ECOLOGICAL AND ECONOMIC ASSESSMENT OF EFFECTIVENESS OF DISTURBED LAND RECLAMATION IN UKRAINE

Anton Koshel, Iryna Kolhanova, Ruslan Tykhenko, Ivan Openko
National University of Life and Environmental Sciences of Ukraine, Ukraine
koshel_a@nubip.edu.ua , kolganova_i@nubip.edu.ua, rvtyhenko@ukr.net, ivan_openko@ukr.net

Abstract. The environmental and economic assessment of the effectiveness of land management projects for the reclamation of disturbed lands in Ukraine is a topical issue in the context of preserving ecological balance and restoring natural resources. This article is aimed at analysing the impact of land management projects on the ecological state of disturbed lands and their economic feasibility for Ukrainian society. Given the huge ploughing of the territory of Ukraine, especially its steppe and forest-steppe parts, attention should be paid to the use of reclaimed areas as a reserve that ensures the preservation of the gene pool of natural flora and fauna. Focusing on reclamation methods and their impact on the natural environment, the article examines the cost and efficiency of such projects in the context of restoring soil fertility, reducing soil and water pollution, and improving the quality of the natural environment. The results of the study will contribute to the formation of reclamation strategies that will be effective from both an ecological and an economic point of view for Ukraine, especially in the post-war period.

Keywords: reclamation, disturbed land, land management, efficiency, soil.

Introduction

In recent years, the environmental and economic aspects of land management projects have become increasingly critical, especially in the context of the territories of regions that face degradation and land disturbance as a result of military operations. The solution to this problem lies in the need to develop large-scale reclamation projects for disturbed lands. The study of the effectiveness of disturbed land reclamation measures was carried out by such scientists as Dhaliwal, S., Singh, J., Tancja, P. in the context of elimination of the consequences of heavy metal pollution [1]. Kumar M. and others studied the peculiarities of soil recovery [2]. Kawałko D., Karczewska A., Lewińska K. conducted research on soil protection and reclamation of degraded areas, focusing on the environmental risks associated with the accumulation of toxic metalloids in soils [3]. Significant progress was made in Poland for the reclamation of sand pits. The lands disturbed due to sand mining in most cases are used for afforestation [4]. The predominant direction of disturbed land reclamation in Estonia is forestry. Extensive experience has been gained in landscaping dumps after extraction of oil shale, ash dumps of thermal power plants and phosphoritic dumps [5-6]. The mining industry in the US spread almost across the entire territory, so the direction of biological reclamation is chosen according to the soil properties and weather conditions. For example, in the Eastern states forest reclamation dominates, in the Western US – disturbed lands are used for pasture, and in the Midwestern – for farmland [7-8].

These works have had an extraordinary impact on the development of environmental science. Our study, unlike the existing ones aims to assess the ecological and economic efficiency of reclamation of disturbed lands to determine the cost of such works (UAH per hectare). By assessing the environmental impact, cost-effectiveness and socio-economic benefits of these projects, we aim to shed light on their overall effectiveness and identify areas for improvement in future initiatives. Using an interdisciplinary approach that combines ecological principles with economic analysis, we aim to offer insights into the complex interrelationships between land use practices, environmental conservation and economic development. Our findings are expected to help decision-makers, environmentalists and land managers make informed decisions about projects to restore war-damaged land. Ultimately contributing to the long-term environmental health and economic prosperity of Ukraine regions.

Materials and methods

The theoretical and methodological basis of the study is the provisions and principles of the modern concept of sustainable development of territories, the results of research by domestic and foreign scientists, which reveal the institutional nature and basic forms of the process of designing the reclamation of disturbed lands and its environmental and economic efficiency. In the course of the study, the authors used general scientific and special research methods, namely: dialectical – to identify the conditions under which the activities of the participants to the process of disturbed land reclamation are

carried out, their focus, efficiency and effectiveness; analysis – to highlight the role and place of disturbed land reclamation in the system of land relations as a factor of sustainable development; synthesis – to combine various doctrines on the formation of the institution of land reclamation; induction and deduction – to identify shortcomings in the regulatory and legal framework.

