JEE Journal of Ecological Engineering

Journal of Ecological Engineering, 2025, 26(4), 15–27
https://doi.org/10.12911/22998993/197439
ISSN 2299–8993, License CC-BY 4.0

Received: 2024.11.27
Accepted: 2025.01.31
Published: 2025.02.17

Research of the systems of environmental and soil protection technologies in erosion-hazardous agrolandscapes

Adolfs Rucins[1*], Larisa Kolomiiets[2], Ivan Shevchenko[2], Volodymyr Bulgakov[3], Ivan Holovach[3], Oleksandra Trokhaniak[3], Zbigniew Kiernicki[4]

[1] Latvia University of Life Sciences and Technologies, 2, Liela str., Jelgava, LV-3001, Latvia
[2] National Scientific Centre, Institute of Agriculture of NAAS of Ukraine, 2b, Mashinobudivnikiv Str., Chabany vil., Kyiv-Svyatoshin Dist., UA 08162, Kyiv Region, Ukraine
[3] National University of Life and Environmental Sciences of Ukraine, 15, Heroyiv Oborony Str., Kyiv, UA 03041, Ukraine
[4] Lublin University of Technology, Nadbystrzycka 38d, 20-618 Lublin, Poland
* Corresponding author's e-mail: adolfs.rucins@lbtu.lv

ABSTRACT

Land degradation is primarily caused by direct destruction of the natural ecosystems, irrational use and depletion of the land resources, and the growing agrotechnogenic load on soils. Contemporary scientific research has been carried out by means of field route studies and land inventory to determine the geomorphological and soil characteristics of the studied polygons, taking into account the basic principles of application in the geospatial analysis and practical use in the landscape studies by means of the Auto CAD computer program, the boundaries of the polygons – watersheds on raster topographic maps being determined, digitized in the local coordinate system (SK-63). It has been established that the introduction of a set of measures for the conservation of the degraded lands of the sloped agrolandscape systems by stopping intensive economic activity with subsequent use of the land plots as hayfields and pastures, ensured a significant reduction in soil loss due to erosion, while the soil loss on heavily and moderately eroded soils of the studied sites amounted to 2.38–4.19 t·ha^{-1}, which differs slightly from the maximum permissible standard indicators of soil loss for the heavily and moderately eroded soils. The main characteristics of the agrochemical, agrophysical and other properties of the washed-out chernozems have stabilized during the conservation period. At the same time, the humus content in the cultivated soil layer has increased to 3.85%, the optimal values are characterized by the soil acidity pH 7.1–7.3 (close to neutral). Attention has been focused on the specifics of the land conservation by excluding it from economic circulation with its subsequent use as pasture and hay lands.

Keywords: phytomeliorative measures, adaptive-landscape farming system, organizational and economic measures, soil erosion, fertility of the washed-out soils.

INTRODUCTION

The current use of land and climate change have led to a dangerous degradation of the erosive land. According to various estimates, these negative processes have spread to almost 15 million hectares, and, together with the wind erosion – to 20–21 million hectares. Every year, on average, about 15–20 t·ha^{-1} of the fertile soil layer is lost, and the area of the eroded land increases to 100 thousand hectares. When the wind erosion and, especially, the dust storms occur, the soil losses reach 50–100 t·ha^{-1}. The amount of humus, nitrogen, phosphorus and potassium, lost as a result of erosion, significantly exceeds their introduction with organic and mineral fertilizers. Therefore, dehumification and depletion of the soil fertility are observed, which negatively affects not only the yield of agricultural crops but also the ecological condition of agricultural landscapes [Baliuk et al., 2015; Bulyhin et al., 2014; Bulyhyn and Belolynskyi, 2012; Velychko, 2010].

In the greatest part of territories, the risks of erosive degradation, dehumification and depletion of fertility are increasing, associated with both changing the climate conditions and imperfect agricultural practices [Pichura, 2016].

Under the conditions of complex negative relief, the soil cover is particularly affected by such factors as rectangular organization of the agricultural lands, destruction of natural watercourses, deterioration of agrophysical properties of soils, sowing of the row crops on slopes > 3°, destruction or deterioration of the forest belts and antierosion forest plantations, as well as suspension of state and regional programs for the protection of soils from erosive degradation. Along with the increase of temperature in the process of climate change in all natural and climatic zones over the past 30 years, there has been an increase in the torrential nature of precipitation, which, with an increase in the sown areas of such intensive crops as maize and sunflower, increases the risks of water and wind soil [Balabukh, 2008; Bulyhin, 2015].

Consequently, the imperfection of agricultural practices and land management, as well as the underestimation of the impact of natural factors, in particular the climate change, increases the risks of intensified degradation of the agricultural lands, deterioration of the soil quality, and their ability to perform agroecological and biospheric functions in the agrosphere.

In the context of fairly rapid climate changes, intensification of agricultural production, high risks of degradation and desertification of agricultural lands, methods for the timely detection and identification of manifestations of degradation processes as a basic foundation for improving the land use systems and sustainable management of agricultural resources are becoming especially relevant.

At the present time in agricultural practice the main provision of the analysis of ecological and landscape conditions as a balanced relationship between the exploitation, conservation and improvement of the land fund of a specific type and kind of agricultural landscapes of a certain natural and climatic region is missed.

At the same time the development of aerospace survey technologies, automated methods for decoding satellite data and spatial simulation, using a geographic information system (GIS), make it possible to quickly identify and assess the risks of the soil degradation and monitor the ecological state of agricultural landscapes and land use systems [Zubov et al.; Baliuk and Tovakhnianskyi, 2008; Krasovskyi and, Petrosov, 2003; Popov et al., 2012; Weslati and Serbaji, 2024; Aiello et al., 2015; Allafta and Opp, 2022; Borrelli et al., 2013; El Jazouli et al., 2017; Şenol and Taş, 2023; Panagos et al., 2015].

The real threat of global land degradation and, in general, the disruption of the sustainability of the biosphere has caused justified concern in the world community and led to an understanding of the need for concerted and coordinated actions by states and the general population at the interstate level to prevent land destruction and mitigate the effects of drought and degradation.

In several countries a significant information database has been accumulated that characterizes the intensity of soil erosion on slopes, the properties of eroded soils, the effectiveness of individual anti-erosion measures and their complexes [Lialko et al., 2018; Lialko et al., 2017; Lialko et al., 2014; Lialko et al. 2018; Kaminskyi et al., 2021; Rucins et al., 2024].

