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Spatial assessment of the agricultural potential of eroded slope lands using USLE model parameters

Abstract. Eroded slope lands are characterised by significant spatial heterogeneity of the soil cover, which complicates an objective assessment of their agricultural potential based on average-field agrochemical indicators. The aim of the study was to establish the patterns of spatial assessment of the agricultural potential of eroded slope lands based on the relationship between agronomic soil indicators and the parameters of the USLE (Universal Soil Loss Equation) model. The study was conducted in 2024-2025 at the "Dokuchaievske" experimental field of the State University of Biotechnology in the Left-Bank Forest-Steppe region of Ukraine. A total of 68 soil samples were collected from the arable layer using an irregular grid pattern, taking into account the characteristics of the terrain. The samples were analysed for organic carbon content, nitrate nitrogen and pH. The spatial distribution of these parameters was assessed using geographic information system (GIS) mapping, whilst erosion risk was characterised using the LS topographic factor of the USLE model. It was found that the organic carbon content ranged from 1.35 to 3.05 per cent, and the LS values ranged from 0.039 to 2.22. A strong inverse relationship was found between LS and organic carbon content: Spearman's correlation coefficient was -0.725. The linear model Y = 2.7175 – 0.5124x confirmed a decrease in organic carbon content as erosion risk increased. When LS values were grouped, the average organic carbon content decreased from 2.610-2.636 to 1.853-1.949%, whilst the relationship

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between LS and nitrate nitrogen was weak, r = -0.066. Thus, organic carbon is a more reliable indicator for the spatial adjustment of the agricultural potential of eroded slope lands. The proposed approach can be used to construct map charts of adjustment coefficients, implement differentiated fertilisation, plan soil conservation measures and introduce elements of precision farming

Keywords: organic carbon; nitrate nitrogen; topographical factor; soil resource potential; geographic information system mapping; haplic chernozem

INTRODUCTION

Eroded slope lands are characterised by a high degree of spatial heterogeneity in the soil cover, which complicates their objective agronomic assessment. Within a single field, there may be areas with varying degrees of erosion, different depths of the humus layer, varying organic matter content and differing resource potential. Under such conditions, the use of only average field-wide agrochemical indicators does not allow for a full assessment of the actual agronomic potential of the soil cover. Of particular relevance is the combination of traditional soil indicators with spatial relief parameters, which determine the conditions for surface runoff and potential soil erosion.

In recent studies, considerable attention has been paid to the digital mapping of organic carbon as one of the key indicators of soil fertility and degradation status. A. Sakhaee *et al.* (2022) demonstrated that machine learning can be an effective tool for the spatial prediction of organic carbon in arable soils, as it allows for the heterogeneity of soil and landscape conditions to be taken into account. S. Nozari *et al.* (2024) confirmed the suitability of digital soil mapping for predicting organic carbon under various soil and landscape conditions. Organic carbon is a more stable and conservative indicator of long-term changes in soil cover than mineral forms of nitrogen, which change rapidly under the influence of moisture, temperature, fertilisation, mineralisation and uptake by plants. Thus, correlating organic carbon with parameters of topography-determined erosion risk may be a promising approach for assessing the actual agricultural potential of eroded slope lands. On slope lands, the spatial distribution of organic carbon is largely linked to the development of water erosion. E. Balontayová *et al.* (2024) found that on arable chernozems, water erosion affects not only the total organic carbon content but also its labile fractions, which are sensitive to degradation processes. H. Fang *et al.* (2024) demonstrated that erosion alters soil quality in agricultural landscapes, and that slope morphology is one of the factors determining the intensity of these changes. Y. Wu *et al.* (2024) also noted the influence of slope aspect and exposure on soil properties and erosion. Thus, topographical conditions not only determine the risk of soil loss but also indirectly influence the spatial variation in the agronomic properties of the soil cover.

The Universal Soil Loss Equation (USLE) and its modified versions are widely used for the spatial assessment of water erosion. M. Singh *et al.* (2023) applied a combination of geoinformation technologies and the Revised Universal Soil Loss Equation (RUSLE) model to assess soil loss and prioritise catchments from the perspective of soil and water conservation planning. F. Bouayad *et al.* (2023) demonstrated the effectiveness of integrating RUSLE, geoinformation analysis and remote sensing to assess erosion dynamics within a catchment. M. Guche *et al.* (2024) confirmed the feasibility of using RUSLE at the catchment level to identify areas with varying levels of erosion risk. These studies demonstrate that erosion models are an effective tool for the spatial diagnosis of degradation processes. At the same time, most studies on the application of USLE or RUSLE focus primarily on assessing potential soil loss. Considerably less attention is paid to using the parameters of these models for the agronomic interpretation of spatial heterogeneity in soil fertility. For production conditions, it is important not only to identify areas of potential soil loss, but also to establish how the topography-induced risk of erosion is linked to changes in organic carbon, nitrate nitrogen and other indicators characterising the resource potential of the soil cover.

Organic carbon is a more stable and conservative indicator of long-term changes in soil cover than mineral forms of nitrogen, which change rapidly under the influence of moisture, temperature, fertilisation, mineralisation and uptake by plants. M. Oukhattar *et al.* (2025) emphasise that the spatial distribution of organic carbon depends significantly on land-use type and can be effectively represented using digital mapping. Thus, correlating organic carbon with parameters of topography-determined erosion risk may be a promising approach for assessing the actual agricultural potential of eroded slope lands. For the chernozems of the Left-Bank Forest-Steppe of Ukraine, such an assessment is of particular importance, as even within a single field, water erosion can cause a significant change in the humus content and resource potential of the soil cover. The combination of agrochemical indicators, geographic information system mapping and USLE model parameters enables a shift from a generalised assessment of fertility to spatially differentiated management of soil resources.

