Use of digital characteristics of soil color for assessing the degree of soil erosion

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Abstract. The present study is aimed at developing and improving approaches to assessment of the degree of soil erosion. The transition from verbal to digital form of determining the color of soils expands the possibilities of using this morphological feature. It allows determining the thickness of soil horizons based on the data of laboratory analysis of the color of soil samples. The methodological basis of the study is represented with the index method or the method of field standardization of territories. According to this method, the main contour of the soil is characterized by a full-profile soil pit, and soil changes caused by the relief near the main pit are estimated by changes in the characteristics of soil layers. Measurement of the latter was carried out in the course of the laboratory analysis of soil samples selected by soil drilling. As a result of the study, the soil color coordinates were determined in the CAI Lab system. The values correspond to the soil samples of the southern chernozem taken at a depth of 1 meter every 10 centimeters. The linear nature of interconnection between the index of organic carbon content in the soil samples and the corresponding values of the lightness index in the CAI Lab color model was confirmed. The soil samples with varying degrees of erosion were identified in a research object: soils of watersheds unaffected by erosion processes; moderately eroded soils of hollows exposed to water erosion; drift soils of the mouth of hollows.

1. Introduction

Solving the problem of diagnosing and classifying soils by the degree of water erosion reveals a variety of methodological approaches [1-4]. In general, classifications are built on two diagnostic features – 1) degree of decrease in the thickness of humus horizons [2-4] and 2) change in the content of organic carbon in the surface layers of soil in % as compared to unwashed soil [1]. The work of G.P. Surmach [5] outlines the positive and negative aspects of each of the methodological approaches. The present paper also substantiates the great practical relevance and accuracy of the method based on the evaluation of the thickness of soil horizons for the purposes of soil erosion mapping. Determining the content of organic carbon in soil requires conducting soil studies in laboratory conditions – burning the soil in an acid solution in a muffle furnace. Determining the thickness of soil horizons involves opening soil horizons in pits or wells and conducting morphological studies of soil. Both approaches are time-consuming and require high qualifications of workers.

To date, a certain amount of data on investigation of soils using digital technology has been accumulated both in our country [9-13] and abroad [14-16]. Modern technologies make it possible to move from a verbal description of soil color to a digital form. This circumstance contributes to the objectivity of studies and makes it possible to increase their effectiveness.
The research tasks include determining the interconnection between the parameters of organic carbon content in soil and the numerical characteristic of soil color; determining the color coordinates corresponding to the profile of the chernozem of the southern Volgograd region using the CAI Lab system; and assessing the degree of soil erosion in the research object.

2. Materials and methods
The research object is represented with the soil cover of the Antipovsky experimental site located in the Elansky district of the Volgograd region. The area of the experimental site is 250 ha. The agroforest landscapes of the study area are typical for the steppe zone of the Volgograd region. The zonal soil types are the following: medium-thick low-humus southern chernozems with medium loamy granulometric composition (according to the classification of soils of the USSR [6]); texture-carbonate chernozem (according to the classification of Russian soils [7]); Calcic Chernozem (according to World reference base for soil resources) [8].

The Antipovsky site is located on the territory of two gully water catchments, on the left bank of the Vyazovka River. The slope with northwestern exposure is 0.5 - 1.0° steep and 3 km long.

The study of water erosion of soil was carried out on the basis of measuring the thickness of soil layers. Soil samples were taken by soil drilling to a depth of 1 m layer by layer every 10 cm. The thickness of soil layers was estimated in laboratory conditions based on the analysis of two parameters: the content of organic carbon in soil samples and the color of soil samples. The CAI Lab color model was used in the study as the most appropriate for the task of determining the content of organic carbon in soil [9].

The thickness of soil horizons was determined on the basis of the data of field standardization. Analysis of soil samples taken from the pits located on the watershed makes it possible to determine the ranges of values of the considered parameters corresponding to the genetic horizons of the studied soils. Thus, the range of values of the index of organic carbon content for the humus horizon (A) is 2.7-2.3%; for the transitional humus horizon (AB), the index is equal to 2.2-1.1%; for the transitional horizon (B), the index is equal to 1.0-0.6%; for the upper layers of the parent rock (C), the index is less than 0.5%. Color of the samples in the CAI Lab system with the index L (lightness) has the following ranges of values: for the humus horizon (A), index L (lightness) is 61.5-55; index a (redness) is 132-131, index b (yellowness) is 134-135; for the transitional humus horizon (AB), index L is 62-90, index a is 131-136, index b is 136-139; for the transitional horizon (B), index L is 91-105, index a is 131-135, index b is 138-142; for the upper layers of the parent rock (C), index L is 106-115, index a is 136-137, index b is 139-142.

The important methodological points of the ongoing research include [11]:

- Preliminary preparation of the soil before photographic survey. Soil samples were crushed, sifted through a sieve with a diameter of 2 mm and dried to an air dry state.
- Unification of the conditions for photographic survey of the soil samples. Photos were taken indoors in artificial light.
- Use of color standards for controlling the accuracy of color rendition.