These facts require increased attention to the study, control and overcoming of erosive degradation, in particular, establishing the scale of degradation processes, identifying current threat.

The problem of determining the role of factors that influence the reduction of the risk of the water erosion processes has been studied by scientists since the middle of the 19th century with the aim to forecast and develop a methods for combating erosion, taking into account the global, regional and local levels. The rate of soil erosion depends on a number of factors, such as the geomorphological features, the soil characteristics, the land using systems, and land management practices [Zuazo and Pleguezuelo, 2009; Shuang et al., 2008; Wang et al. 2022; Jothimani et al. 2024; Udayagee, 2021; Dahanayake et al., 2024].

Over the past decades the factor of the land using system (land ratio) has acquired particular relevance in connection with the large-scale progression of the erosion processes, which are associated with the increase in the arable land, and which, with time, lead to the loss of biodiversity, soil degradation, and deterioration of the environmental services [Dahanayake et al., 2024; Mesfln, 1994].

Thus, the global scientific community faces the need to find ways to solve the problem of rationalizing land use.

The EU countries are pursuing an active land policy to create a balanced system of natural resource management. Thus in Great Britain a concept of a scale of landscape conservation has been developed with the aim to solve the issues of the climate change, and to restore biodiversity in the conditions of a complex landscape [Renard et al., 1991].

In order to preserve and increase the biodiversity in the EU countries, a network of protected areas (Natura-2000) has been created. The elements of this network are types of natural environments (Special Areas of Conservation), rare and under threat of destruction [Renard et al. 1991; Dutta et al., 2015].

Agricultural and management practices play an important role in the control of the soil erosion. For example, the rate of the soil loss decreases exponentially as the vegetation cover increases. The impact of the land usage and management is often parameterized in the covering management coefficient. The researchers propose a methodology for assessment of the covering management coefficient in the European Union (EU), using statistical data about agricultural crops and practices [Terranova et al., 2009; Auerswald, 1992; Auerswald, 2008].

The aim of the research is to determine the soil conservation capacity of technologies for creating a system of phytomeliorative measures (land conservation), to establish patterns of restoration of herbaceous phytocenoses on anthropogenically trans-formed lands in the system of soil conservation agriculture in the context of the risks of increased manifestations of water and wind erosions and determining ways to solve existing problems.

MATERIALS AND METHODS

As a basic territorial unit of research there was chosen an elementary river basin, characterized by a complex structure and mutual dependence relationships between the components, which meets all the requirements of a geosystem, but the integral function of the runoff was chosen by the physical impact, as the main territorial unit of research, through the influence primarily of physical factors, reflecting the development, functioning and state of the natural-territorial complexes.

The main component of the soil conservation farming system is the implementation of a set of measures to optimize the structure of the land use of a specific farm by removing eroded arable and other low-productivity lands, located on slopes with an inclination of 3 degrees or more, from intensive cultivation, expanding the area of the forage lands and forest-covered lands.

When processing the methodological and methodical approaches to determine the directions of efficient use of phytomeliorative measures in the system of adaptive-landscape agriculture of the farm, typical research objects were selected – polygons, their geobotanical and land management field survey was carried out, the characteristics of the studied natural, social and anthropogenic factors within the element (polygons-tracts) were determined. The conducted scientific research is based on the methodology of landscape ecology, landscape science and applied methods of observation and determination by applying the methodological foundations of the land management field route, ecological-geographical and geomorphological studies and research, processing of cartographic materials and results, obtained in the field experiments. The results of the field landscape and landscape-geochemical studies and surveys, geobotanical descriptions of the investigated areas were used. Monitoring studies were conducted to study the dynamics of the species' ecological and biological structure of spontaneously regenerating herbages in the process of their formation in six landscape-geochemical systems – tracts (polygons No. 1–3), and the geomorphological characteristics and condition of the studied polygons were determined. The scientific observations were performed through field route surveys and the land inventory.

The monitoring route studies were carried out at specific and recorded sites (polygons) on the ground (in nature), and on cartographic materials (polygons) at a scale of 1:10.000.

The field and laboratory methods to determine the inter-action of the research object with weather and soil factors; the monitoring route, visual, descriptive, measuring and weighing and calculation – to determine the qualitative characteristics of the grass stands; the chemical – to determine the physical and chemical properties and agrochemical indicators of the washed-out soils; the mathematical and statistical – to determine the reliability of the results obtained; the ecological, economic and soil protection efficiency of the developed technological measures for the formation and reproduction of forage lands on eroded lands of agricultural landscapes.

As the main territorial unit of research there was chosen an elementary river basin, characterized by a complex structure and mutual dependence relationships between its components, which meets all the requirements of a geosystem, and the integral function of runoff, through the influence of primarily physical factors, that reflects the development, functioning and state of natural-territorial complexes [Kovalchuk and Chalov, 1992].

The main morphometric indicators of the relief that were taken into account in the studies are the vertical and horizontal dissection, the value of absolute altitudes, the steepness of the slopes, which are calculated using formulas [Nesterchuk, 2007, Bajrak, 2018], RUSLE (Revised Universal Soil Loss Equation) [Morgan, 1998].

The soil losses due to the water erosion at the study sites (No. 1–3) were determined using the universal equation for soil erosion losses: [DSTU ISO 10390:2022, 2022, DSTU 7862:2015, 2015, DSTU 4289:2004, 2004, DSTU 4115-2002, 2002, DSTU 7537:2014, 2014, DSTU 4770 (1, 2, 3, 4, 6, 7, 9)-2007, 2007, DSTU 7921:2015, 2015].

RESULTS

The results of cartographic and field surveys of the state of land in order to assess the natural resource potential and environmental stability of land use was shown on Figure 1.

In the study area, the rainfall erosion dominates over the meltwater erosion. High-intensity summer precipitation (up to 4 mm per minute) is observed, often falling in layers of more than 50 mm (Fig. 2).

Along with the highly dissected relief and deep (up to 60 m) erosion base, heavy rains are the main factor in the intensive development of the erosion processes (Fig. 3).

The area of the polygon 1 is 20 hectares. Slopes with the western, north western and south-western exposures. The absolute maximum elevation of the earth's surface is 177 meters, the minimum is 127 meters. The average length of the slopes is 149.1 meters, the steepness is 4.024% (Fig. 4).