The aim of the study was to identify patterns in the spatial assessment of the agricultural potential of eroded slope lands based on an analysis of the relationship between agronomic soil indicators and the parameters of the USLE model, and to justify the feasibility of using this approach to adjust the resource potential of the soil cover.

MATERIALS AND METHODS

The study was conducted during 2024-2025 at the "Dokuchaievske Experimental Field", an educational, scientific, and production centre of the State Biotechnological University, located in the Kharkiv District of Kharkiv region within the Left-Bank Forest-Steppe of Ukraine. The experimental site is characterised by sloping terrain and a spatially heterogeneous soil cover formed under the prolonged influence of water erosion. The study area comprises a complex of eroded and depositional soil units typical of eroded sloping land in the Forest-Steppe zone. The soil cover on non-eroded watershed positions is represented by medium-humus, heavy loam haplic chernozem. In the non-eroded soils, the parent material occurs at a depth of 123-125 cm, while the humus-rich horizon extends to a depth of 73 cm. On eroded slope positions, the thickness of the humus-rich horizon decreases, whereas it increases in depositional zones. The soils of the experimental site have a heavy loam texture. According to the preliminary survey, organic carbon content ranged from 1.35% to 3.05%, while soil pH (water) varied from 6.52 to 8.51.

Soil samples were collected from the arable soil layer using an irregular grid, designed to take into account the characteristics of the relief and the spatial heterogeneity of the sloping terrain. This approach made it possible to cover areas with varying degrees of erosional transformation of the soil cover, including watershed, slope, depression and accumulation features. A total of 68 soil samples were collected. Agronomic indicators characterising the resource potential of the soil cover were determined in the collected samples: organic carbon content, nitrate nitrogen content and pH (water). Organic carbon was considered as an integral indicator of long-term changes in fertility under the influence of erosion processes. Nitrate nitrogen was used as an indicator of the current level of mineral nitrogen supply, and soil pH as a characteristic of the soil environment's reaction.

Laboratory analyses were performed on air-dried soil samples prepared in accordance with the relevant standards. Organic carbon content was determined by the oxidimetric method, based on the oxidation of organic matter in a sulphochromic medium, in accordance with DSTU ISO 14235:2005 (2005). To ensure methodological consistency in the assessment of soil organic matter status, the provisions of DSTU 4289:2004 (2004), which specifies methods for determining organic matter in soils, were also taken into consideration. Nitrate nitrogen content was determined in accordance with DSTU 4729:2007 (2007), which specifies methods for determining nitrate and ammonium nitrogen in soils using the modification developed by the NSC "O.N. Sokolovsky Institute for Soil Science and Agrochemistry". Soil pH was measured potentiometrically in a water suspension in accordance with DSTU ISO 10390:2022 (2022).

Spatial analysis was carried out using geographic information system (GIS) mapping. Based on the laboratory results, spatial distribution maps were produced for organic carbon content, nitrate nitrogen content, and other agronomic soil properties. The topographic base map was digitised, and subsequent spatial data processing was performed in QGIS (Quantum GIS) using the SAGA and GRASS toolsets. The analyses were based on digitised topographic maps at scales of 1:5,000 and 1:10,000. Parameters of the Universal Soil Loss Equation (USLE) were used to quantify terrain-induced erosion hazard. The classical structure of the USLE model followed the methodological framework proposed by Wischmeier & Smith (1978), which remains the foundation for subsequent modifications and spatial applications of the model in the assessment of water-induced soil erosion. The general form of the model is as follows:

$$A = R \times K \times LS \times C \times P, \qquad (1)$$

where A – average annual soil loss; R – precipitation erosion potential factor; K – soil erodibility factor; LS – topographical factor for slope length and steepness; C – vegetation cover and crop management factor; P – anti-erosion measures factor.

Within the scope of this study, the model was used not to calculate absolute soil losses, but to assess the spatial variation in erosion risk and its relationship with agronomic soil indicators. The main parameter was the topographical factor LS, which combines the effects of slope length and steepness. The slope steepness factor was determined using formula (2):

$$S = 0.065 + 0.0454I + 0.006I^2, \qquad (2)$$

where S – the slope steepness factor, characterising the influence of surface gradient on the potential intensity of water erosion; I — the slope steepness, %.

The slope length factor was determined using formula (3):

$$L = (x/22.13)^m, \qquad (3)$$

where L – the slope length factor, which characterises the influence of the length of the slope surface on the formation of surface runoff and potential soil loss; x – slope length, m; 22.13 – standard slope length adopted in the USLE model, m; m – exponent, the value of which depends on the slope gradient. The value of the coefficient m was selected depending on the slope gradient: 0.5 – for $I \geq 5\%$; 0.4 – for $3 < I < 5\%$; 0.3 – for $1 < I < 3\%$; 0.2 – for $I < 1\%$.

For agronomic interpretation of the established relationship, it was presented as a regression model in which organic carbon content was treated as the dependent variable and the topographical factor LS as the independent variable:

$$Y = 2.7175 - 0.5124x, \qquad (4)$$

where Y – organic carbon content, %, x – value of the topographical factor LS.

