Relationship between the looseness of soil and the electric conductivity

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Abstract: The present article reports on an experiment as part of the research in the frame of which I search after the relationship between the looseness *L* of soil characterising the operating quality of the chisel-type subsoilers of a medium working depth, and the change in the electric conductivity in the soil caused by the loosening cultivation. The investigation was carried out with the help of the mobile electric-conductivity measuring device – accounted as a novelty in field-land tests – type Veris 3100 with disc electrodes, operating in field-land conditions. As the results of the investigation, the relation between the electric conductivity and looseness *L* of soil are presented in this article.

Keywords: looseness *L* of soil; electric conductivity; subsoil chisel; Veris 3100

The objective of the research is to find a relationship between the degree of looseness – after the cultivation by subsoilers at medium depth – and the electric conductivity of the soil layer. The reason for the experiments carried out is that several different factors exist influencing the electric conductivity as well as the looseness degree of the soil. Among these, the most important characteristic values are e.g. the moisture content of soil (Schwark 2005), the resistance against penetration, the nutrients contents of the soil (Birkás *et al.* 2007), etc. Accordingly, determining the degree of the soil looseness as a function of this electric material characteristic is a well founded aim. The present article contains the results obtained.

MATERIAL AND METHODS

The measurement tests were carried out in the last summer under the following conditions: dry, sunny weather, air temperature about 30°C; plane land, cereal stubble, medium-adherent soil; the moisture content of the soil was 13.2% in the top layer of 30–40 cm, its Arany's cohesiveness number is 56, its average penetration resistance is 5.1 MPa; by the physical classification it is a clayey-loam soil. The loosening was carried out with a chisel-type, straight five-blade subsoiler (Figure 1). For measuring and determining the electric conductivity of the soil, the device type Veris 3100 made in the USA was used. The tests were carried out along the measuring-section lengths of 150 m. Before starting the tests, the tractor-implement combination as well as the measuring device Veris were set on a so-called adjustment field-spot (Sasaki *et al.* 2007). The Veris 3100 type is such a tractor-drawn unit measuring the electric conductivity of the soil which, with the help of GPS working on the principle DGPS, collects the data showing the electric conductivity (Boydell *et al.* 2007). This provides the accurate determination of the electric-conductivity data along the measuring-section length.

Knowing the actual amount of the electric current, the value of the electric conductivity can be calculated in mS/m. The inner two electrodes measure the electric conductivity of the soil in the upper layer of 30–40 cm while the two side electrodes – in the lower layer at a depth of 80 cm. Previously the conductivity of the settled (before-tillage) soil was measured along all the five measuring sections and then all measuring sections were loosened at a medium depth (Busscher *et al.* 2006). Finally, the measurement of electric conductivity (χ) was repeated in the soil along the loosened measuring sections; during these tests the measuring equipment Veris 3100 was towed along about the same

Figure 1. Work of subsoil chisel

Figure 2. Veris 3100 in a field-test on a loosened land

track as was that along which the conductivity had been determined in the settled soil (Figure 2).

RESULTS

My objective of the investigation was to ascertain the applicability of the novel measurement technique at the actual depth and under the conditions stated.

As the result of the experiment, the following relationship can be used to determine the degree of looseness from the electric-conductivity measured in different soil states:

$$L_{\chi'} = \left(\frac{\chi_{le}}{\chi_{lu}} - 1\right) \times 100 = \frac{\chi_{lu} + \Delta\chi_l - \chi_{lu}}{\chi_{lu}} \times 100 = \frac{\Delta\chi_l}{\chi_{lu}} \times 100 \quad (\%) \qquad (1)$$

where:

$\Delta\chi_1 = \chi_{1e} - \chi_{1u}$

χ_{1e} – in shallow layers, electric conductivity before the loosening (mS/m)

χ_{1u} – in shallow layers, electric conductivity after the loosening (mS/m)

Table 1. Data of the values L measured in the traditional way, and $L_{\chi'}$ expressed by conductivities (mS/m)