Results fortypical chernozems and highly degraded chernozems, moderately eroded, light loamy presented in Figure 5. The slopes are blackened and covered with grassy vegetation. The

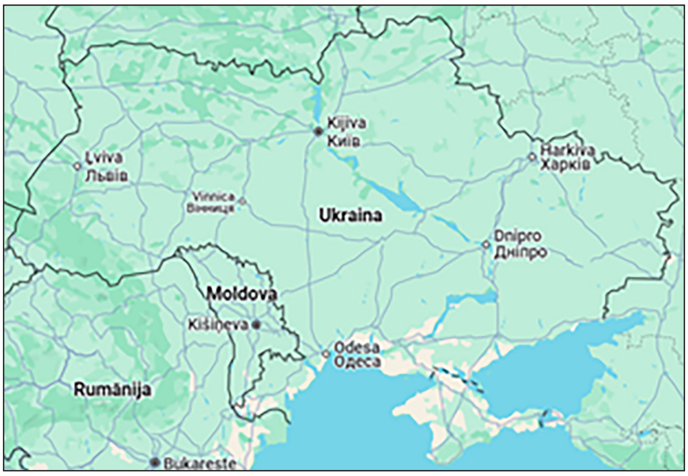

Figure 1. Cartographic representation of the research site

Figure 2. Erosion situation on intensively cultivated arable lands of sloping agricultural land-scapes

Figure 3. Monitoring the development of the water-erosion processes

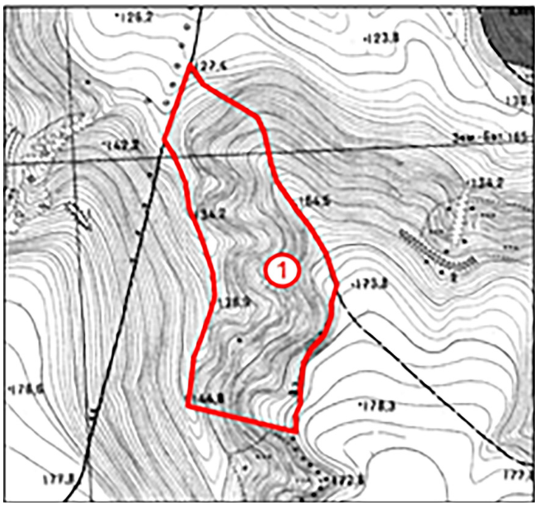

Figure 4. Layout of the route research object Polygon 1

plant groups – phytocenoses of the ravine slopes are rich in their diversity and density. There are about 300–400 plants per 1 m^2.

The species saturation of the phytocenosis at the site belongs to the 1st density class – (a plant community) – the plants, close with their above-ground upper parts and form a 100% projective cover, which has a positive effect on the protection of soils from their washout and flooding by heavy rainfall. In spring, during the snow melting, the developed root system and dead aboveground grass mass (natural mulch) prevent the erosion processes.

There are also found the grassy grass groups, mainly represented by the creeping wheatgrass (*Elymus repen*), occasionally by the bristle grasses (*Setaria*), and by feather grass (*Stipa pennata* L). The slopes are turfed, covered with dense herbaceous vegetation; there are single bushes of silverberry (*Elaeagnus commutata*). The plant groups – phytocenoses of the ravine slopes are rich in their diversity and density. There are from 300 to 500 plants per 1 m^2. The phytocenoses of mixed grasses have a rich species composition of tall plants, in particular; some of them: musk thistle (*Carduus nutans*); common milkweed (*Asclepias syriaca* L.); Common yarrow (*Achillea millefolium*); St. John's wort (*Hypericum perforatum* L.); Common tansy (*Tanacetum vulgare* L.); White cinquefoil (*Potentilla alba* L.); Scentless chamomile (*Unscented chamomile*); sea mayweed (*Tripleurospermum maritimum*); hoary alyssum (*Berteroa incana* L.)

Figure 5. Phytocenoses of slopes within polygon 1

musk thistle (*Carduus nutans*); common milkweed (*Asclepias syriaca* L.); Common yarrow (*Achillea millefoli-um*); St. John's wort (*Hypericum perforatum* L.); Common tansy (*Tanacetum vulgare* L.); White cinquefoil (*Potentilla alba* L.); Scentless chamomile (*Unscented chamomile*); sea mayweed (Tripleurospermum maritimum); hoary alyssum (*Berteroa incana* L.), musk this-tle (*Carduus nutans*); common milkweed (*Asclepias syriaca* L.); Common Yarrow (*Achil-lea millefolium*); St. John's wort (*Hypericum perforatum* L.); Common tansy (*Tanacetum vulgare* L.); White Cinquefoil (*Potentilla alba* L.); Sea Mayweed (*Tripleurospermum maritimum*); hoary alyssum (*Berteroa incana* L).

The polygon 2 area is 25 ha. The slopes with eastern and northern exposure. The absolute maximum elevation of the earth's surface is 190 meters, the minimum is 130 meters. The average length of the slopes is 112.2 meters, the steepness of slopes is 7.125% (Fig. 6).

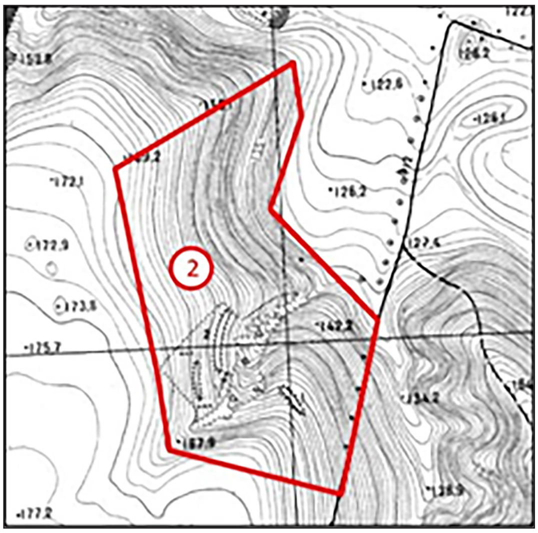

Figure 6. Layout of the route research object of polygon 2

Results for typical chernozems and highly degraded, highly eroded, light loamy chernozems shows Figure 7. The slopes are turfed and covered with grassy vegetation. The plant groups – phytocenoses of the ravine slopes are rich in their diversity and density. There are up to 300 plants per 1 m^2.