For complex slope topographies, the calculations were carried out for individual slope sections, taking into account variations in slope length and steepness. This made it possible to reflect the spatial heterogeneity of the relief more accurately and to identify sections with varying potential for erosion processes. The locally refined soil erosion factor K was used as a methodological refinement for assessing the sensitivity of the soil cover to potential erosion. At the same time, the main indicator for spatial comparison with the agronomic properties of the soil was the topographic factor LS of the USLE model. For the conditions of the study site, a locally calculated value of $K = 1.17 \pm 7.8\%$ was adopted in the corresponding units of the model. It was also taken into account that the difference between the K values for the upper and lower parts of the slope was approximately 5%, with a linear increase down the slope. As a detailed analysis of the structural factors influencing the K-factor is the subject of a separate study, in this article the K-factor was considered solely as a methodological refinement for assessing erosion risk. The locally refined soil erodibility factor K was regarded as a tool for improving the accuracy of assessing the soil cover's susceptibility to potential erosion. The main spatial indicator, which was correlated with the content of organic carbon, nitrate nitrogen and soil pH, was the topographic factor LS of the USLE model.

Statistical analysis of the results was carried out using Microsoft Excel and Statistica 10.0. To characterise the variability of the indicators, the arithmetic mean, standard deviation, standard error and coefficient of variation were determined. The relationship between the topographic LS factor, organic carbon content and nitrate nitrogen content was assessed using Spearman's non-parametric rank correlation coefficient. A linear regression model was used to quantitatively describe changes in organic carbon as a function of the topographic LS factor. Additionally, the values of the LS factor were grouped in intervals of 0.22, after which the statistical characteristics of organic carbon content were determined for each group. Differences and relationships were considered statistically significant at a significance level of $p < 0.05$. Based on the established relationship between erosion risk parameters and organic carbon content, an approach was developed for constructing a map of correction coefficients for the resource potential of the soil cover. The organic carbon values in the least eroded areas were taken as the baseline, and deviations of the actual values from this baseline were used to assess the spatial decline in agricultural potential.

RESULTS

The study conducted in 2024-2025 showed that the soil cover of eroded slope lands is characterised by marked spatial heterogeneity in agronomic indicators. This heterogeneity is a natural consequence of the long-term development of water erosion, which has resulted in the formation of eroded, slightly eroded, and depositional soil units within the same experimental site. This leads to varying levels of resource potential in the soil cover, even within a single field. Laboratory analysis of 68 soil samples collected from the arable soil layer revealed significant variability in organic carbon content. The values ranged from 1.35 to 3.05%, indicating significant spatial differentiation in the humus content of the soils in the study area (Fig. 1). The lowest organic carbon values were found in the most eroded parts of the slope and in the drainage depressions, where prolonged leaching of the topsoil had led to a reduction in the humus content and a decline in the resource potential of the soil cover. At the same time, higher values of this indicator were observed in less eroded or accumulative areas, where there was a partial accumulation of fine soil and organic matter. The spatial distribution of organic carbon, as shown on the map, confirms a systematic relationship between the erosional transformation of slope lands and changes in soil agronomic potential. Areas with reduced organic carbon content form spatial zones with lower resource potential, which is of significant agronomic importance for planning fertilisation systems, assessing the stability of agrophytocenoses and implementing elements of precision farming.

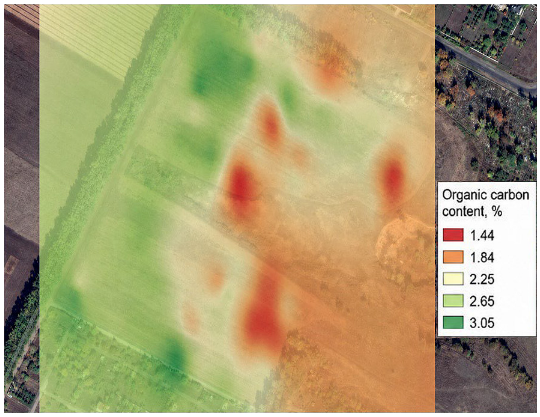

Figure 1. Spatial distribution cartogram of organic carbon content in the soils of the experimental site

Source: compiled by the authors

Unlike organic carbon, the spatial distribution of nitrate nitrogen was more localised and less stable (Fig. 2). The map of nitrate nitrogen content shows a marked mosaic pattern, which does not always coincide with the main features of the terrain. This is explained by the high dynamism of the nitrate form of nitrogen, its dependence on current moisture levels, temperature conditions, the rate of organic matter mineralisation, uptake by plants and previous agronomic practices. It is therefore advisable to regard nitrate nitrogen primarily as an indicator of the current state of plant mineral nutrition, rather than as a stable indicator of long-term erosional transformation of the soil cover.

