THE POSSIBILITY OF USING SPECTROGRAPHIC DATA TO ASSESS SOILS FERTILITY

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ABSTRACT

In order to determine the dependencies between the chemical indices of the soils of the automorphic series and the results of spectrographic analysis, the field survey with HandHeld2 spectrograph was conducted at cleaned surfaces of the soil sections at soil sampling site. Data for zonal soils of Chuvash Republic (podzolic chernozem, dark grey forest soils, typical grey forest soils and light grey forest soils) with different erosion degree were obtained. The results of agrochemical inspection were analyzed along with spectrographic curves of the given soils. A dependency between labile phosphorus (P_2O_5) and exchangeable potassium (K_2O) content in soils and spectrographic curve form was found. As a result, it managed to identify three main types of spectrographic curves for soils with different content of P_2O_5 and K_2O. The results of this work can be used for express analysis of erosion characteristics of different types of soils and for in-farm land management projects for agricultural enterprises.

Keywords: zonal soils, erosion, spectrographic analysis, soil fertility

INTRODUCTION

Numerous soil studies have shown that in most cases the soil fertility of agricultural lands is deteriorating due to inadequate farming techniques, water erosion, insufficient or excessive fertilization. The latter also leads to underground and surface waters contamination or to chemicals accumulation in the soil in hazardous concentrations. The development of the agricultural lands use principles that do not permit such extremes is the main purpose of so-called precision agriculture concept, aimed at providing of necessary nutrients quantity and optimum moisture characteristics in the soil, to maintain optimal growth of agricultural plants. One of the main obstacles of this concept application is the heterogeneity of the soil cover, often even within a single land plot. Because of this, even the performance of a wide range of analyzes and determination of soil fertility by different methods [1], [2] does not allow comparing of the soil properties of agricultural lands with necessary spatial and/or temporal resolution.

In this article, the team of authors proposes the development of an express method for determining of soil fertility parameters for agricultural lands based on spectroscopic physical principles. Infrared spectroscopy methods based on the interaction of molecules with electromagnetic energy in the infrared spectrum recognized as one of the most promising methods for soils study [3]. Mid-infrared band includes the so-called fundamental molecular vibrations. When a molecule absorbs IR radiation at

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frequencies corresponding to the natural vibrations of molecules, this leads to an increase in the vibration amplitude. Since each frequency corresponds to a certain amount of energy and specific motion of molecules (for example, stretching, bending of chemical bonds), the type of molecular movements and functional groups that present in the molecule can be revealed in the average IR spectrum. Therefore, this information can be used as a unique feature of the soil, just as fingerprint.

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. The problems solved with the help of these methods in the field of soil research are most often resolved to assess the microelements and organic matter of the soil. Such soil mineral elements as C, N, P, K, S, Ca, microelements play a primary role in crops development, so determining their concentrations is important for precise farming concept application.

In the scientific literature there is a significant number of publications on this topic. Rossell et al (2006) have prepared one of the best reviews of spectroradiometric methods application in this field [4]. Most studies show high values of correlation coefficients (more than 0,9) between actual and estimated values of carbon, and in particular, organic carbon. Good results were obtained for determination of total nitrogen content ratings (R> 0,80). Although Rossell et al (2006) did not find significant dependency for nitrates [4], this conclusion is refuted by good results obtained by other researchers [5], [6]. Contradictory results were obtained for potassium, phosphorus and organic substances. The studies found both high – 0,85 [7], and low – 0,6 [8] and 0,76 [9] values of correlation coefficient for potassium concentrations. For phosphorus, different researchers have found a high correlation between 0,81 and 0,87 [10], [11]. Despite the fact that almost all studies have obtained very good results for organic substances with values of correlation coefficients above 0,90 [11], there are works that revealed very weak relationship between the spectra and content of organic matter [12]. Thus, to date, 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. In any case, all researchers emphasize the need for further study of soil features by these methods with increasing of geographic coverage of soils under study.

This paper is a continuation of the work on spectrographic studies of zonal soils at Chuvash Republic territory [13].

METHODS

Thirteen farms were selected in the well-studied soil areas of Chuvash Republic with different soil varieties. Soil samples were taken in order to determine the dependencies between spectrographic data and chemical parameters for soils of the automorphic series [14]. In Table 1 description of soil features and washout degree at the sampling points are given.