Results and discussion

Soil cover is one of nature's most vulnerable objects. As the basis of humanity existence on the planet, soil suffers from unbalanced anthropogenic pressure on the environment. Over the past 50 years, the rate of loss of productive soil has increased 30 times compared to the historical average. Degradation processes have covered almost the entire land use area, which significantly increases the level of risk in agricultural production.

Land reclamation is an integral part of the overall problem of protecting and rationally using natural resources. Mining disturbs soil cover and reduces the area of agricultural and forestry land. Mining operations cause soil destruction, subsidence, and the formation of water bodies. In watersheds, quarry workings lower the water table. Land reclamation is a set of activities aimed at restoring the productivity and economic value of disturbed land, as well as improving environmental conditions.

Industrial quarries are located in different climatic zones, and almost all overburden that makes up external and internal dumps be reclaimed and put to agricultural use. To develop measures for the rational use of waste heaps and increase the fertility of overburden, it is necessary to know the climatic conditions, topography, soil composition and properties, and the characteristics of the plants that will be grown after land reclamation.

The land plot that was the object of the study is located in the forest-steppe zone of Ukraine, in its Right-Bank province, and according to agroclimatic conditions belongs to the second agroclimatic region (sub-region "b") Fig. 1.

Fig. 1. **Map of the land plot that was the subject of the study within Cherkasy region**

The land plot covers an area of 4.5090 hectares. Land category – industrial, transport, communications, energy, defence and other purposes. Purpose – for placement and operation of main, auxiliary and auxiliary buildings and structures by enterprises related to subsoil use. The configuration of the land plot is close to an irregular triangle. The land plot will be used for open-pit mining of the Butske brick clay deposit for the production of ceramic bricks. The quarry is expected to operate for 30 years.

The Butske loam deposit is classified as Group 1 in terms of its geological structure. The terrain within the mining allotment is uneven. The deposit is represented by a hill, which will be developed from south to north.

The mineral deposit is characterised by a thickness of 9.9 m. The soil cover of the land plot under study is as follows: soil code 30 (regraded chernozems), Fig. 2.

In accordance with the laws and regulations of Ukraine, regraded soils are found on flat, elevated areas of watersheds and on gentle slopes. These are mainly dark grey soils and chernozems. The greatest influence on the formation of these soils was made by the herbaceous vegetation that replaced the forest and dramatically changed the soil formation process.

The reaction of the soil solution of these soils is slightly acidic, close to neutral, and therefore the soils do not require liming. The absorbed calcium prevents the destruction and leaching of mineral and organic soil colloids. Regraded soils are moderately supplied with nitrogen (Table 1).

According to Article 52. of the Law of Ukraine **"**On Land Protection**"**, land subject to reclamation is subject to changes in the relief structure, ecological condition of soils and bedrock, and hydrological regime as a result of mining, geological exploration, construction and other activities [9].