The species saturation of the phytocenosis at the site is according to the Drude scale belongs to the 1-st class of projective cover – the plants, close with their aboveground upper parts, forming 100% of the projective cover, which has a positive effect on the protection of the soils from their washout and flooding by rainfall.

In spring, during the melting of snow, the developed root system of perennial grasses and the dead aboveground grass mass (natural mulch) prevent the erosion processes.

The cereal grass groups are represented mainly by the creeping wheatgrass (*Elymus repen*), and occasionally by the bristle grasses (*Setaria*).

Phytocenoses of the mixed herbs have a rich species composition of tall plants, in particular, some of them: Common yarrow (*Achillea millefolium*); common St. John's wort (*Hypericum perforatum* L.); field spurge (*Euphorbia agraria*); common tansy (*Tanacetum vulgare* L.); white cinquefoil (*Potentilla alba* L.); nonscented chamomile (*non-scented tricostal*); sea mayweed (Tripleurospermum maritimum); hoary alyssum (*Berteroa incana* L.); Common yarrow (*Achillea millefolium*); St. John's wort (*Hypericum perforatum* L.); Euphorbia arvense (*Euphorbia agraria*); common tansy (*Tanacetum vulgare* L.); white cinquefoil (*Potentilla alba* L.); chamomile not fragrant (three-rib not odorous) sea mayweed (*Tripleurospermum maritimum*); hoary alyssum

Figure 7. Phytocenoses within polygon 2

(*Berteroa incana* L). The grass cover is not mown and is not grazed by the livestock.

The area of the polygon 3 is 30 ha. The slopes with the eastern and north-eastern exposures. The absolute maximum marks of the earth's surface are 170 meters, the minimum are 130 meters. The average length of slopes is 123.2 meters, the steepness of slopes is 6.49% (Fig. 8).

Results for typical chernozems and degraded chernozems, heavily eroded, light loamy presented in Figure 9. The slopes are turfed and covered with grassy vegetation. Plant groups – phytocenoses of the ravine slopes are rich in their diversity and density. There are up to 300 plants per 1 m^2

The species saturation of phytocenosis at the polygon belongs to Class 1 projective cover – (a plant community) – plants, close with their aboveground upper parts, forming a 100% projective cover, which has a positive effect upon the protection of soils from their washout and flooding by heavy rainfall. In spring, during the melting of snow, the developed root system of the perennial grasses and the dead aboveground grass mass (natural mulch) prevent the erosion processes. The grassy grass groups are occasionally represented by creeping wheatgrass (*Elymus repen*).

The phytocenoses of mixed herbs have a rich species composition of tall plants, in particular, some of them: Common milkweed (*Asclepias syriaca* L.); Common yarrow (*Achillea millefolium*); common St. John's wort (*Hypericum perforatum* L.); Common mullein (bear's ear) (*Verbascum thapsus* L.); Field spurge (*Euphorbia agraria*); Hoary alyssum (*Berteroa incana* L.).

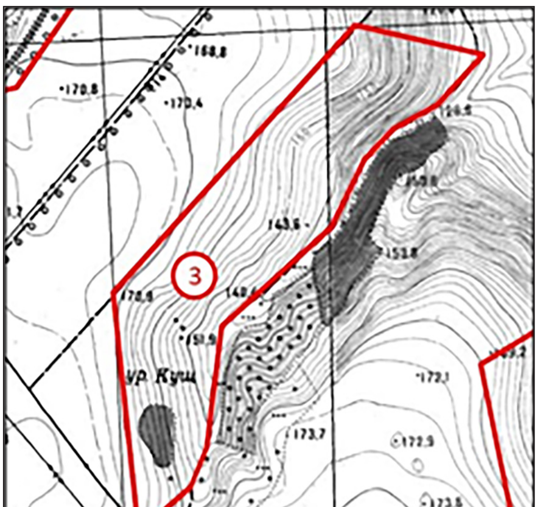

Figure 8. Layout of the route research object of polygon 3

Figure 9. Phytocenoses of slopes within polygon 3

By the conducted determinations and geobotanical descriptions it has been established that the spontaneously restored herbages were distinguished not only by the presence of a significant number of species and increased projective cover but also by a sufficiently high diversity of taxonomic structure, as one of the important indicators of the state and functional properties of phytodiversity of cenoses, the implementation of their adaptive and soil-protective self-regulation capabilities and the formation of stable grassy ecosystems.

In spontaneous restoration of herbage on strongly and moderately washed soils in the composition of vegetative vegetation groups, drooping brome (*Anisanthus tectorum*), creeping wheatgrass (*Elymus repen*), common milkweed (*Asclepias syriaca*), hoary alyssum (*Berteroa incana*), i.e. representatives of various grasses with the exception of creeping wheatgrass, prevailed.

It should also be noted that in the composition of the spontaneously regenerating herbage in a fairly wide spectrum were represented adventive (introduced) species, such as Cheatgrass (*Bromus tectorum*), Common milkweed (*Asclepias syriaca*), Bitter wormwood (*Artemisia absinthium*), Wild radish (*Raphanus raphanistrum*), Annual fleabane (*Erigeron annuus*) (Fig. 10).

Agrocenoses of perennial grasses to the greatest extent protect the washed-out soils of the slope agricultural landscapes from the active development of water erosion processes. At the same time the quantitative assessment of the soil conservation efficiency of perennial herbaceous agrocenoses reflects the multifactorial conditions of the formation of the erosion situation in a specifically designated territorial area (polygon).