Table 1. Description of the different soil types at sampling points

Point number	Soil type	Granulometric texture	Sampling site	Washout by…, t /ha/yr			Washout degree
				heavy rain	snowmelt runoff	Total	
1	light grey forest	heavy loam	arable	13,502	2,708	16,210	light
2	light grey forest	medium loam	arable	0	0	0	—
3	light grey forest	heavy loam	arable	8,247	1,061	9,309	medium
4	dark grey forest	heavy loam	arable	3,375	0,306	3,681	light
5	typical grey forest	heavy loam	arable	7,314	1,152	8,466	medium
6	podzolic chernozem	heavy loam	arable	3,884	0,358	4,242	light
7	podzolic chernozem	heavy loam	arable	2,749	0,338	3,087	light
8	podzolic chernozem	heavy loam	arable	3,095	0,308	3,403	light
9	podzolic chernozem	heavy loam	arable	3,095	0,308	3,403	light
10	podzolic chernozem	heavy loam	arable	3,111	0,239	3,350	light
11	typical grey forest	heavy loam	perennial grasses	0	0	0	—
12	light grey forest	medium loam	arable	1,793	0,120	1,913	light
13	typical grey forest	heavy loam	arable	5,243	0,753	5,996	light

At the same time, the soil profile cuts were surveyed by HandHeld2 ASD spectroradiometer. As a result, spectrographic curves were obtained and analyzed. Due to the fact that the brightness characteristics depend on a variety of factors (humidity, soil-forming rock, etc.), which are sufficiently variable even within one soil difference, the spectrographic data were analyzed by the character (appearance) of the curves, i.e. the degree of the graph line extent in different spectral zones (in nm) within the same spectrographic curve. All received spectrographic data was ranked according to this principle.

RESULTS

Three types of spectrographic curves were conditionally identified for the study area:

Type 1: It has two distinct peaks, the first with a wavelength of 250 nm, the second – 400 nm and 460 nm. The spectral brightness of the first peak (250 nm) is 2.5 times less than the second (Fig. 1). Sampling points № 1, №2, №4, №12 with light grey and typical grey forest soils, medium or strong podsolization degree, light or medium washout attributed to this type.

Type 2: Also has well-defined two peaks, the first with a wavelength of 250 nm, the second – 400 nm and 460 nm. But the spectral brightness of the 250 nm peak is either equal or less than 10-20% to the brightness of the second peak (Fig. 1). Sampling points №7, №8, №13 with typical grey forest soils and podzolic chernozem, with light washout attributed to this type.

Type 3: For this type of spectrogram, the spectral brightness of the first peak (250 nm) larger than the second peak by 20-30% (Fig. 3). Sampling points №3, №5, №6, №9, №10, №11 with typical grey forest soils and podzolic chernozem, unexpressed signs of podsolization, unwashed, light or medium washout attributed to this type.

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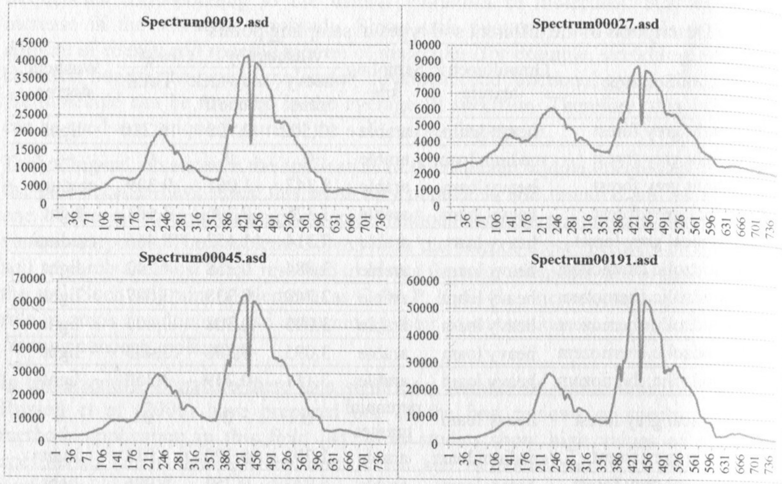

Figure 1. Spectrographic curves, type 1
X axis – wavelength, nm; Y axis – spectral brightness, DN

