland occupies 54% of the territory of Ukraine. Violations "rules of limits in natural systems transformation" (Rejmers, 1990) and ecological balance in the structure of lands, underestimation of reclamative functions of forests and existing functional relationships between landscape components in the process of economic activity led to the emergence and development of environmental risks intensified by climate change: 1) activation of water and wind erosion; 2) dehumidification and reduction of soil fertility; 3) a significant reduction in the water storage capacity of the territory and, as a consequence, floods and freshets, unproductive water losses on sloping lands due to increased surface runoff, as well as shallowing of rivers in the intermittent periods; 4) surface water pollution, eutrophication and degradation of aquatic geosystems. Therefore, the urgent task is to develop a scientific basis to minimize the negative anthropogenic impact on agricultural landscapes by optimizing and planning.

Theory

Research on the optimization and planning of landscapes is presented in the works of S.A. Hensiruk, M.A. Holubets, M.D. Hrodninskyi, H.I. Denysyk, L.I. Kopii, M.M. Prykhodko, A.P. Stadnyk, A.M. Tretiak, O.I. Furdychka and others. The scientists' conclusions can by summarized by the fact that ecologically unjustified production in agricultural landscapes will lead to desertification, loss of soil fertility and reduction of geosystems ecological potential. Agricultural landscapes are natural landscapes man-transformed (forest, meadow, steppe and wetland) into combined landscape systems, consisting of anthropogenically modified field (crops), meadows (hayfields and pastures) and orchards (orchards and vineyards) among which can be located natural / conditionally natural (forest, meadow, wetland), as well as anthropogenic (road, residential and other) geosystems. This indicates, on the one hand, the complexity of the structural and functional organization of agricultural landscapes, on the other - the relevance of forming their optimal morphological and functional structure to increase the ecological potential of agricultural landscapes, as well as protecting their components (soil, water and air) from degradation as well as the development of environmental risks. The possibility of creating conditions that would reduce the negative impact of economic activity on agricultural landscapes while improving them is realized through their optimization and planning. The optimal agricultural landscape is a territorial complex with an optimized structure (ratio) and spatial location of field, meadow and forest geosystems, the interaction between which provides: 1) achievement of the most efficient energy flows and the cycle of substances in these conditions; 2) the formation of a favourable microclimate and water regime of soils; 3) increasing the stability and productivity of agroecosystems; 4) conservation / restoration of biotic and landscape diversity; 5) prevention of the emergence and development of environmental risks.

The tool used to optimize agricultural landscapes is landscape planning based on GIS technologies (Prykhodko et al., 2019, 2020), which provides a justification for management decisions (measures) to improve the condition and increase the level of environmental safety of geosystems. Agricultural planning is a process of modeling and constructing the organization of their territory. The result of planning is a "construct" - a cartographic model (Figure 1), reflecting the spatial and functional organization of the territory, in particular the territory of the village / settlement council. Planning should ensure the maximum possible increase in the area of forest, meadow and water geosystems and achieve the optimal (balanced) relationship between natural and anthropogenic geosystems.
Optimization and planning presuppose restructuring (reconstruction) of agricultural landscapes by creating territorial systems as close as possible to natural, which are endowed with favorable for human production properties and do not cause negative processes and phenomena in the environment. The peculiarities of the slope-terrace parodynamic ranges must be taken into account, as the slope lands are the main territory on which the reconstruction should be carried out in the first place. When arable land is placed on the slopes due to erosion, the processes of removal of organic matter, soil particles, and mineral elements develop. In addition, man, taking away from the sloping lands with the harvest of organic matter, deepens the processes of impoverishment of such areas. Therefore, the main result of anthropogenic changes is the biochemical depletion of agricultural landscapes. The transit type of migration of substances turns into impoverishment. Therefore, the preservation and increase of the area of vegetation on the sloping lands is a primary and mandatory condition for the optimization and planning of agricultural landscapes.
The existing structure of geosystems in agricultural landscapes should be changed in order to ensure the formation of a complex and mosaic spatial structure, saturation of the agricultural landscapes with buffer-type geosystems, including forest and meadow geosystems, which perform the role of biogeochemical barriers, soil and water protection functions, increase species diversity and ecological capacity. An important consequence of agricultural landscape optimization is that, as geosystems are integrated into interacting functional units, they develop qualitatively new, emergent properties that were absent at the previous ecological level (Odum, 1975). In agricultural landscapes new spatial structures should be created in order to form landscapes in which functions are restored: economic - includes preservation and increase of resource potential; social - involves the formation of a favorable environment for living and recreation of people; ecological - aimed at restoring the mechanisms of biotic regulation and increasing the level of environmental safety.

