Spectroscopic methods for determining of zonal soils erosion (Chuvash Republic, Russia)

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Abstract. Results of spectrographic study of zonal soils with different erosion degree on the territory of the Chuvash Republic are given. In the points of spectrographic research, the soil specimens were taken and agrochemically tested. Changes in received spectrograms were analyzed in soils subtypes context with subsequent comparison with agrochemical indicators. The obtained data will help to develop new rapid methods for determining soil fertility parameters for agricultural lands based on spectroscopic physical principles.

1. Introduction

There are many classifications of eroded soils but all variety of methods for determining erosion can be reduced to four large groups:

1. Based on the morphological differences between eroded and non-eroded soils, with taking into account the nature of the relief.

2. Based on the change in humus content.

3. Based on other chemical, biological or physico-chemical changes occurring in eroded soils.

4. Using several of the above listed indicators.

According to the classification of eroded soils, published in "All-union instruction on soil surveys and large-scale soil maps of land use composition", USSR standard, soil washout in comparison with the unwashed soils was taken as a basis of soils washout classification degree.

An exception was the classification of eroded sod-podzolic and light gray forest soils, where the degree of erosion is determined for agricultural soils by complex of factors: what horizons are under the arable layer, dependence on the slope inclination, and so on [1, 2]. In some classifications [3, 4, 5], indicators characterizing the relief (steepness, length, exposure of slopes, degree of slope dissection), soil-forming rocks, and erosion resistance of soils are used [6]. Currently, several common field methods for soil erosion determination are used for Chuvash Republic territory. Visually-morphological classification developed by S.S. Sobolev [7, 8] and adapted to the conditions of Chuvashia by S.I. Andreev and F.Y. Mikhailov [9, 10] is the most well-known. S.I. Andreev used a set of indicators as the basis for eroded agricultural soils classification and assessment: slope inclination, degree of humus horizon washout, decrease in genetic horizons thickness, plowing layer color, presence and quantity of rills, humus content (for loamy sod-podzolic and light gray forest soils), growth and development of agricultural crops. F.Y. Mikhailov used these diagnostic features of eroded soils in the context of soil types and degree of erosion [10]. It should be noted that the last Chuvash Republic soils descriptions received at 1980s, are still used in cadastral

evaluation of agricultural lands as the basis for the tax accruals, calculation of land plots redemption price determining the size of penalties. Therefore, it should be realized that this information on the cadastral value of agricultural lands is at least unreliable. In addition, the given criteria of soil cover used to determine a significant reduction of agricultural land fertility and can be the probable cause for compulsory removal of agricultural land plots from the owners in accordance with the Russian legislation [11, 12].

In contrast to the geomorphological indicators that are easily described using GIS technology and external features of erosion that can be identified by analysis of remote sensing data, agrochemical parameters of soils (humus content, acidity, phosphorus and potassium content, etc.) are very dynamic and require direct field definition. As the network of representative sampling points should be sufficiently dense, development of accessible, low-cost and fast methods for determining agrochemical attributes of soil changes is required [13, 14, 15, 16]. In this article, the team of authors proposes the development of an express method for determining of soil erosion for agricultural lands based on spectroscopic physical principles. Infrared spectroscopy methods based on the interaction of molecules with electromagnetic energy in the infrared spectrum is recognized to be one of the most promising methods for soils study [17]. Technological advances in the application of the near and middle infrared spectrum over the past decades have made this band very popular in soil research and recognized as one of the most promising non-contact methods for determining soil parameters for various purposes [18, 19, 20]. Thus, the current state in the field of soils spectrometric analysis is contradictory. Apparently, there is a need for standardization of sampling and soil analyzes as well as geographical localization for specific types and subtypes of zonal soils [21, 22].

This paper presents the results of spectrographic studies of zonal soils on the territory of the Chuvash Republic.

2. Methods
In this work long-term observation points of the Federal Organization "State Center of Agrochemical Service "Chuvashskiy" organized in the well-studied soil areas with different soil varieties have been used.

The sample includes chernozem and gray forest soil varieties:
1. Dark-grey forest, light washout (9 samples).
2. Dark-grey forest, medium washout (40 samples).
3. Dark-grey forest, typical gley (light clay texture of surface soil layer) (10 samples).
4. Chernozems leached, medium thickness, medium-humic (7 samples).
5. Chernozems leached, light washout, medium loamy (9 samples).
6. Chernozems leached, light washout, (light clay) (11 samples).
7. Chernozems leached, light washout, (medium clay) (8 samples)
8. Chernozems leached, medium thickness, medium-humic (light clay) (7 samples).