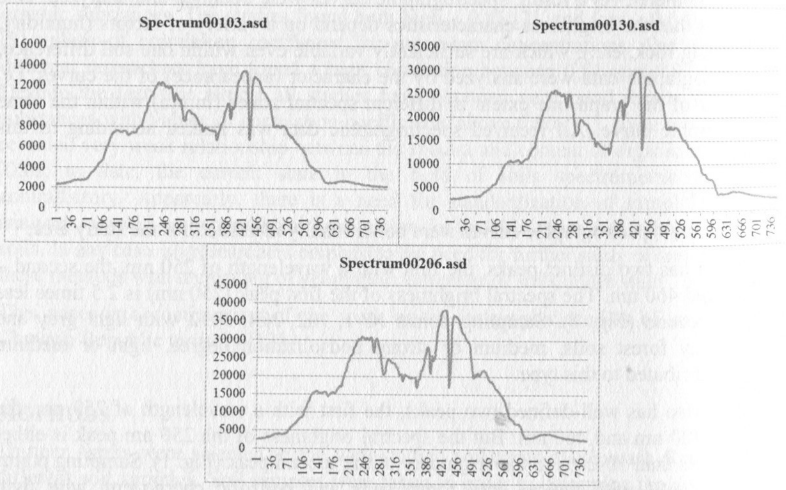

Figure 2. Spectrographic curves, type 2
X axis – wavelength, nm; Y axis – spectral brightness, DN

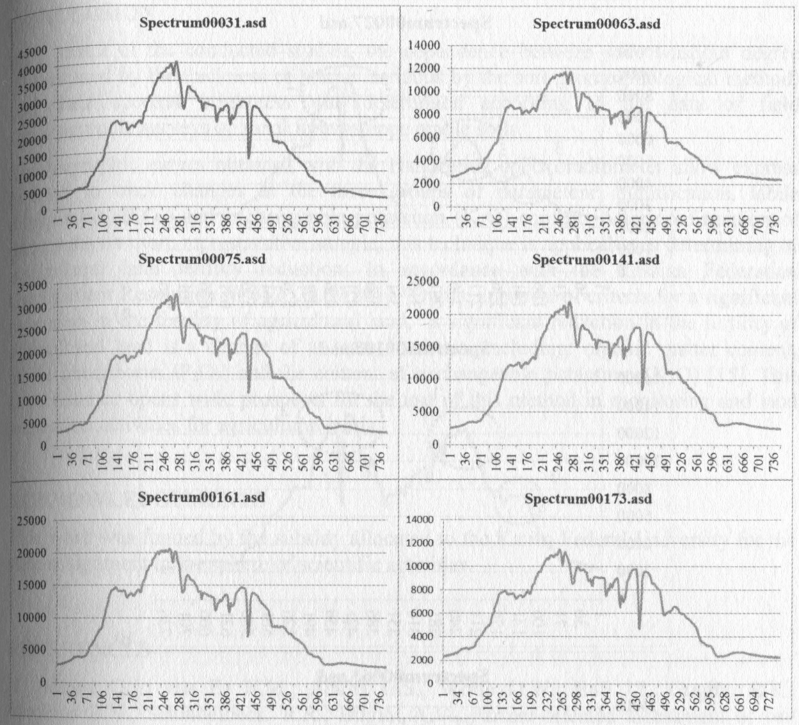

Figure 3. Spectrographic curves, type 3
X axis – wavelength, nm; Y axis – spectral brightness, DN

Thus, the analysis of spectrograms obtained by the HandHeld2 spectroradiometer for all the considered zonal types and subtypes of arable soils with different erosion degree (Table 1) showed a clear regularity: change in the form of the spectrographic curve, depending on the degree of humus content of the soils. Two peaks, the first with a wavelength of 250 nm, the second – with wavelengths of 400 nm and 460 nm can be used as a marker of humus content. Determination of humification needs to be made by comparing of the first peak to a second – with less humus content second peak rises more expressed above the first one, the differences in height may reach 2-2,5 times. Conversely, the more humified the soil, the more sharply the first peak rises above the second, the differences can reach 1,15-1,3 times.

As a result, three main types of spectrographic curves were identified for the studied soils: for slightly, medium and strongy humic soils (Fig. 4).