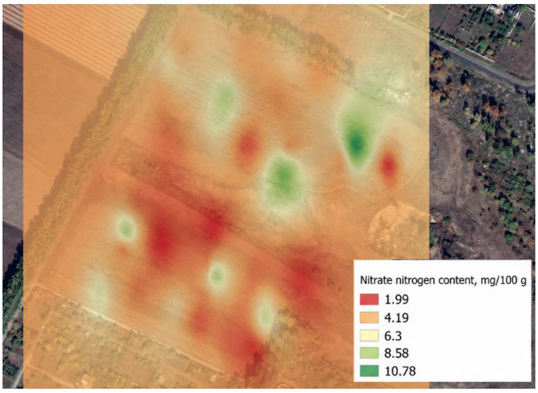

Figure 2. Spatial distribution cartogram of nitrate nitrogen content in the soils of the experimental site
Source: compiled by the authors

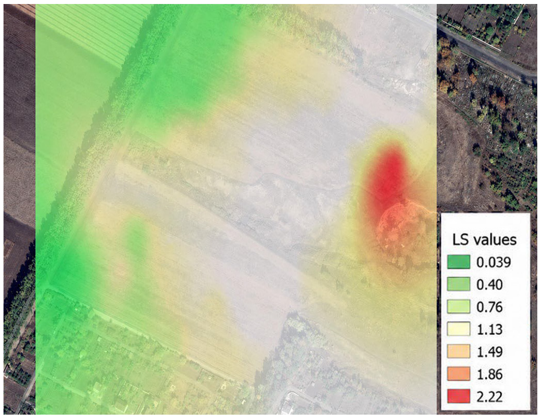

Figure 3. Spatial distribution cartogram of LS topographic factor values of the USLE model at the experimental site
Source: compiled by the authors

The soil environment also exhibited spatial variability: the pH values of the soil solution ranged from 6.52 to 8.51. This range indicates the heterogeneity of soil conditions within the study plot, which may be linked to erosion and accumulation processes, the redistribution of carbonate material, and differences between eroded and deposited components of the soil cover. However, within the scope of this study, the main focus was on organic carbon content as the most informative indicator of long-term changes in the agropotential of eroded slope lands. The next stage of the study involved determining the spatial distribution of the topographic factor LS in the USLE model, which characterises the influence of slope length and steepness on the potential for water erosion. Within the study area, LS values ranged from 0.039 to 2.22, indicating significant spatial heterogeneity in the relief-induced erosion risk. The lowest values of the topographic factor were characteristic of the flatter parts of the area, whilst the highest values were confined to slope features, where the combination of slope length and steepness creates conditions for increased surface runoff and potential soil erosion. It is precisely these areas that can be regarded as zones of increased risk of a reduction in the agricultural potential of the soil cover (Fig. 3).

A comparison of the spatial distribution of the topographic factor LS with organic carbon content revealed a clear pattern: as the relief-induced risk of erosion increased, the organic carbon content in the arable soil layer decreased. This relationship is agronomically sound, as it is precisely in areas with higher LS values that conditions are created for more intense surface runoff, leaching of the topsoil and loss of organic matter. Correlation analysis confirmed a strong inverse relationship between the topographic factor LS and organic carbon content. Spearman's rank correlation coefficient was $r = -0.725$, indicating a statistically significant relationship between the parameters of slope processes and the humus status of the soil cover. The result obtained confirms that organic carbon is a sensitive indicator of long-term erosional transformation of haplic chernozem on sloping land. A graphical representation of the relationship between organic carbon content and the topographic factor LS is shown in Figure 4. The distribution of data points on the graph confirms a general trend towards a decrease in organic carbon content as LS values increase. At the same time, the presence of isolated deviations from the trend line indicates the influence of additional spatial factors, in particular micro-relief, local accumulation zones, protective forest strips and the characteristics of previous agronomic use of individual parts of the study plot.

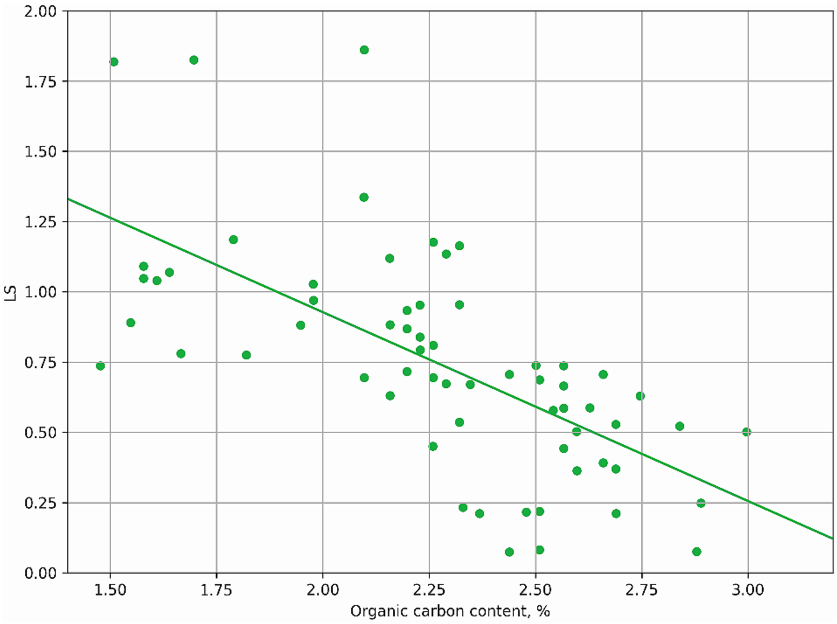

Figure 4. Relationship between organic carbon content and the LS topographic factor of the USLE model in soils of the experimental site

Source: compiled by the authors

According to Equation 4, an increase in the LS value by one conventional unit is accompanied by a 0.5124% reduction in organic carbon content. This makes it possible not only to identify spatial heterogeneity in soil humus content, but also to quantitatively assess the potential reduction in the resource capacity of the soil cover as the risk of erosion increases. The practical significance of this relationship lies in the fact that the topographical LS factor can be used as a spatial predictor of the decline in the agricultural potential of eroded slope lands. Combined with actual data on organic carbon content, this provides a basis for constructing map charts showing adjustments to the resource capacity of the soil cover and for the subsequent application of differentiated agronomic measures. A correlation analysis was carried out to clarify the nature of the relationships between erosion risk parameters and agronomic soil indicators. The results confirmed that the strongest relationship was found between the topographic factor LS and organic carbon content. In contrast, the relationship between LS and nitrate nitrogen content was weak.