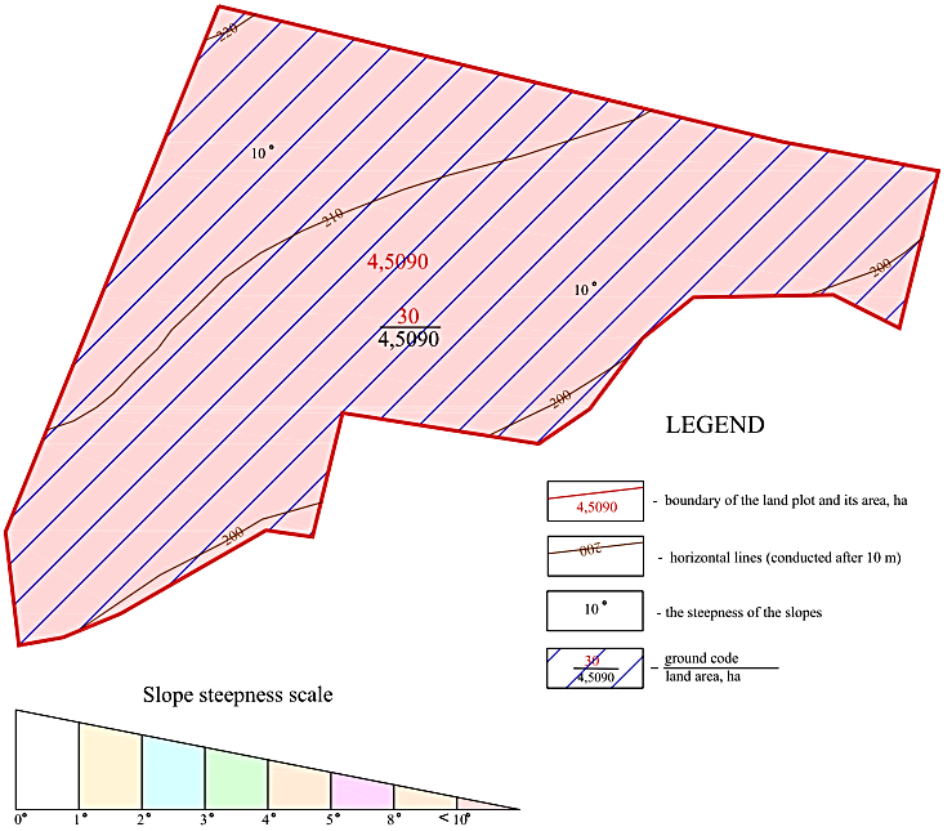

Fig. 2. **Soil cover and slope of the land plot under study**

Table 1

Physical and chemical parameters of regraded soils

Soils	Sample depth, cm	Humus content, %	pH of the salt hood	Hydrolytic acidity	Amount of the absorbed bases	Degree of saturation with the basics, %
				m *eq* per 100 g of soil		
Regraded soils	0-20	3.4 2.6-3.8	6.0 2.6-3.8	2.4 1.3-2.6	25.3 21.9-28.3	91.3 87.0-98.6
	20-40	3.0 1.9-3.4	3.4 2.6-3.8	1.6 0.9-2.0	25.5 20.2-28.5	93.7 91.2-98.2
	40-60	2.32 1.2-3.0	3.4 2.6-3.8	0.9 0.6-1.8	26.2 22.8-30.0	96.7

In the course of mining, exploration, construction and other activities involving disturbance of the soil cover, the separated soil mass shall be removed, stored, preserved and transferred to disturbed or unproductive land plots. When removing the soil cover, the top, most fertile soil layer and other soil layers shall be removed in layers and stored separately in accordance with the structure of the soil profile and the parent rock.

The depth of excavation for regraded chernozems (soil code 30) will be 0.60 m, of which 0.40 m is the top, most fertile soil layer, and 0.20 m is other soil layers.

The main decisions in the implementation of land reclamation measures are as follows: the excavated topsoil should be stored in the northern part of the land plot in temporary dumps No. 1 (other

soil layers) and No. 2 (the top, most fertile soil layer) and protected from destruction by denudation processes (washing, blowing, etc.) through sowing perennial grasses on the surface; after the deposit development is completed, the excavated topsoil will be used for land reclamation measures; reclamation is carried out in two stages: technical and biological (Fig. 3).

Laying out the area with loam. Rough layout of the pit floor. The surface should be graded gradually as the mining front is advanced by a bulldozer. When developing the territory for arable land, its surface is sloped up to 2°, otherwise, slopes are provided to allow for anti-erosion measures. For forestry land, the longitudinal slope should not exceed 10° and the transverse slope should not exceed 4°.

After these works are completed, the restriction dam is thrown into the middle of the site by a hydraulic escalator, followed by the spreading of loam on the sides by a bulldozer.