The statistical sampling analyzed in the laboratory conditions consists of 348 samples. Sampling was carried out from 32 soil wells and 2 soil pits.

During the field stage of the studies, sampling was carried out in such a way that the general set of the studied samples corresponded to soils with varying degrees of erosion. The soil wells were laid on the watershed, various parts of the slope, as well as along the thalweg of hollows located on the cultivated arable land.

3. Results
Comparison of the data on the color coordinates of soil samples in the CAI Lab system with the index of organic carbon content made it possible to reveal that the lightness parameter (L) is the most informative indicator. The value of the lightness parameter (L) in the CAI Lab system is inversely
related to the content of organic carbon in the soil. This relationship is described by a linear equation with a determination coefficient $R^2 = 0.7558$ (figure 1).

**Figure 1.** Diagram of dependence of a soil sample color on organic carbon content.

Table 1 presents the values of the obtained color coordinates of the soil samples of the watershed.

| Sampling depth, cm | Organic carbon content, % | Color coordinates in the CAI Lab system |
|-------------------|---------------------------|----------------------------------------|
| 0.7               | 2.7                       | 57.3/132.3/133.8                       |
| 0.7               | 2.2                       | 52.9/131.9/133.6                       |
| 0.7               | 1.6                       | 65.6/133.6/134.8                       |
| 1.6               | 2.2                       | 61.4/133.7/134.7                       |
| 2.1               | 2.1                       | 64.6/134.4/135.3                       |
| 1.6               | 1.6                       | 84.2/135.9/137.6                       |
| 0.9               | 0.9                       | 95.4/137.8/140.5                       |
| 0.7               | 0.7                       | 98.4/136.6/140.8                       |
| 0.7               | 0.7                       | 83/136.9/140.1                         |
| 0.7               | 0.7                       | 88.6/137.4/139.4                       |

Analysis of the change in the value of the lightness parameter (L) in the soil profiles of the key site confirms the presence of soil erosion process in the study area. The soils of hollows turned out to be the most susceptible to the impact of erosion-accumulation processes. Table 2 presents the data corresponding to the washed-out soil located in the middle part of the hollow. Comparison of the values of the studied indicators with the values corresponding to the soil located on the watershed makes it possible to determine the thickness of the washed-out layer – it makes about 30-40 cm.
Table 2. Organic carbon content and color coordinates of the soil samples of the middle part of the hollow.

| Sampling depth, cm | Organic carbon content, % | Color coordinates in the CAI Lab system |
|--------------------|--------------------------|----------------------------------------|
| 2.6                | 65.2/131.2/135.3         |                                        |
| 2.5                | 65.1/132.9/133.6         |                                        |
| 1.3                | 88.4/135.2/138.9         |                                        |
| 0.8                | 90.1/137.1/141.5         |                                        |
| 0.9                | 91.7/137.1/139.6         |                                        |
| 0.6                | 103.5/136.4/140.9        |                                        |
| 0.7                | 98.5/136.8/141.1         |                                        |
| 1.1                | 102.2/136.7/139.5        |                                        |
| 0.5                | 115.9/136.5/142.3        |                                        |
| 0.5                | 102.3/137.4/142.6        |                                        |

Table 3 presents the data corresponding to the drift soil located at the mouth of the hollow. Comparison of this soil with the soil of the watershed makes it possible to estimate the thickness of the drifted layer, which is about 30–40 cm.

Table 3. Organic carbon content and color coordinates of the soil samples of the mouth of the hollow.

| Sampling depth, cm | Organic carbon content, % | Color coordinates in the CAI Lab system |
|--------------------|--------------------------|----------------------------------------|
| 3.3                | 43.8/131.3/132.8         |                                        |
| 3.1                | 47.8/132.9/132.9         |                                        |
| 3.2                | 47.8/132.3/133.1         |                                        |
| 2.7                | 53.1/132.7/133.4         |                                        |
| 2.8                | 60.5/133.6/133.8         |                                        |
| 2.5                | 63.3/134.5/134.3         |                                        |
| 1.8                | 68.3/137.4/138.6         |                                        |
| 1.7                | 79.3/136.3/136.6         |                                        |
| 1.7                | 66.3/135.6/136.5         |                                        |
| 1.7                | 70.5/135.5/135.7         |                                        |

4. Discussion
The revealed pattern of the interconnection between the parameters of organic carbon content and the value of the lightness index in the CAI Lab system is consistent with the results of studies on the identification of soil color coordinates obtained for soddy-podzolic soil [9].

A significant degree of interconnection between the parameters of organic carbon content in the soil and the digital characteristics of soil color, the relative ease of color determination allows for the use of digital photographs in preliminary studies related to the analysis of a larger number of soil samples for the purpose of assessing the degree of soil erosion.

5. Conclusion
Thus, the present research conducted with the use of the CAI Lab system allowed us to determine the color coordinates of soil samples corresponding to the soil profile of southern chernozem, to determine the interconnection between the content of organic carbon in the soil and the value of the lightness parameter (L), to assess the soils of the key site from the point of view of erosion development.
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