The data presented indicate that the topographical factor LS has a close inverse relationship with organic carbon content, whilst its relationship with nitrate nitrogen is almost non-existent (Table 1). This is explained by the different nature of the indicators under study. Organic carbon is a relatively stable indicator of long-term changes in soil cover; thus, it more clearly reflects the effects of erosional redistribution of soil mass within a slope. Nitrate nitrogen, by contrast, is a dynamic form of mineral nutrition, the content of which changes rapidly under the influence of soil moisture, temperature, the rate of organic matter mineralisation, uptake by plants and previous agronomic practices.

Table 1. Correlation matrix between the USLE LS topographic factor and agronomic soil indicators

Indicator	USLE LS factor	Nitrate nitrogen content	Organic carbon content
LS USLE	–	-0.066	-0.725
Nitrate nitrogen content	-0.066	–	0.241
Organic carbon content	-0.725	0.241	–

Source: compiled by the authors

The weak correlation coefficient between LS and nitrate nitrogen, which stood at r = -0.066, indicates that the nitrate form of nitrogen cannot serve as a reliable indicator of long-term erosion-induced differentiation in agricultural potential. Its spatial distribution primarily reflects the current state of nitrogen supply, rather than the cumulative result of erosion-induced transformation of the soil cover. At the same time, the weak positive correlation between nitrate nitrogen content and organic carbon, r = 0.241, may indicate that organic matter plays a certain role in shaping the soil's mineral nitrogen regime. However, this correlation was not strong enough to consider nitrate nitrogen as the primary indicator for the spatial assessment of the agricultural potential of eroded slope lands. Thus, in the subsequent analysis, the main focus was placed on organic carbon as an integral indicator of the resource potential of the soil cover. To assess in greater detail the impact of relief-induced erosion risk on soil humus content, the values of the topographic factor LS were grouped in increments of 0.22. This approach made it possible not only to establish the general trend in organic carbon changes but also to assess the variability of this indicator across different levels of potential slope process activity. The results of the grouping showed that, at lower values of the topographic factor, the average organic carbon content was higher. In groups with relatively low LS values, the average organic carbon content ranged from 2.610-2.636% (Table 2). In contrast, in groups with higher LS values, this figure decreased to 1.853-1.949%. This pattern confirms that an increase in relief-induced erosion risk is accompanied by a reduction in the resource potential of the soil cover.

Table 2. Statistical characteristics of the distribution of organic carbon content depending on the values of the topographic factor LS

Group	Number of observations	Mean organic carbon content, %	Standard deviation	Standard error	Coefficient of variation, %
1	3	2.610	0.236	0.137	9.059
3	4	2.540	0.101	0.050	3.976
4	5	2.634	0.272	0.122	10.337
5	10	2.636	0.198	0.063	7.509
6	15	2.394	0.307	0.075	12.842
7	16	2.123	0.260	0.065	12.242
8	11	1.949	0.314	0.095	16.087
9	4	1.853	0.296	0.148	15.986
Total	68	2.302	0.374	0.046	16.194

Source: compiled by the authors

The data in Table 2 show that as the LS factor increases, not only does the average organic carbon content decrease, but the spatial variability of this parameter also increases. In groups with lower LS values, the coefficient of variation generally did not exceed 10.337%, whereas in groups with a higher risk of erosion, it rose to 15.986-16.087%. This indicates a more complex spatial structure of the soil cover under conditions of intensified slope processes. The increase in the variability of organic carbon at high LS values can be explained by a combination of planar and linear erosion, local redistribution of soil material, the influence of micro-relief and the presence of accumulation zones. Under such conditions, even closely situated plots may differ significantly in their organic carbon content, which complicates the application of a single, field-wide assessment of fertility.

The results obtained are of significant agronomic importance. At lower levels of erosion risk, the soil cover was characterised by a relatively higher and more stable organic carbon content. At higher levels of the LS factor, there was a simultaneous decrease in the average value of the indicator and an increase in its heterogeneity. This implies that eroded slope lands require not only a general improvement in soil resource capacity but also a spatially differentiated approach to fertility management. The grouping of LS-factor values confirmed the feasibility of using parameters of relief-determined erosion risk to identify zones with varying levels of agropotential. The parts of the study plot most at risk of erosion were characterised by lower organic carbon content and greater variability in humus status, which provides a basis for constructing map charts of correction coefficients for the resource capacity of the soil cover.