To obtain the spectral characteristics of soils spectroradiometer HandHeld2 ASD was used. Besides, the main agrochemical indicators were obtained for all the samples as the criterion for agricultural soils rational use: Ph, humus, P2O5, K2O, total absorbed bases and hydrolytic acidity.

3. Results
Analysis and determination of spectrograms main types for the studied soils was carried out. As a result, five main types of spectrographic curves were identified for the studied soil varieties.

First type of the spectrographic curve (figure 1) includes all the studied varieties of soils with the exception of №8 – chernozems leached, medium thickness, medium-humic (light clay).

The second type of spectrographic curve (figure 2) includes all studied varieties of soils with the exception of №4 – chernozems leached, medium thickness, medium-humic.

The third type (figure 3) is typical for all studied varieties of soils, except №4 – chernozems leached, medium thickness, medium-humic and №5 – chernozems leached, light washout, medium loamy.

The fourth type of spectrographic curve (figure 4) was noted for №8 – chernozems leached, medium thickness, medium-humic (light clay) and №2 – dark-grey forest, medium washout and the fifth type (figure 5) of spectrographic curve is peculiar to dark gray forest medium-washed soil.
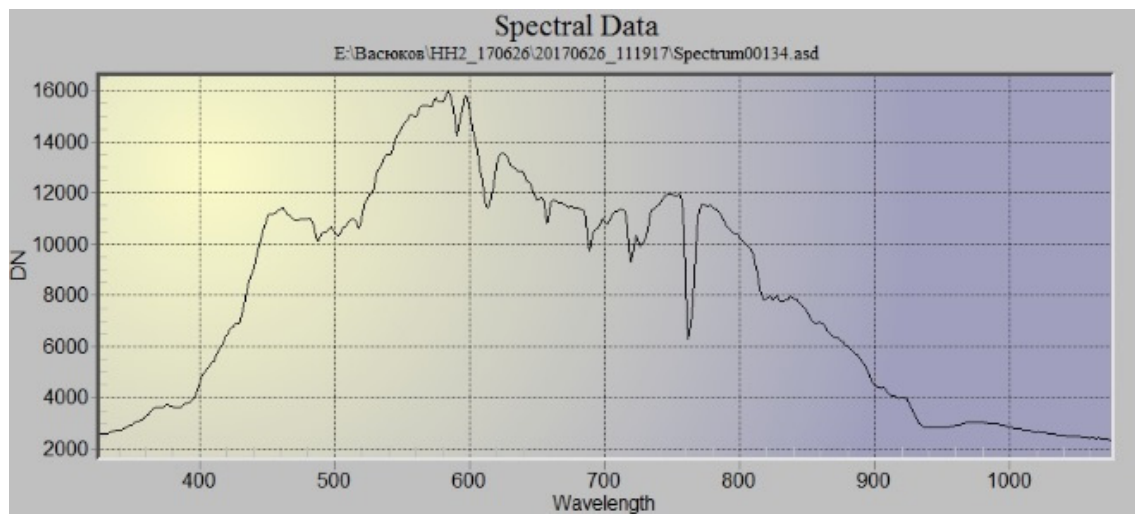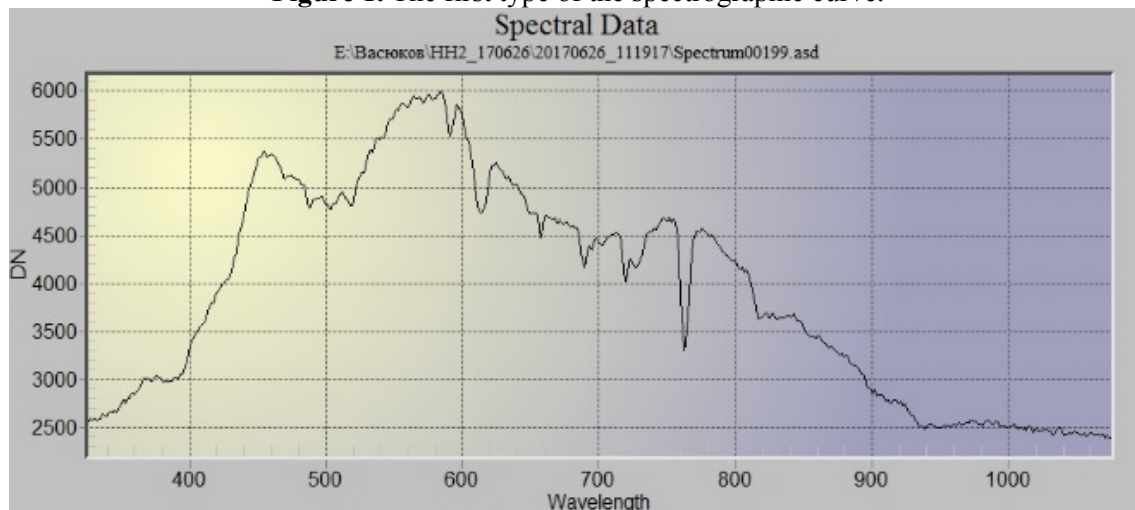
Figure 1. The first type of the spectrographic curve.