There was carried out determination of the predicted soil losses as a result of water erosion

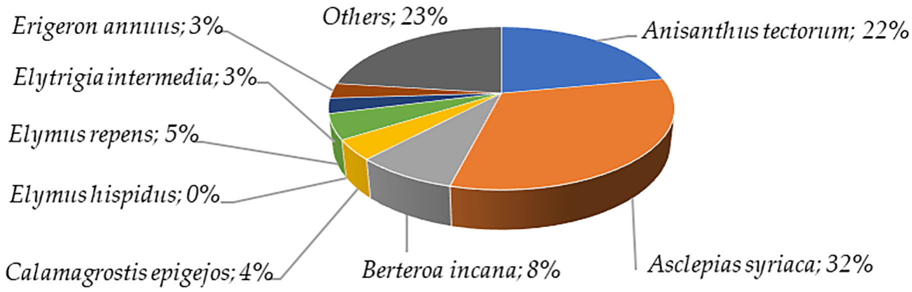

Figure 10. Phytocenoses of slopes within polygon 3

within the territorial boundaries of the investigation sites No. 1–3. The soil losses were found out using the universal equation of erosive soil losses (Universal Soil Loss Equation – USLE):

$$W = R \cdot K \cdot LS \cdot C \cdot H \quad (1)$$

where: W – the calculated total soil loss per year t·ha^{-1}; R – the rain erosive capacity factor; K – the soil susceptibility factor to the erosion processes, t·ha^{-1}; L – the slope length factor, m; S – the slope steepness factor, %; C – the vegetation and crop rotation factor; H – the soil conservation practice factor (dimensionless).

The calculated quantitative indicators of the soil loss due to the water erosion at the investigated sites W – 2.38; 4.19; 3.88 t·ha^{-1} (Table 1) with maximum allowed erosion rates for typical eroded chernozems 1.1–1.5 t·ha^{-1} indicate a very high anti-erosion efficiency of the soil protection (preservation) technologies from the soil loss and erosion. In addition, this makes it possible to judge about the comparative intensity of the erosion processes depending on the technologies for using the soil cover in erosion-hazardous agricultural landscapes, the methods and techniques for allocating land for conservation, and the development of management decisions in the design and implementation of the soil-protective agricultural systems (Table 1).

Under the conditions of complex relief of the slope agro-landscape systems as a result of irrational human activity, a sufficiently high part of the energy, contained in the soil in the form of humus and nutrients, can be lost with washed-out soil beyond the agro-ecosystem, which leads not only to a decrease in its productivity but also affects its sustainable functioning. The eroded soils of the studied polygons are represented by medium and highly eroded typical chernozems, where the fertile soil layer is completely or 75–80% washed away, and in many cases the upper transitional horizon is also washed away. In this case the humus losses amount to 50–65% in highly eroded soils and 40–45% in moderately eroded soils.

The degree of erosion of typical chernozem soil in the investigated areas had a significant impact on the humus content in the 0–20 cm soil layer (Table 2).

Thus, on the heavily eroded soil cover differences of polygons No. 2–3, the humus content indicators were 1.96–2.13%, with its initial values for the period of putting the slope lands into conservation being 1.75–1.98%. The moderately eroded typical chernozem, which, as a result of water erosion, has lost about one third of the upper genetic horizon with washout, with the humus content indicators corresponding to the aver-age values (DSTU 4362:2004). The moderately eroded typical chernozem, which, as a result of the water erosion, has lost about one third of the upper genetic horizon with washout, with the humus content indicators corresponding to the average values (DSTU 4362:2004).

Table 1. The calculated quantitative indicators of the soil loss

Polygon number	Horizontal position of segments, m	Horizontal position of segments, m	Angle of inclination (steepness), α°	Slope length factor, m	Rain erosivity factor	Soil susceptibility factor to erosion processes, t·ha^{-1}	Slope steepness factor, %	Vegetation and crop rotation factor	Factor of efficiency of anti-erosion measures	Calculated total soil loss per year, t·ha^{-1}
1	149	6	2.306	149.12	9.5	2.0	4.024	0.17	1	2.38
2	112	8	4.086	112.29	9.5	2.0	7.125	0.17	1	4.19
3	123	8	3.721	123.26	9.5	2.0	6.490	0.17	1	3.88

Table 2. Fertility indicators of the washed-out soil depending on the method of using sloping lands and the period of their conservation

Polygon number	Type of soil	Method of using sloping lands	Number of years of grassing	Slope inclination, degrees	Contents				
					pH	Humus, %	N, mg $кg^{-1}$	P_2O_5, mg	K_2O, mg
1.	Typical medium-eroded light loamy chernozem	Spontaneous restoration of the herbage (conservation)	22	11–12	7.3	3.85	16.1	19.3	12.7
2.	Typical heavily eroded light loamy chernozem	Spontaneous restoration of the herbage (conservation)	21	7–10	7.1	1.96	9.6	5.5	9.7
3.	Typical chernozem, medium and highly eroded, light loamy	Spontaneous restoration of the herbage (conservation)	23	8–9	7.3	2.13	7.8	8.5	15.7

For the soils, formed on loess rocks, erosive losses of the surface genetic horizons lead to an increase in the content of the meadow and meadow-earth metals in the soil absorption complex, while the reaction of the soil solution (pH) approaches neutral values (7.1–7.3) (Table 2).

The practice of applying land conservation measures shows that, in agroecological terms, this technology ensures a significant reduction in the soil loss during agricultural use of such lands as part of forage lands (hayfields, pastures) and contributes to an increase in the fertility of the washed-out soils, improving the ecological state of the environment, as a whole.

During the functioning of spontaneously restorative herbage changes in the mineral component of the soil conditions are observed, as a result of an increase in fractions and gross forms of phosphorus, fixed potassium and total nitrogen that are difficult for plants to access, that is, changes occur in the direction of gradual restoration of the basic components of the fertility of the degraded soils.

DISCUSSION

The analysis of the results of the studies has shown that the meadow lands will function harmoniously only when they simultaneously fully per-form not only a forage production role but also a nature conservation role. As has already been noted, with an increase in the forage production value of the meadow lands, that is, their productivity or ecological capacity, their nature conservation role, that is, their soil protection capacity, also increases [Bulyhin et al., 2014; Bulyhyn and Belolynskyi, 2012; Velychko, 2010; Pichura, 2016].

It should be noted that one of the most effective methods of controlling soil erosion is the use of vegetative cover. Vegetation helps to stabilise the soil, reduce run-off and improve soil structure. A comprehensive review highlighted the importance of vegetative cover in reducing soil erosion, particularly in Mediterranean regions where vegetation plays a crucial role in maintaining soil health [Aiello et al., 2015]. The authors of this study justified the need for regional assessments to develop and restore plant cover in high-risk areas.