Based on the established relationship between the topographic factor LS and organic carbon content, an approach was developed for constructing a map of correction coefficients for the resource capacity of the soil cover. The average organic carbon content in the least eroded areas, which stood at 2.61%, was taken as the baseline. Deviations of actual organic carbon values from this level were used as the basis for the spatial adjustment of agricultural potential. This approach makes it possible to move from an average-field assessment of fertility to a spatially differentiated characterisation of the soil cover. Areas where the organic carbon content was close to or exceeded the baseline level can be regarded as zones with relatively higher resource potential. Conversely, areas with reduced organic carbon content are characterised by lower agricultural potential and require adjustments to the fertilisation regime, erosion control measures and agricultural management practices. The map of correction factors shows that the spatial decline in soil resource potential is uneven (Fig. 5). The greatest deviations from the baseline organic carbon level are confined to erosion-prone sections of slopes and drainage basins. This indicates that it is precisely these parts of the field that are most vulnerable to degradation processes and require priority attention when planning soil conservation measures.

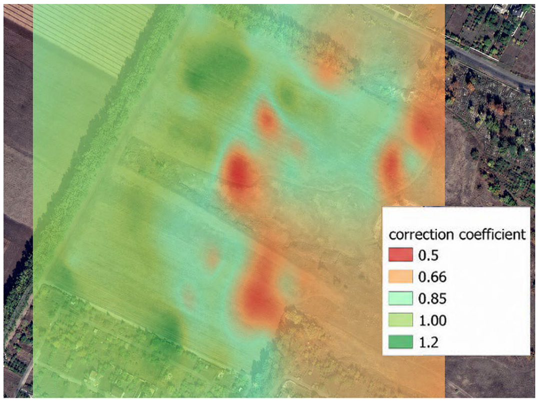

Figure 5. Cartogram of correction coefficients for soil cover resource capacity at the experimental site

Source: compiled by the authors

The practical value of the proposed map lies in its potential for use in differentiated fertility management. In particular, it can serve as a basis for refining application rates of organic and mineral fertilisers, planning measures to preserve soil organic matter, selecting soil-conserving tillage techniques, and identifying areas where agro-phytocenoses may be more susceptible to drought, nutrient deficiency or other stress factors. Of particular significance is the potential for using such maps in precision farming systems. Given the spatial heterogeneity of eroded slope lands, applying a single fertiliser rate across the entire field may not be sufficiently effective. On plots with lower agricultural potential, it is advisable to implement measures aimed not only at compensating for nutrient deficiencies, but also at restoring organic matter, improving soil structure and reducing the risk of further erosion.

The proposed approach can also be used to adjust the application rates of certain soil-applied products, the efficacy and safety of which depend on organic matter content. This is particularly relevant for basal soil herbicides, whose action is largely linked to the soil's sorption capacity. In areas with reduced organic carbon content, the risk of changes in the behaviour of such products may be higher; therefore, taking the humus status into account spatially is of significant agronomic importance. Thus, the map of correction factors is not only the result of spatial analysis but also a practical tool for management decision-making. It enables the assessment of the heterogeneity of the agropotential of eroded slope lands, the identification of zones with varying levels of soil resource capacity, and the establishment of a basis for the differentiated application of agrotechnological and soil conservation measures.

DISCUSSION

The results obtained confirm that the spatial differentiation of the agricultural potential of eroded slope lands should be assessed not only on the basis of average agrochemical indicators, but also in relation to their connection with the morphometric parameters of the relief. The most important scientific finding established in this study is the close inverse relationship between the topographic factor LS of the USLE model and the organic carbon content in the arable soil layer. Spearman's correlation coefficient was r = -0.725, and the linear model Y = 2.7175 – 0.5124x showed that as the LS value increases, there is a systematic decrease in organic carbon content. This provides grounds for considering the LS factor not only as an indicator of potential erosion risk, but also as a spatial predictor of the decline in the resource capacity of the soil cover. The validity of this approach is consistent with current developments in erosion modelling. P. Borrelli *et al*. (2021) note that water erosion models are increasingly being used not only to assess soil loss but also for the spatial analysis of degradation processes in agricultural landscapes. N. Bezak *et al.* (2024) also emphasise the importance of multi-model approaches to assessing erosion risk, as different models and parameters may reflect the spatial heterogeneity of erosion processes in different ways. In this context, the use of the LS factor for the agronomic interpretation of the spatial differentiation of organic carbon is a logical extension of modern approaches to assessing soil cover degradation.

This finding is consistent with modern approaches to assessing intra-field variability in organic carbon. B. Cutting *et al.* (2024) demonstrated that topography plays an important role in shaping the spatial distribution of organic carbon within a field; consequently, relief parameters can be used for its remote and spatial assessment. Similarly, in the current study, it was the topographic factor LS that explained the systematic decrease in organic carbon on erosion-prone sections of the slope. At the same time, this study extends this approach, as it uses LS not only as an auxiliary topographic variable, but as a basis for the agronomic interpretation of the agricultural potential of eroded land. To a certain extent, the authors' results are also consistent with the findings of R. Näsi *et al.* (2023), who note that basic soil quality indicators and topographical parameters can explain the spatial heterogeneity of agricultural fields. For eroded slope lands in the Left-Bank Forest-Steppe of Ukraine, this pattern manifested itself in a decrease in the average organic carbon content from 2.610-2.636% in groups with lower LS values to 1.853-1.949% in groups with an increased level of relief-induced erosion risk. Consequently, spatial variations in humus status are not random but are linked to the long-term impact of slope processes.