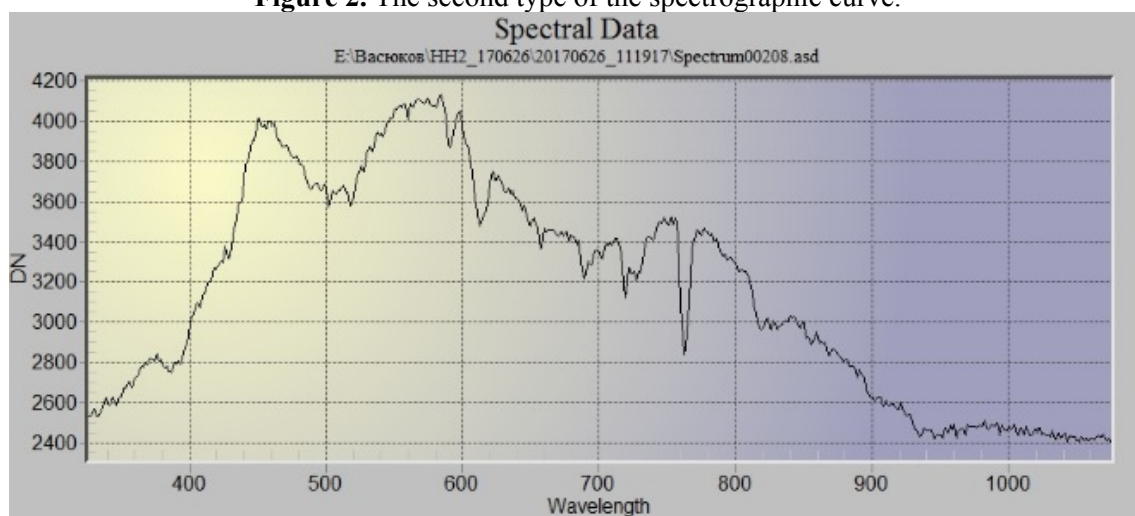**Figure 2.** The second type of the spectrographic curve.

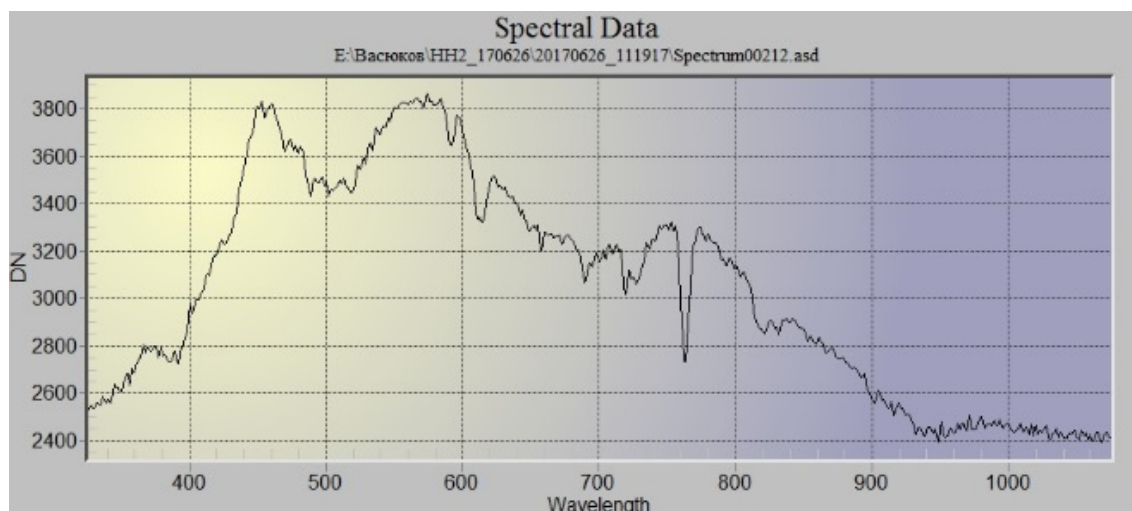**Figure 3.** The third type of the spectrographic curve.