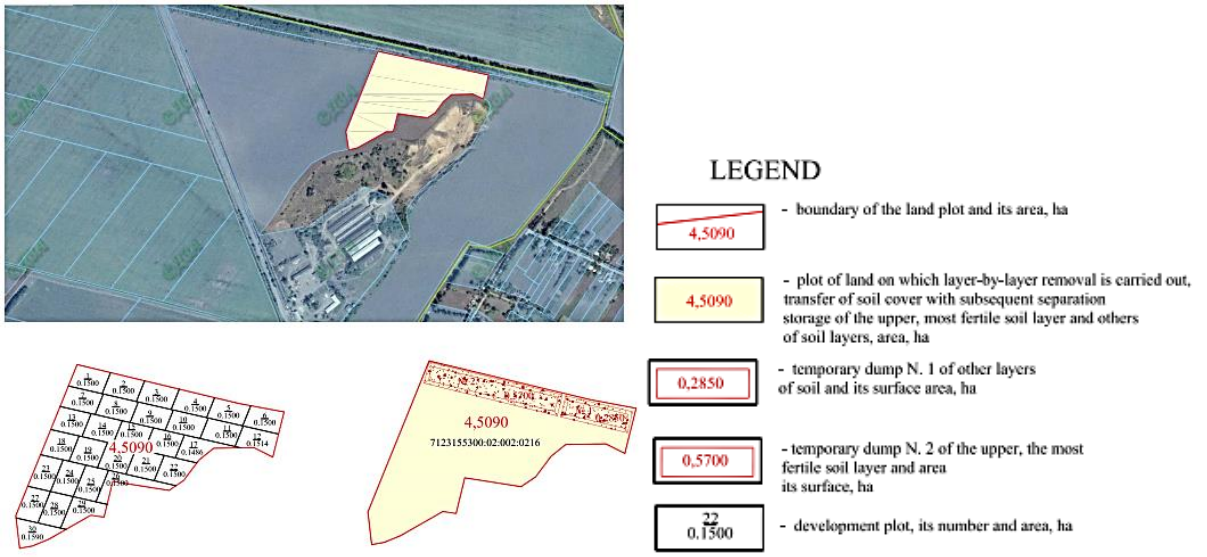

Fig. 3. **Scheme of the main decisions when carrying out activities for removal and storage of soils from a land plot**

Covering and layout of the areas with loam: the area of application is 45090 m^2 in the following directions: forestry, on the sides of the quarry, 5743 m^2; improved pasture at the bottom of the quarry excavation, 39347 m^2.

Application of a fertile soil layer. The next stage involves the application of topsoil. The topsoil is transported from the northern part of the land plot, which was stored in a dump, to the planned site by road and placed in cone-to-cone ridges. The height of the ridge is 1.35 m and the distance between the ridges is 9.6 m. A bulldozer cuts off the tops of the ridge. The cut soil is placed in the inter-row space (layer h = 0.6 m). After completion of the technical stage of disturbed land reclamation and before starting the biological stage of disturbed land reclamation, it is necessary to conduct soil and agrochemical surveys of these land plots to determine the physical and agrochemical properties of the anthropogenically formed soils. The biological stage of reclamation is the final stage of land improvement and includes: reclamation of the open pit, the bottom of which is 39347 m^2 and is being reclaimed for improved pastures (sowing perennial grasses), preceded by deep ploughing and cultivation with harrowing; slopes of the dump sides of 5743 m^2 are being reclaimed as forestry land.

The agricultural reclamation process does not allow for the application of fertile soil to rocks that are unsuitable for their chemical composition and physical properties. The application of the fertile soil layer to the reclaimed surface should be carried out not earlier than in 1.5-2 years. The thickness of the fertile soil layer depends on the natural and climatic conditions: 70 to 80 cm for cereals, 30 to 50 cm for annual and perennial grasses. For sowing on the surface, the following grass mixtures are recommended: tall ryegrass, sainfoin.

In the course of forestry reclamation, assortment of tree and shrub species is selected, and technologies for planting and caring for forest crops are developed. The selection of species for reforestation is based on zonal conditions, physical, chemical, agrochemical and water-physical properties of soils, as well as the intended purpose of the plantations [10]. To create environmentally

sustainable plantations, mixed types of forest crops are created with up to 60% of main species, up to 20% of related species, and up to 20% of shrubs.

When creating forest plantations, the surface topography of reclaimed quarries should be flat and undulating, without closed depressions, which allows the use of machinery for planting trees and cultivating row spacing. Landscaping should be carried out with trees that are not demanding on soil fertility and that provide a productive protective cover. Planting of trees of various local species is allowed [11].