It is important to note that as the LS factor increased, there was not only a decrease in the average organic carbon content, but also an increase in its variability. The coefficient of variation in groups with higher LS values rose to 15.986-16.087%. This indicates a more complex spatial structure of the soil cover under conditions characterised by a combination of planar erosion, local accumulative redistribution of soil material, the influence of micro-relief and the possible influence of protective forest strips. A similar role of relief in shaping the spatial heterogeneity of organic carbon is noted by J. Kalambukattu *et al.* (2025), who emphasise the importance of digital mapping of organic carbon in complex relief conditions. In the case of this study, such heterogeneity confirms the need to move from an average-field assessment of fertility to spatially differentiated management. The importance of organic carbon as an indicator of erosion-induced transformation is also confirmed by the findings of N. Manninen *et al.* (2023), who demonstrated the contribution of water erosion to the transport of organic carbon and total nitrogen from agricultural soils. These findings reinforce the conclusion that organic carbon reflects not only the current level of soil fertility but also the cumulative effects of erosion-induced redistribution of soil material.

The weak relationship between the LS topographic factor and nitrate nitrogen content also merits discussion. In the present study, the correlation coefficient between these variables was only $r = -0.066$, indicating an almost non-existent direct relationship between relief-induced erosion risk and the current content of nitrate nitrogen. This does not mean that nitrate nitrogen is of no agronomic significance. On the contrary, it is an important indicator of the current state of plant nutrient supply. However, its spatial distribution is influenced by many short-term factors: soil moisture, temperature, mineralisation of organic matter, fertilisation, plant uptake and previous agronomic operations. This conclusion is consistent with the findings of J. Schuster *et al.* (2023), who demonstrated that spatial variations in the nitrogen balance and nitrate leaching on heterogeneous arable fields depend on a combination of soil properties and digital indicators of field condition. O. Chiriac *et al.* (2025) also emphasise the complex nature of the spatial variability of the nitrogen balance and its relationship with soil properties. Thus, the weak correlation between nitrate nitrogen and the LS factor in this study is to be expected: nitrate nitrogen primarily reflects the short-term functional state of the soil, whereas organic carbon better characterises the long-term erosional transformation of the soil cover.

The weak positive correlation between nitrate nitrogen and organic carbon content, which was $r = 0.241$, indicates that organic matter plays a certain role in shaping the soil's mineral nitrogen regime. However, this correlation was not strong enough to allow nitrate nitrogen to be used as the primary indicator of the agricultural potential of eroded slope lands. A similar distinction between the more stable indicators of carbon status and the more dynamic indicators of the nitrogen regime is evident in the study by B. Xu *et al.* (2024), where the spatial distribution of carbon and nitrogen depended on land-use type and soil conditions. In the context of this study, this confirms the appropriateness of using organic carbon as a baseline indicator for the spatial adjustment of the resource capacity of the soil cover. This is precisely why organic carbon, rather than nitrate nitrogen, was used to construct the map of agro-potential correction factors, as the former reflects the cumulative result of erosion-induced transformation, whilst the latter primarily reflects the current state of mineral nutrition. A similar pattern is reported by J. Tian *et al.* (2023), who found that the spatial distribution of organic carbon and nitrogen within a micro-catchment is shaped by a combination of natural and soil-related factors. This confirms that nitrogen indicators cannot always be directly linked solely to the morphometric parameters of the relief, whereas organic carbon better reflects the long-term spatial differentiation of the soil cover.

An important point of discussion is the use of USLE model parameters not only to assess potential soil erosion, but also for the agronomic zoning of fields. N. Koralay & Ö. Kara (2025) applied RUSLE in combination with geoinformation technologies to assess the risk of erosion, as well as losses of organic carbon and total nitrogen via suspended sediments. In this study, the modelling approach was used in a different but logically similar direction: not to directly determine losses via sediment, but to spatially assess the reduction in agricultural potential due to changes in organic carbon content. This opens up a broader discussion regarding the potential use of erosion models as a tool not only for soil conservation but also for agronomic planning. A similar approach to the application of erosion risk models can also be seen in other recent studies. M. Fadl *et al.* (2025) combined RUSLE, geoinformation technologies and multi-criteria analysis to assess soil erosion in Mediterranean conditions. A. Fredj *et al.* (2024) demonstrated the effectiveness of using RUSLE and geospatial technologies to identify areas of heightened erosion risk within catchment basins. N. Samarinas *et al.* (2024) expanded the capabilities of RUSLE by incorporating artificial intelligence and geospatial layers to assess soil loss in agricultural areas. In contrast to these studies, the present research focuses not on mapping soil loss as an end result, but on using the model parameters to spatially adjust agricultural potential based on organic carbon content.

Local refinement of the soil erosion factor is also crucial for interpreting the results obtained. In the authors' study, the K-factor was not the central focus of the analysis; however, taking it into account made it possible to characterise the sensitivity of the soil cover to potential erosion more accurately. B. Yosef *et al.* (2025) emphasise that spatial variation in soil characteristics can significantly influence the assessment of soil erosion. This is consistent with the approach adopted in the present study, as the soil cover within a single slope is not homogeneous with respect to erosion susceptibility. At the same time, a more detailed assessment of the K-factor, particularly taking into account structural condition, aggregate water resistance and water permeability, requires a separate study. The practical value of the results obtained lies in the fact that the established relationship between the LS-factor and organic carbon can be used to construct map charts of correction coefficients for the resource potential of the soil cover. The organic carbon content in the least eroded areas was taken as the baseline, and deviations from this level were used for spatial adjustment of agricultural potential. This approach makes it possible to identify areas where a reduction in organic carbon is not only an indicator of degradation but also a practical signal for changing the fertilisation regime, implementing soil conservation measures and adjusting agricultural practices.