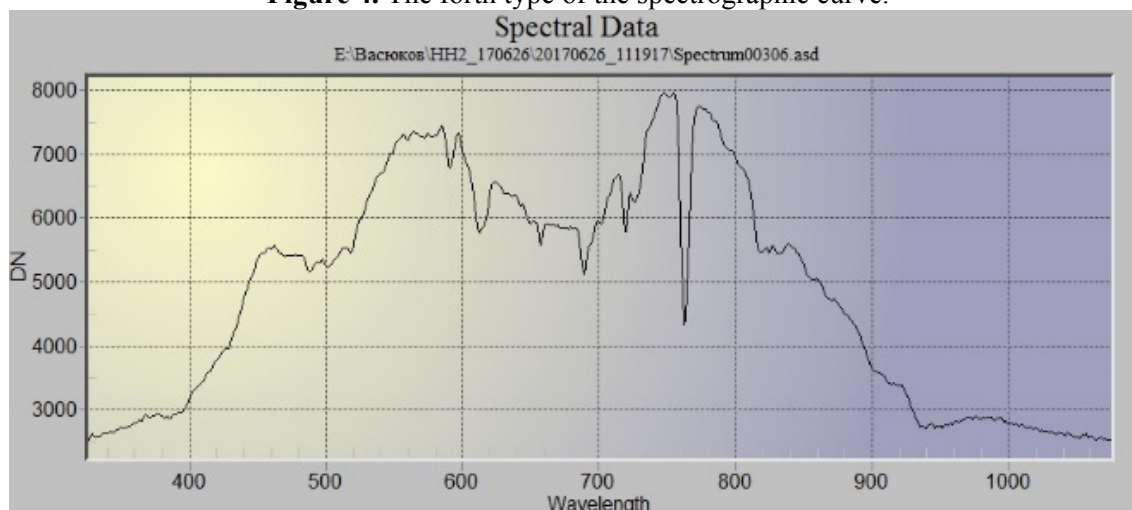**Figure 4.** The forth type of the spectrographic curve.

Figure 5. The fifth type of the spectrographic curve.

Further, the relationship between the spectrographic curves types and agrochemical indicators of soils was analyzed. The following results were obtained:

1. The first type of the spectrographic curve has maximum values of humus and K_2O;
2. The second type of the spectrographic curve has lower values of humus and K_2O;
3. Humus content and exchange potassium decreases from third to fifth type of the spectrographic curve.

Correlation analysis was performed to determine the relationships between agrochemical parameters and spectrographic curves types. Obtained values of correlation coefficients show statistically significant connections between spectrographic curve type and four agrochemical indicators. For the humus content and exchange potassium, an inverse correlation is observed – -0.73 and -0.66, respectively. Between the total absorbed bases and hydrolytic acidity the relationship is direct – 0.66 and 0.98, respectively.

Thus, spectrographic curve nature clearly reflects the changes in agrochemical indicators mentioned above. In this case, the marking indicator of humus content in different soil types is 550 and 750 nm peaks ratio. For well-humified soils the 550 nm peak is above the 750 nm peak. We can see the same picture with an increase in soils erosion degree within a single subtype. There is also a clearly traceable dependence of humus content and the 450 nm peak, especially within one type of soil. The more it extends within one soil type with unchanged other peaks, the lower is the humus content.

The obtained intermediate results make it possible to state about the possibility of using spectrographic methods to determine and to map soil erosion degree. However, for reliable interpretation of spectrographic data it is necessary to perform control measurements of soils with known humus content and erosion values. These can be pre-defined soil areas or control measurements of agrochemical indicators. In combination with a hypsometric basis (slopes inclination and length) the spectrographic data will allow to obtain maps of the soil cover erosion and determine the degree of soil humus content.

Thus, the results of the studies can be used as the basis for rapid mapping of soil erosion since spectrographic data takes time and material expenses on several orders lower than "classical" methods of studying and mapping of soil cover.

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