Improving the structure of land use should be based on the concept of ecological and economic balance, according to which lands occupied by natural geosystems are considered as lands from which the “ecological framework” of the territory is formed. Part of the crop land should be withdrawn from agricultural use (conservation of land), which allows to reduce the level of agricultural development and plowing, concentrate machinery, fertilizers, labour resources and significantly increase the productivity of agroecososes, thus ensuring the production of the same amount of agricultural products. The irrationality of modern land use forms is manifested in the fact that the balance between the lands of different purposes is interrupted. In this regard, A.V. Chaianov wrote in 1924: "... improving the organization of the territory is perhaps the most necessary and most important of agricultural measures, and land management is one of the main branches of economic policy of all agricultural countries". The organization of the territory of agricultural landscapes should provide connection of lands (geosystems) structure and the sizes and forms of fields with structure of natural landscapes. The landscape approach to substantiation of economic activity and use of resource potential gives the chance to carry out an estimation of characteristic features of landscapes, as well as functional typification of the territory on the basis of which to develop optimum ways of landscape complex useNatural territorial systems, especially in the conditions of dissected relief, have a strip structure. Therefore, the most rational form of organization of the territory in agricultural landscapes, which ensures the preservation of the natural spatial structure of the landscape, is strip (contour-strip). It involves the formation of fields considering the features of the terrain and soils, as well as the placement of linear elements (field boundaries, forest belts, roads) along the contour, in the direction of the horizontals (Furdychko and Stadnyk, 2012; Prykhodko, 2017).

There appears a need for a detailed study of the territory, compiling landscape maps with the classification of lands by types of areas and ecological characteristics (soil character, terrain, climate, water regime, the presence of natural plant communities). This approach makes it possible to correctly identify anti-erosion and other reclamation measures that ensure the preservation and enhancement of soil fertility and environmental safety in agricultural production.

The formation of complex and sustainable agricultural landscapes is ensured by creating bioengineering systems (Prykhodko, 2017). Bioengineering systems are formed on the basis of basin and landscape approaches and presuppose: planning of economic activity on river basins; optimization of the structure, parameters and spatial location of field, meadow and forest geosystems, considering the structural and functional structure of landscapes; introduction of crop rotations and soil fertility management system; formation within the river basin (territory of the village council) of a mosaic spatial structure and a natural framework of ecological safety of the territory (ecological network); increasing the water storage capacity of the territory by surface runoff complex regulation (accumulation).

For each river basin, and within its the territories of village / settlement councils, it is necessary to develop land management projects with optimized geosystem ratio, necessary reclamation elements (protective forest plantations, tinned buffer strips, hydraulic structures), road network and other infrastructure components. The optimal ratio of geosystems (field: meadow: forest) within the river basins is respectively: for mountainous areas - 8:10: 20-30: 70-90, for foothills - 30-40: 25-35: 30-50, for plain surfaces - 40-50: 25-30: 20-30.
Conclusions

As a result of priority agricultural development, natural landscapes on the territory of Ukraine have undergone significant changes. The modern landscape structure is dominated by agricultural landscapes, the ecological condition of which is characterized by the manifestation of negative processes and phenomena (environmental risks), in particular: water and wind erosion; dehumidification and reduction of soil fertility; loss of ecological potential and degradation of agricultural landscapes. In order to stop the development of these environmental risks, there is an obvious necessity to optimize and plan agricultural landscapes using GIS technologies, whose task is to form a complex (mosaic) spatial structure, coordinate the location of agricultural geosystems with the spatial structure of the landscape, saturation of agricultural landscapes with geosystems that contribute to their ecosystems. The solution of these problems is provided by creation in agricultural landscapes of bioengineering systems which include organizational, agrotechnical, meadows reclamation, forest reclamation and hydrotechnical actions.

References