Geospatial technologies, including remote sensing and GIS, are increasingly being used to monitor and monitor soil erosion. A study on the application of these technologies in the Dagu River Basin in China demonstrated their effectiveness in dynamically monitoring soil erosion and identifying key factors such as land use, vegetation cover and human activities. These technologies allow precise mapping and analysis, which is essential for the development of targeted erosion control measures [England, 2011].

Sediment fingerprinting is a technique used to identify the sources of sediment in water bodies, which can be used to inform soil conservation strategies. One of the studies used this approach in a small agricultural catchment to determine the contributions of different land uses and geological sources to lakeshore sediment. The results suggest that management of abandoned farmland and control of sediment sources can significantly reduce soil erosion [Aiello et al., 2015, Report, 2013].

A decision support tool, the analytical hierarchy process (AHP), has been developed to prioritise areas at risk of soil erosion. A study integrating AHP with geospatial technologies identified susceptible areas and developed effective soil erosion management plans. This approach allows the systematic evaluation of multiple factors, including topography, land use and climate, to prioritise conservation efforts [Report 2013].

In a study, the authors point out that recent advances in soil erosion management include the development of new technologies and innovative applications. A review of these technologies highlights the potential of bioengineering, soil amendments and advanced monitoring systems to improve soil protection. Future trends point to the integration of traditional methods with modern technologies to achieve sustainable soil management [Panagos et al., 2015, Pasquale et al., 2017, Senol and Tas, 2023].

In this respect, when solving the problems of soil protecting from erosion and improvement of the condition of agricultural territories, a landscape approach is promising, which necessitates a systemic analysis, taking into account many factors that influence the environmental optimization of the agricultural landscape [Popov et al., 2012, Weslati and Serbaji, 2024].

CONCLUSIONS

Conservation of eroded slope lands is an important legislative measure in order to preserve and increase the fertility of the degraded cultivated soils of agricultural landscapes, and it also ensures optimization of the agricultural land use by removing lands, unsuitable for intensive economic use and transferring them to another category of land.

The removal of eroded soils of sloping agricultural landscapes from economic circulation; and conservation as part of agricultural lands for a certain period of time, to implement measures with the introduction of environmental management systems and technologies, to protect the soils from erosion, to restore their fertility and ensure an ecologically satisfactory state of soils, they must be considered as a complex of agro-ecological, organizational, economic and regulatory measures.

The practice of applying the land conservation measures shows that, in agroecological terms, this technology ensures a significant reduction in the soil loss during the agricultural use of such lands as part of forage lands (hayfields, pastures), contributing to an increase in the fertility of the washed-out soils, improving the ecological state of the environment, as a whole.

Effective soil erosion control on agricultural land requires a combination of traditional practices and modern technologies. Plant cover, geospatial technologies, sediment fingerprinting and decision support tools such as AHP are critical to the development of comprehensive soil conservation strategies. Continued research and innovation are essential to address the evolving challenges of soil erosion and ensure sustainable agricultural practices.

It has been established that ecologically justified optimization of the structure of agricultural lands by withdrawing the eroded slope lands from intensive use for conservation under the establishment of land for the purpose of improving natural ecosystems, preserving and increasing the fertility of degraded soils of agricultural landscapes is an important legislative measure in the field of formation of environmental protection systems for managing soil protection technologies from erosion.

The conducted scientific research, based on the use of the landscape ecology methodology, ecological-geographical and geomorphological studies, the study of the dynamics of the species' ecological-biological structure of spontaneously regenerating grass stands in the process of their growth and development on the key landscape-geochemical systems-tracts established the patterns of formation of ecologically stable grassy biogeocenoses on anthropotransformed edaphotopes. It was determined that the plant groups - phytocenoses of slopes are rich in their plant diversity and density, and their species saturation refers to the first class of density, while forming 100% projective anti-erosion soil cover.

Based on the conducted research, it was established that spontaneously restored grass stands are characterized by high soil-protective resistance, significant diversity of taxonomic structure, as one of the most important indicators of the state and functional properties of phytodiversity of cenoses, the implementation of their adaptive capabilities for self-regulation and the formation of stable, highly productive grassy ecosystems.

Based on the predicted soil losses due to the water erosion in the slope agrolandscapes of the study sites No. 1–3, it was proven that the soil-protective efficiency of the anti-erosion phytomeliorative complex, soil loss was 2.38–4.19 $t \cdot ha^{-1}$ ha due to the presence of densely covering perennial herbaceous cenoses on the soil surface, which protected the soil from the loss and erosion at the level of permitted erosion standards, established for typical eroded chernozems.

Taking into account the main fertility indicators of the washed-out typical chernozem, it was established that, depending on the duration of the stay of the degraded soil cover of the studied polygons under conservation (under grassing), the characteristics of agrochemical, agrophysical and other properties of the eroded chernozems improve. At the same time, the humus content in the processed soil layer increased to 3.85%, the acidity of the soil solution pH 7.1–7.3 (close to neutral) is characterized by optimal values, the content of the main soil macroelements – nitrogen, exchangeable phosphorus and potassium – has stabilized.

Thus the removal of the degraded and low-value lands from the arable land for planting to improve and preserve the soil fertility, and the protection of agricultural lands from the destructive effects of the water erosion are united by one strategic goal - the formation of a model for the rational use of eroded lands and increasing the environmental sustainability of slope farming.