Traditional (L)	New method ($L_{\chi'}$)
47.62	57.25
45.72	48.60
44.04	49.40
46.44	50.94
50.78	53.53

The values of $L_{\chi'}$ were derived from the conjugate electric-conductivity data collected before and after loosening by the subsoiler along the measuring section, with the help of the above formula, and I formed data groups in the deviation range of ± 10%. I chose the 10% value because I considered the degree of soil looseness given with this accuracy as practically acceptable, due to the relatively high homogeneity of the soil. Subsequently, I averaged the data of the data group with the greatest number of values. This average of the most characteristic values of the measuring section was compared with the looseness values measured in the conventional

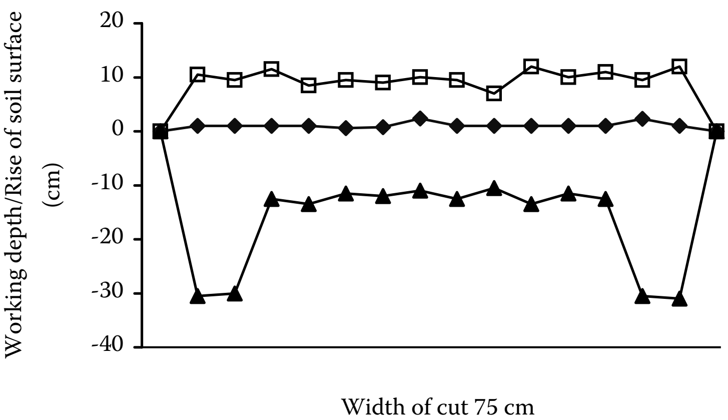

Figure 3. Cross-section in the loosened soil

Table 2. The results of the Student's test for five repetitions

The values of t at the 0.1% significance level		Number of the characteristic data (n)	Repetitions (–)
t_{n-1}	$t_{0.1\%,\, n-1}$		
5.33	3.85	20	1
2.63	3.82	21	2
3.87	3.85	20	3
4.00	4.02	17	4
2.61	3.92	19	5

way. The symbol $L_{\chi'}$ was given to the degree of looseness measured by this technique – referring to its determination way.

The looseness L of soil measured in the traditional way (Figure 3) is:

$$L = \left(\frac{\Delta A + A_0}{A_0} - 1\right) \times 100 = \frac{\Delta A + A_0 - A_0}{A_0} \times 100 = \frac{\Delta A}{A_0} \times 100\ (\%) \qquad (2)$$

where:

ΔA – expansion of the soil surface (m^2)

A_0 – loosened cross-section surface (m^2)

In this formula, actually, the section area of the rise of the soil surface due to the loosening effect is correlated with the area of the loosened cross section (Figure 3) and this relationship, in effect, demonstrates the drastic physical change produced in the soil.

The received relationships (1) and (2) correlate with each other since the conductivity is greatly influenced by the physical state of the conducting soil-section face. Actually, the more the electric conductivity of the soil decreases due to the loosening, the greater will be the degree of the change (gradient) in conductivity ($\Delta\chi_1$) and together with this, after loosening, a low value of conductivity ($\Delta\chi_{1u}$) can be measured. Consequently, $L_{\chi'}$ will show a relatively great value. This can be connected with the relationship (2) in the way that the high rise of the ground level is attended by a great decrease in conductivity while the conductivity values measured after the shallow loosening are formed by the large loosened cross-section area. Consequently, the relatively great-degree surface increasing (rising) is attended by a considerable decrease in conductivity while the large loosened cross-section area – by low values of after-loosening conductivity. As a result, in both relationships (1) and (2), the ratios of the above two factors, respectively, form two well correlating data lines.