The main solutions for the reclamation of disturbed lands are shown in Fig. 4.

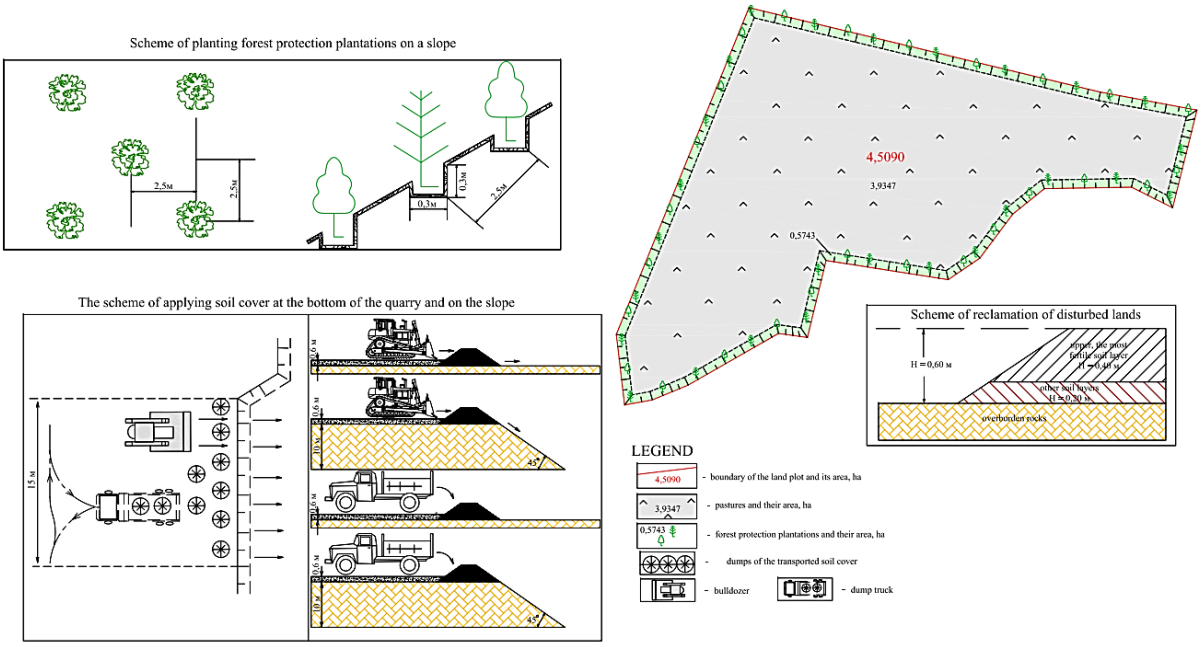

Fig. 4. **Schematic of the main decisions during the technical and biological stage of disturbed land reclamation**

The estimated cost of works related to the reclamation of the above-mentioned disturbed lands is UAH 5634.32 thousand (01.01.2022). Hours estimated salary – UAH 587.83 thousand (01.01.2022). Per hectare, the estimated cost of the disturbed land reclamation works is UAH 1249.57 thousand (01.01.2022). The environmental and economic efficiency of developing reclamation projects can be significant at a cost of UAH 1.2 million per hectare. For example, if the cost of reclamation of one hectare of land is UAH 1.2 million, and the reclamation improves soil quality, increases biodiversity and reduces the risk of environmental pollution, then a significant environmental benefit can be expected. On the other hand, improved soil quality can lead to higher agricultural yields and increased incomes for farmers. Thus, the costs of reclamation are offset by increased land productivity and reduced costs for future pollution remediation. In general, with proper planning and implementation of reclamation projects, it is possible to achieve a positive environmental and economic impact on land resources and the environment. Thus, further use of reclaimed land should be environmentally safe and economically beneficial for the landowner and land user for each hectare of land.

Conclusions

Our research has shown that one of the most effective ways to restore land affected by military operations is to develop projects for the reclamation of disturbed land in order to return it to effective use. At the same time, the study found that the cost of developing such projects in Ukraine under current conditions would be around UAH 1.2 million per hectare. Given more than 20% of Ukraine land area is currently disturbed by hostilities, even this level of expenditure is significant for a devastated economy and will require additional budgetary allocations. In addition, the restoration of degraded land can lead to an increase in property values, tourism revenues and the overall quality of life for local communities. The economic returns from restored land, including increased yields, reduced erosion and improved water quality, exceed the costs incurred during project implementation.