REFERENCES

1. Aiello, A., Adamo, M. and Canora, F. (2015). Remote sensing and GIS to assess soil erosion with RUSLE3D and USPED at River Basin scale in Southern Italy. *Catena*, *131*, 174–158. https://doi.org/10.1016/j.catena.2015.04.003
2. Allafta, H., & Opp C. (2022). Soil erosion assessment using the RUSLE model, Remote Sensing, and GIS in the Shatt Al-Arab Basin (Iraq-Iran). *Applied sciences*, *12*(15), 7776. https://doi.org/10.3390/app12157776
3. Auerswald, K. (1992). Predicted and measured sediment loads of large watersheds in Bavaria. *In Proceedings of the Fifth International Symposium on River Sedimentation*, Karlsruhe, Germany, 6–10 April 1992. 1031–1036. [Google Scholar]
4. Auerswald, K. (2008). Water erosion. In: *The Encyclopaedia of Soil Science*, W. Chesworth (Ed.). Springer-Verlag, 817–822. [Google Scholar]
5. Bajrak, G. (2018). *Methods of geomorphological research*. Lviv: Ivan Franko National University of Lviv, 292 [in Ukrainian].
6. Balabukh, V. O. (2008). Variability of rains and downpours in Ukraine. *Naukovi pratsi UkrNDHMI, 257*, 61–72 [in Ukrainian].
7. Baliuk, S. A., Nosko B. S., Zaryshniak A. S., Lisovyi M. V. (2015). *Agrochemical service in the system of factors for preserving and improving soil fertility*. Kharkiv: TOV Smuhasta typohrafiia [in Ukrainian].
8. Baliuka, S. A. Tovakhnianskoho, L. L. (2008). *The concept of soil erosion protection in Ukraine*. za red. Kharkiv: Instytut hruntoznavstva ta ahrokhimii im. O.N. Sokolovskoho [in Ukrainian].
9. Borrelli, P., Robinson, D.A., Fleischer, L.R., Lugato, E., Ballabio, C., Alewell, C., Meusburger, K., Modugno, S., Schütt, B., Ferro, V., Bagarello, V., Oost, K. V., Montanarella, L., Panagos, P. (2017). An assessment of the global impact of 21st century land use change on soil erosion. *Nature Communications 8*(1), 2041–1723. https://doi.org/10.1038/s41467-017-02142-7
10. Bulyhin, S. Yu. (2015) Land quality as a basis for land use control. *Ahroekolohichnyi zhurnal 1*, 26–46 [in Ukrainian]. Kyiv: Ahrarna nauka [in Ukrainian].
11. Bulyhin, S.Yu., Achasov A.B., Achasova A.O. (2014) *Land quality assessment and forecasting system (status, concept and algorithms)*. Kyiv: Ahrarna nauka [in Ukrainian].
12. Bulyhyn, S.Yu., Belolynskyi V.A. (2012). Soil and water optimisation of agricultural landscapes. Kyiv: Ahrarna nauka [in Russian].
13. Dahanayake, A.C., Webb J.A., Greet J., Brookes J.D. (2024) How do plants reduce erosion? An Eco Evidence assessment. *Plant Ecology, 225*. 593–604. https://doi.org/10.1007/s11258-024-01414-9
14. DSTU 4115-2002. (2022). *Soils quality. Determination of mobile compounds of phosphorus and potassium according to the modified Chirikov method*. Kyiv: Derzhstandart Ukraine [in Ukrainian].
15. DSTU 4289:2004. (2004). *Soil quality. Method for determining organic matter*. Kyiv: Derzhstandart Ukraine [in Ukrainian].
16. DSTU 4770 (1, 2, 3, 4, 6, 7, 9)-2007. (2007). *Soil quality. Determination of the content of mobile compounds Mn, Zn, Cd, Fe, Cu, Ni, Pb in the buffered acetate-ammonium extract*. Kyiv: Derzhstandart Ukraine [in Ukrainian].
17. DSTU 7537:2014. (2014). *Soil quality. Determination of hydrolytic acidity*. Kyiv: Derzhstandart Ukraine [in Ukrainian].
18. DSTU 7862:2015. (2015). *Soil quality. Determination of active acidity*. Kyiv: Derzhstandart Ukraine [in Ukrainian].
19. DSTU 7863:2015. (2015). *Soil quality. Determination of easily hydrolysable nitrogen by the Kornfield method*. Kyiv: Derzhstandart Ukraine [in Ukrainian].
20. DSTU 7921:2015. (2015). *Soil quality. Large-scale study of soil cover. General requirements*. Kyiv: Derzhstandart Ukraine [in Ukrainian].
21. DSTU ISO 10390:2022. (2022). *Soil quality. Determination of pH* (ISO 10390:2019, IDT). Kyiv: Derzhstandart Ukraine [in Ukrainian].
22. Dutta, D., Das, S., Kundu, A., Taj, A. (2015). Soil erosion risk assessment in Sanjal watershed, Jharkhand (India) using geo-informatics, RUSLE model and TRMM data. *Modeling Earth Syst.*

Environ, 1, 37. Retrieved from: https://link.springer.com/article/10.1007/s40808-015-0034-1