Figure 4 shows that the looseness values received for the separate measuring sections and determined by the two methods, respectively, correlate well with

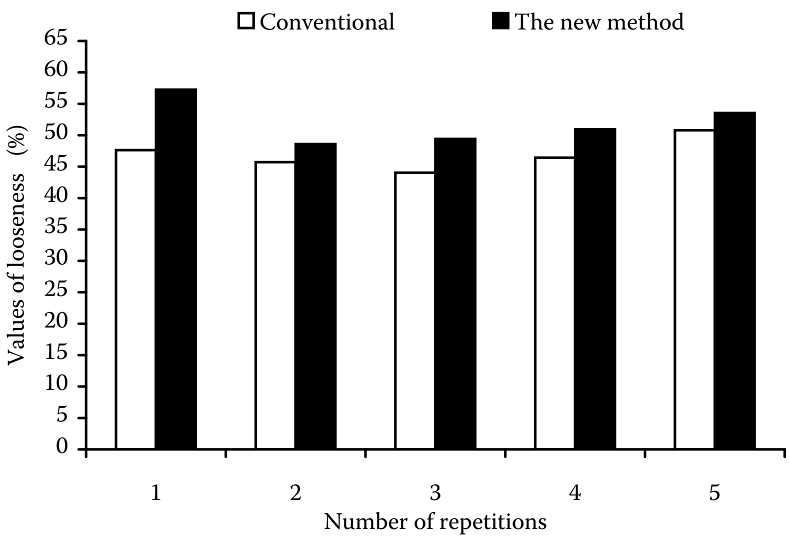

Figure 4. Comparison of the looseness values L of soil measured in the conventional way and the $L_{\chi'}$ data

each other. At the same time, I proved the identity of these two data lines by the method of mathematical statistics as well. This was carried out with the help of the one-sample Student's test; the process is shown in the following section.

The relationships used in Student's test (Sváb 1981) are as follows:

Hypothesis:

$$t_{n-1} \leq t_{\alpha,\, n-1} \tag{3}$$

$$t_{n-1} = \frac{\overline{L}_{X'} - L}{\dfrac{\sigma^*}{\sqrt{n}}} \tag{4}$$

$$\sigma^* = \sqrt{\left(\overline{L^2}_{X'} - \overline{L}^2_{X'}\right) \times \frac{n}{n-1}} \tag{5}$$

The values $t_{\alpha,n-1}$ related to the number of data collected in the course of the individual repetitions at the significance level of 0.1%, are shown in table 2:

The value of t_{n-1} was lower than that of $t_{0.1\%,\,n}$ in four cases. Accordingly, the hypothesis is also acceptable at the 0.1% significance level as the looseness degrees $L_{X'}$ determined with the help of the novel measurement technique and the conventionally measured values of looseness L proved to be approximately equal in the cases of separate repetitions. It also appears from the investigation that the grading with the ± 10% deviation was consistent; it was proved by the slight difference between the two value lines.

Distribution analysis by measuring sections

By this step of the evaluation, I wanted to ascertain the distribution type of the ratio aggregate collected along the actual measuring sections, and whether the single empirical deviation values belong to the same theoretical distribution model with the actual soil. During the tests I received five diagrams like this (Figure 5).

Table 3. The Bartlett's test and its partial results

σ^2	$f_j \times \lg\sigma^2$
33.53905251	30.51101579
25.13988677	29.40762966
38.32993346	31.67076131
21.54152316	22.66569894
21.04316223	25.13910906
	$\Sigma f_j \times \lg\sigma^2$
27.91 $s_{L_{X'}}^2$	139.39
1.44 $\lg s_{L_{X'}}^2$	
140.25 $f_0 \times \lg s_{L_{X'}}^2$	
χ^2 = 9.488	1.9404 = B

Figure 5 definitely proves the Gaussian distribution of the most characteristic data gained during the repetitions. The equation of the density function of the Gaussian distribution is:

$$f(y) = \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{-(L_{X'} - \overline{L}_{X'})^2}{2\sigma^2}} \tag{6}$$

Accordingly, for the normality test, I applied Bartlett's chi-squared (χ^2) statistic in the frame of which the joint deviation analysis of all the most characteristic values has to be carried out.