At the same time, the proposed approach has certain limitations. The agricultural potential of sloping land is determined not only by the length and steepness of the slope. It can also be influenced by aspect, insolation conditions, micro-relief, wind erosion, previous land use, local agronomic practices and protective forest strips. For this reason, the map of correction factors should not be regarded as a definitive, unchanging characteristic of the field. It serves as a basis for further refinement of a spatially differentiated soil resource management system. Overall, the results obtained confirm that the parameters of relief-induced erosion risk can be used for the agronomic interpretation of spatial heterogeneity in soil cover. In contrast to the traditional approach, in which the USLE is used primarily to predict soil loss, this study considers the topographic factor LS as an indicator of a spatial reduction in agricultural potential. This proposition may become the subject of further scientific debate, as it combines erosion modelling, geoinformation analysis and the practical challenges of precision farming.

CONCLUSIONS

The use of geographic information system mapping in combination with the parameters of the USLE model made it possible to identify the spatial heterogeneity of the agricultural potential of eroded slope lands. Within the study plot, values of the topographic factor LS ranged from 0.039 to 2.22, indicating significant differences in the conditions governing surface runoff and potential soil loss even within a single field. The most sensitive agronomic indicator of spatial differentiation in the soil cover was the organic carbon content. Its values in the arable soil layer ranged from 1.35 to 3.05%, with lower values occurring in erosion-prone sections of the slope and in runoff basins. This confirms that the long-term impact of water erosion manifests itself not only in morphological changes to the soil cover but also in a reduction in its resource potential. An inverse relationship between the topographical factor LS and organic carbon content has been quantitatively confirmed. The Spearman's correlation coefficient was $r = -0.725$, and the regression model $Y = 2.7175 - 0.5124x$ showed that an increase in LS is accompanied by a systematic decrease in organic carbon content. This provides grounds for using the LS factor not only to characterise erosion risk, but also as a spatial indicator of the decline in the agricultural potential of sloping land.

Clustering of the LS factor values revealed that, as erosion risk increased, the average organic carbon content decreased from 2.610-2.636% to 1.853-1.949%. At the same time, the coefficient of variation increased to 15.986-16.087%, indicating a more complex spatial structure of the soil cover under conditions of intensified slope processes. Nitrate nitrogen showed a weak correlation with the topographic factor LS, r = -0.066; thus, it is advisable to consider it primarily as an indicator of the current state of mineral nutrition. For the spatial adjustment of the agropotential of eroded slope lands, the use of organic carbon is more justified, as it better reflects the accumulated effects of erosional transformation of the soil cover. Based on the established relationship between the LS factor and organic carbon, the construction of a map of correction coefficients for the resource potential of the soil cover is justified. This approach makes it possible to identify plots with varying levels of agricultural potential and can be used for differentiated fertilisation, planning soil conservation measures, refining agricultural practices and implementing elements of precision farming. Prospects for further research lie in verifying the proposed correction coefficients in relation to crop yields, productive moisture reserves, soil structure and the effectiveness of differentiated fertilisation. The influence of protective forest strips, slope aspect, micro-relief and local variability in soil erosion on the spatial assessment of agricultural potential also requires separate study.

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CONFLICT OF INTEREST

None.

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Просторова оцінка агропотенціалу еродованих схилових земель за параметрами моделі USLE

Анотація. Еродовані схилові землі характеризуються значною просторовою неоднорідністю ґрунтового покриву, що ускладнює об'єктивну оцінку їхнього агропотенціалу за середньопольовими агрохімічними показниками. Метою дослідження було встановити закономірності просторової оцінки агропотенціалу еродованих схилових земель за зв'язком агрономічних показників ґрунту з параметрами моделі USLE (Universal Soil Loss Equation). Дослідження проводили у 2024-2025 роках на дослідному полі «Докучаєвське» Державного біотехнологічного університету в умовах Лівобережного Лісостепу України. Відбір 68 ґрунтових проб здійснювали з орного шару за нерегулярною мережею з урахуванням особливостей рельєфу. У зразках визначали вміст органічного вуглецю, нітратного азоту та pH водний. Просторовий розподіл показників оцінювали методом геоінформаційного картографування, а ерозійну небезпеку характеризували за топографічним фактором LS моделі USLE. Установлено, що вміст органічного вуглецю змінювався від 1,35 до 3,05 %, а значення LS – від 0,039 до 2,22. Виявлено тісний обернений зв'язок між LS і вмістом органічного вуглецю: коефіцієнт кореляції Спірмена становив -0,725. Лінійна модель Y = 2,7175 – 0,5124x підтвердила зниження вмісту органічного вуглецю зі зростанням ерозійної небезпеки. За групування значень LS середній уміст органічного вуглецю зменшувався з 2,610-2,636 до 1,853-1,949 %, тоді як зв'язок LS із нітратним азотом був слабким, r = -0,066. Отже, органічний вуглець є більш надійним індикатором просторового коригування агропотенціалу еродованих схилових земель. Запропонований підхід може бути використаний для побудови картограм поправочних коефіцієнтів, диференційованого удобрення, планування ґрунтозахисних заходів і впровадження елементів точного землеробства

Ключові слова: органічний вуглець; нітратний азот; топографічний фактор; ресурсна можливість ґрунту; геоінформаційне картографування; чорнозем типовий