23. El Jazouli, A., Barakat, A., Ghafiri, A. et al. (2017). Soil erosion modelled with USLE, GIS, and remote sensing: a case study of Ikkour watershed in Middle Atlas (Morocco). *Geosci. Lett. 4*, 25. https://doi.org/10.1186/s40562-017-0091-6
24. England, N. (2011). *Think BIG: How and why landscape-scale conservation benefits wildlife, people and the wider economy.* Produced for the England Biodiversity Group, 44. Retrieved from: http://publications.naturalengland.org.uk/publication/30047.
25. Jothimani, M., Getahun, E., Abebe, A., Gunalan, J., Shano, L., Oyda, Y. (2024). *Application of Geospatial Technologies and AHP Technique in the Identification of Soil Erosion-Prone Zones in the Rift Valley, Southern Ethiopia*. In: Choudhury, T., Koley, B., Nath, A., Um, JS., Patidar, A.K. (eds) Geo-Environmental Hazards using AI-enabled Geospatial Techniques and Earth Observation Systems. Advances in Geographic Information Science. Springer, Cham. https://doi.org/10.1007/978-3-031-53763-9_4
26. Kaminskyi, V., Kolomiiets, L., Bulgakov, V., Olt, J. (2021). An investigation into the state of agricultural lands under water erosion conditions. *Agronomy Research. 19*(2), 458–471. https://doi.org/10.15159/AR.21.029
27. Kovalchuk, I.P., Chalov, R.S. (1992). Ecological and geomorphological aspects of studying erosion-accumulative processes in the basins of different-rank rivers of developed region. Problemi erozionnikh ruslovikh i ustevikh protsessov: *Tezi doklada mezhvuzovikh soveshchanii– Ishchevsk*. 45–47. [in Russian].
28. Krasovskyi, H. Ya., Petrosov, V.A. (2003). *Information technologies for space-based monitoring of aquatic ecosystems and forecasting urban water consumption*. Kyiv: Naukova Dumka [in Ukrainian].
29. Lialko, V.I., Yelistratova, L.O., Apostolov, O.A. (2018). Rapid assessment of erosion-prone areas of soil cover on the territory of Ukraine using remote sensing data with consideration of climatic factors and vegetation. *Dopovidi NAN Ukrainy, 3,* 87–94 [in Ukrainian].
30. Lialko, V.I., Yelistratova, L.O., Apostolov, O.A., Chekhnii, V.M. (2017). Analysis of soil-erosion processes in Ukraine based on the use of remote sensing data. *Visnyk NAN Ukrainy, 10*, 34–41 [in Ukrainian]. https://doi.org/10.15407/visn2017.10.034
31. Lialko, V., Popov, M., Stankevych, S. (2014). Remote sensing polygons in Ukraine: current status and directions for further research and development. *Ukrainian Metrological, 2*, 15–26 [in Ukrainian].
32. Lialko, V.I., Yelistratova, L.O., Apostolov, O.A. (2018). Rapid assessment of erosion-prone areas of soil cover on the territory of Ukraine using remote sensing data with regard to climatic factors and vegetation. *Dopovid Natsionalnoi akademii nauk Ukrainy 3*, 87–94 [in Ukrainian]. https://doi.org/10.15407/ dopovidi2018.03.087
33. Mesfln, A. (1994). The Nile-source of regional cooperation or conflict. In Proceedings of the Eighth Iwra World Congress on Water Resources "Satisfying Future National and Global Water Demand", Cairo, Egypt, 21–25 November 1994. [Google Scholar]
34. Morgan, R.P.C. Quinton, J.N. Smith, R.E. Govers, G. Poesen, J.W.A. Chisci, G. Torri, D. (1998). The EUROSEM Model. In: *Boardman J., Fvis-Mortlock D*. (eds) Modelling Soil Erosion by Water. NATO ASI Series (Seri I: Global Environmental Change). V. 55. Springer, Berlin, Heidelberg. http://doi.org/10.1007/978-3-642-58913-3_29
35. Nesterchuk, I.K. (2007). Geoecological approach to the problem of nature management: theoretical aspects and methodology. *Fizychna geografiya ta geomorfologiya, 52*, 51–66 [in Ukrainian].
36. Panagos, P., Borrelli, P., Meusburger, C., Alewell, C., Lugato, E., Montanarella, L. (2015). Estimating the soil erosion cover-management factor at European scale. *Land Use policy journal. 48*, 38–50.
37. Panagos, P., Borrellia, P., Meusburgerb, K., Alewellb, C., Lugatoa, E., Montanarella L. (2015). Estimating the soil erosion cover-management factor at the European scale. *Land Use Policy, 48*, 38–50. http://dx.doi.org/10.1016/j.landusepol.2015.05.021
38. Pasquale, B., Robinson D. A., Fleischer L.R. et al. (2017). *An assessment of the global impact of 21st century land use change on soil erosion*. Nature Communications, 1. Retrieved from: https://www.nature.com/articles/s41467-017-02142-7.
39. Pichura, V.I. (2016). Geomodelling of water-erosion processes in the Dnipro River basin. *Ahroekolohichnyi zhurnal 4*, 66–73 [in Ukrainian].
40. Popov, M.A., Stankevych, S. A., Kozlova, A.A. (2012). Remote land degradation risk assessment using space images and geospatial modelling. *Dopovidi NAN Ukrainy, 6*, 100–104 [in Ukrainian].
41. Renard, K.G., Foster, G.R., Wessies, G.A., Porter, J.P. (1991). RUSLE-Revised universal soil loss equation. *Journal of Soil and Water Conservation, 46*, 30–33.
42. Report (2013). *Rural Development in the European Union: statistical and economic information.* Retrieved from: http://ec.europa.eu/agriculture/statistics/rural- development/2013/full-text_en.pdf.
43. Rucins, A., Kaminskyi, V., Kolomiiets, L., Bulgakov, V., Olt, J., Kaminska, V., Shevchenko, I., Ihnatiev, Y. (2024). Research into soil resource management technologies in context of aggravating exogenic processes. *Journal of Ecological Engineering (JEE), 25*(6), 128–143. https://doi.

org/10.12911/22998993/186950

44. Senol, C., & Tas, M.A. (2023). Trends of changing land use dynamics in the Terkos Lake basin between 1980 and 2023 and their impact on natural ecosystems. *Frontiers in Life Sciences and Related Technologies, 4*(1), 20–31. https://doi.org/10.51753/flsrt.1250948
45. Shuang, W., Chao, Z., Changxu, L., Zhurong, X. (2008). Study on Soil erosion Dynamic monitoring Based on "3S" technology. *IOP Conf. Series: Earth and Environmental Science 208*. https://doi.org/10.1088/1755-1315/208/1/012088
46. Terranova, O., Antronico, L., Coscarelli, R., Iaquinta, P. (2009). Soil erosion risk scenarios in the Mediterranean environment using RUSLE and GIS: An application model for Calabria (southern Italy). *Geomorphology, 112*, 228–245.
47. Udayagee K. (2021). A review on new technologies in soil erosion management. *Journal of research technology and engineering, 2*(1), https://jrte.org/wp-content/uploads/2021/01/A-review-on-new-technologies-in-soil-erosion-management.pdf
48. Velychko, V.A. (2010). Ecology of soil fertility. Kyiv: Ahrarna nauka [in Ukrainian].
49. Wang, X., Zhao, Z., Han, X., Liu, J., Kitch, J., Liu, Y., Yang, H. (2022). Evaluating the evolution of soil erosion under catchment farmland abandonment using lakeshore sediment. *Sustainability 14*, 12241. https://doi.org/10.3390/su141912241
50. Weslati, O., Serbaji, M.M. (2024). Spatial assessment of soil erosion by water using RUSLE model, remote sensing and GIS: a case study of Mellegue Watershed, Algeria–Tunisia. Environ Monit. *Assess 196*, 14. https://doi.org/10.1007/s10661-023-12163-z
51. Zuazo, V.H.D., Pleguezuelo, C.R.R. (2009). Soil-Erosion and Runoff Prevention by Plant Covers: A Review. In: Lichtfouse, E., Navarrete, M., Debaeke, P., Véronique, S., Alberola, C. (eds) *Sustainable Agriculture*. Springer, Dordrecht. https://doi.org/10.1007/978-90-481-2666-8,_48.
52. Zubov, A.O., Ilienko, T.V., Bilokin, O.A. (2023). *Assessment of the environmental danger of natural dumps for agricultural land in agro-industrial landscapes*. Kyiv: Ahrarna nauka [in Ukrainian].