The relationships used in the Bartlett's test (χ^2) (Sváb 1981) are as follows:

$$B = \frac{1}{c}\left[f_0 \lg S_{L_{X'}}{}^2 - \sum_{j=1}^{N} f_j \lg \sigma^2\right] \leq \chi^2 \tag{7}$$

$$c = 0.4343\left[1 + \frac{1}{3(N-1)}\left(\sum_{j=1}^{N} \frac{1}{f_j} - \frac{1}{f_0}\right)\right] \tag{8}$$

The value of χ^2 with the degrees of freedom $f = N - 1 = 5 - 1 = 4$ is 9.448.

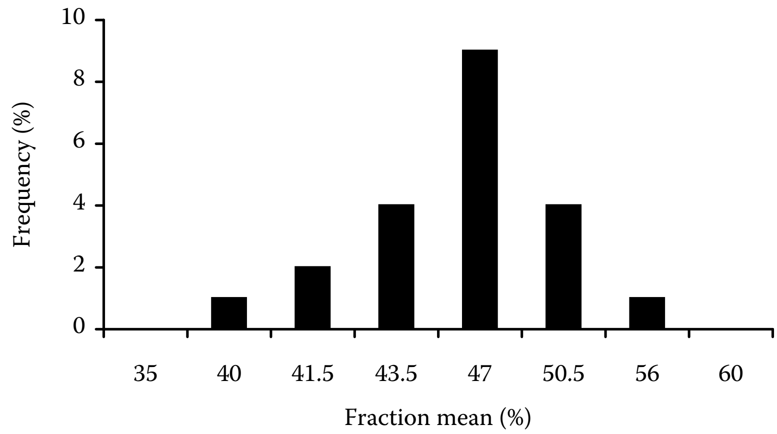

Figure 5. Distribution of the values $L_{X'}$ in the chosen measuring section

$$c = 0.4343\left[1 + \frac{1}{3(N-1)}\left(\sum_{j=1}^{N}\frac{1}{f_j} - \frac{1}{f_0}\right)\right] \quad (9)$$

$$= 0.4343\left[1 + \frac{1}{3(5-1)}\left(2\times\frac{1}{20} + \frac{1}{21} + \frac{1}{17} + \frac{1}{19} + \frac{1}{97}\right)\right] =$$

$$= 0.4432 \quad (10)$$

$$f_0 = \sum_{j=1}^{N} f_j = 2\times 20 + 21 + 17 + 19 = 97 \quad (11)$$

The relevance of the inequality (7) proves that the value of the calculated B is lower than the value of χ^2 from the table, so it can be stated that all of the empirical deviation values belong to the same theoretical deviation function (Figure 5) and, in addition, the single data follows the Gaussian distribution.

CONCLUSIONS AND DISCUSSION

On the basis of the results and experiences of the measuring tests, the following facts can be established:

– Between the electric conductivity and the degree of loosening an empirical relationship has been found.
– The identity of the looseness values measured by the two methods can be perfectly proved by means of statistical analysis.
– The $L_{\chi'}$ fractions characterise the degree of the looseness of soil at an acceptable level.
– I establish that the differences between the looseness degrees L of soil measured in the traditional way and the $L_{\chi'}$ data defined by electric conductivities are quite small (Figure 4).
– The method is suitable for testing the working quality of subsoil chisels, in the experimental conditions shown, in shallow (30 cm) layers.
– The aggregate of data $L_{\chi'}$ collected along the individual measuring sections follows the Gaussian distribution model.

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Abstrakt

Rácz P., Szüle Z. (2009): **Vztah mezi kyprostí půdy a elektrickou vodivostí**. Res. Agr. Eng., **55**: 136–140.

Článek podává zprávu o výzkumu, v jehož rámci je hledán vztah mezi kyprostí půdy *L* jako ukazatelem pracovní kvality orného zařízení radličného typu pro střední hloubky a změnou elektrické vodivosti půdy způsobenou kypřením. Při výzkumu bylo pro měření elektrické vodivosti použito mobilního zařízení – považovaného za novinku v polních testech – typu Veris 3100 s diskovými elektrodami pro polní podmínky. Výsledkem práce je zjištění vztahu mezi elektrickou vodivostí a kyprostí půdy.

Klíčová slova: kyprost půdy; elektrická vodivost; rádlo na spodní půdy; Veris 3100

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