The same dependence was obtained in the analysis of bare soil spectra on soil-geomorphological profiles. The most clear-cut dependence (r = 0,55) between soil surface spectral brightness and washout degree is observed from the total thickness of humus horizons A + AB for light gray and light gray podzolic soils.

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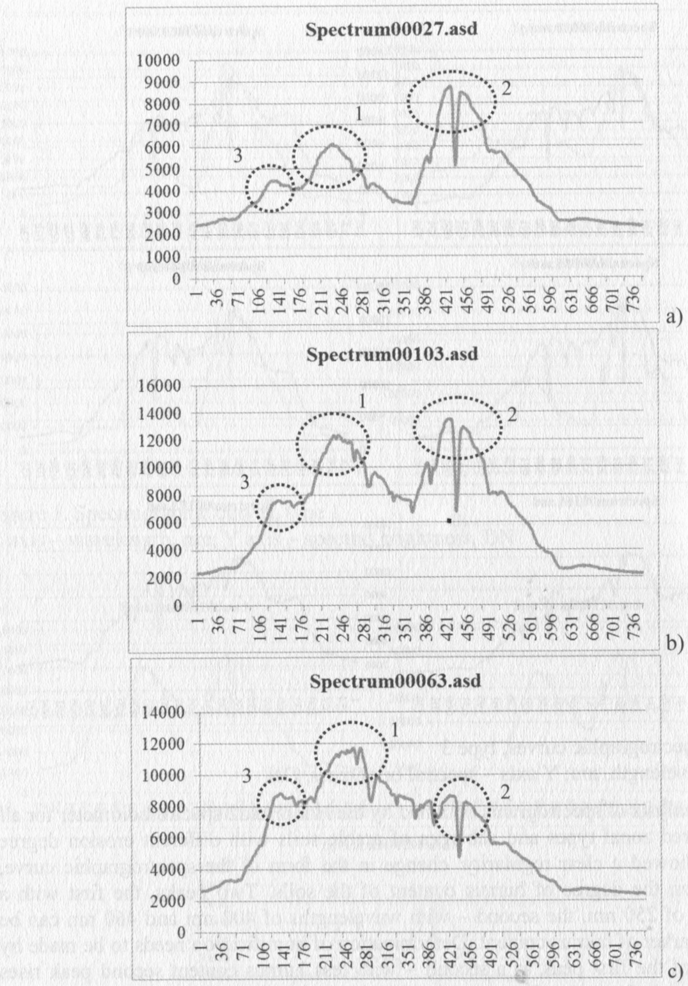

Figure 4. Differences in the graph for slightly (a), medium (b) and strongly (c) humic soils
The numbers are the types of peaks

In addition, the dependences between the labile phosphorus (P_2O_5) and exchangeable potassium (K_2O) content and spectrographic curve changes for was determined. The higher is P_2O_5 content in the soil, the higher is the peak 2 in comparison with peak 1 in spectrographic curve and vice versa. The K_2O content is approximately the same for curves of 2 and 3 type, but for type 1 it is much smaller. With this situation, in our opinion, correlates the so-called peak 3 (130 nm) (Fig. 4). For curve types 2 and 3, it is expressed stepwise, and for type 1 it appears as a small elevation. The more peak 3 has a stepped character, the higher the content of K2O in the soil.

CONCLUSION

As a result of the conducted studies, the dependence between soils washout degree (determined by the thickness of humus horizons by the soil-geomorphological method) and their spectral brightness was determined according to the data of field spectrographic surveys of zonal forest-steppe arable soils.

Spectrographic curves obtained with the HandHeld2 spectroradiometer allow express method to track changes in the three groups of parameters: humification, labile phosphorus (P_2O_5) and exchangeable potassium (K_2O) content. After confirmation of the results on more representative sample, this technique is applicable in determining of agricultural land fertility reduction. In accordance with the Russian Federation Government Resolution № 612, 22.07.2011 "On the approval of criteria for a significant reduction in the fertility of agricultural land," a significant reduction in the fertility of agricultural land is a change of at least 3 criteria, including: organic matter content, labile phosphorus (P_2O_5) and the content of exchangeable potassium (K_2O) [15]. This circumstance opens wide prospects for the use of this method in monitoring and land inspection activities for agricultural lands.

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