The next stage of research should be to find ways to optimise the process of developing land management projects for the reclamation of disturbed land as a result of military operations. The authors see such an opportunity in the widespread introduction of geographic information systems into the development cycle and the use of artificial intelligence elements to identify land uses to be reclaimed. Such actions will automate a part of the design process and reduce the cost of reclamation of disturbed land by about 40%. By implementing evidence-based policies and investing in sustainable land management practices, Ukraine can achieve its goals of post-conflict recovery, environmental protection, economic development and improving the quality of life for its citizens.

Author contributions

The contribution of each author. Conceptualization, A. Koshel; methodology, A. Koshel, R. Tykhenko and I. Kolhanova; formal analysis, R. Tykhenko and I. Openko; investigation, A. Koshel, I. Kolhanova, R. Tykhenko and I. Openko; writing – original draft preparation, I. Kolhanova; writing – review and editing, A. Koshel and R. Tykhenko; visualization, I. Kolhanova and A. Koshel; project administration, A. Koshel; funding acquisition, I. Openko. All authors have read and agreed to the published version of the manuscript.

References

[1] Dhaliwal S., Singh J., Tancja P. Remediation techniques for removal of heavy metals from the soil contaminated through different sources: a review. Environmental Science and Pollution Research, Vol. 27, 2020, pp.1319-1333.
[2] Kumar M. at al. Mobilization of contaminants: Potential for soil remediation and unintended consequences. Science of the Total Environment, September 15, 2022, 839:156373.
[3] Kawałko D., Karczewska A., Lewińska K. Environmental risk associated with accumulation of toxic metalloids in soils of the Odra river floodplain - case study of the assessment based on total concentrations, fractionation and geochemical indices. Environmental Geochemistry and Health, No. 45, pp. 4461-4476.
[4] Pietrzykowski, M., & Krzaklewski, W. Reclamation of Mine Lands in Poland. In Bio-Geotechnologies for Mine Site Rehabilitation, Elseiver, 2018, pp. 493-513. DOI:10.1016/ b978-0-12-812986-9.00027-0.
[5] Tymchuk I., Malovanyy M., Shkvirko O., Chornomaz N., Popovych O., Grechanik R., Symak D. Review of the global experience in reclamation of disturbed lands. Ecological Engineering & Environmental Technology, No. 22(1), 2021, pp. 24-30.
[6] Lohmus K., Kull A., Truu J., Truu M., Kaar E., Ostonen I. & Kurvits V. The reclamation of the North Estonian oil shale mining area. In Multifunctional Land Use. Springer, Berlin, Heidelberg, 2007, pp. 387-401.
[7] Burger J. Sustainable mined land reclamation in the eastern US coalfields: A case for an ecosystem reclamation approach. In Proceedings of the National Meeting of the American Society of Mining and Reclamation, Bismark, ND, USA, 2011, pp. 113-141.
[8] Schladweiler B. 40 years of the surface mining control and reclamation act (SMCRA): what have we learned in the State of Wyoming. International Journal of Coal Science & Technology, No 5(1), 2018, pp. 3-7.
[9] The Law of Ukraine "On land protection". News of the Verkhovna Rada of Ukraine, July 29, 2003. No. 349
[10] Мартин А., Колганова І. До питання про правила робочого проектування у землеустрої. [To the question about the rules of working design in land management]. Land Management, Cadastre and Land Monitoring, No.4, 2021, pp. 73-93. [in Ukrainian]
[11] Openko I., Tykhenko R., Tsvyakh O., Shevchenko O., Stepchuk Ya., Rokochinskiy A., Volk P., Zhyla I., Chumachenko O., Kryvoviaz Ye., Horodnycha A. Improvement of economic mechanism of rational use of forest resources using discrete mathematics method. Engineering for Rural Development, No. 22, 2023, pp.544-522.