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Research Article

Opinion Concerning Express-Diagnostics Evaluation of the Soil Physical Properties

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Abstract

This opinion presents the express-diagnostics method related scientific research concerning soil physical properties. The general focus is on methodological aspects of a comprehensive rapid diagnostic assessment of the soil physical properties after influence heavy mobile technical means (HMTM) on soil, i.e. example of maximum influence. This opinion includes a more attention to science and practice on environmental issues, i.e. agro ecological states (AES) of soil. Maybe this will be served as a good example comprehensive express-diagnostics evaluation of the soil physical properties which is result of long-term field experiments related Estonian soil and climatic conditions. Elaboration of suitable express-diagnostics method and relevant results related complex estimation of soil physical properties have been obtained. In this result, we have proposed the five basic diagnostics indicators of the soil physical properties: bulk density (Mg m^{-3}), humidity (g g^{-1}%), humus content (%) and soil macrostructure (relative units) which hereafter is simply - structure. All these diagnostic indicators were ranked as follows: a more favourable level (MFL), favourable level (FL), to be sparing with something level (SSL), unfavourable level (UFL). Concerning soil vulnerability, the main indicator of evaluation is degrees (levels) H_i of the soil physical properties. The results of calculation of the H_i which is based on comparing different level of soil vulnerability were provided. According comparative assessment based calculation of H_i after results usage of different agricultural technology we could be found FL - the least soil vulnerability; SSL - moderate soil vulnerability, and UFL - the soil is firmly unfavourable level of negative influence of the heavy mobile technical means (HMTM) on soil.

Keywords: *Soil; Physical Properties; Method Assessment; Index of Ago-Ecological States*

Introduction

This is fact that the farmers in conditions modern agriculture are needed simple and reliable methods for assessing the soil condition, i.e. its physical properties we have an especially effects on the soil when is used heavy mobile technical means (HMTM) for working in the fields [2]. If to analyze what part of the soil profile has the most characteristic information carrier from the point of view of agro-ecological states (AES), then it seems to us that initially the seed bed can be such a layer [1] and ultimately the entire humus horizon, especially in conditions of humid zone. At the same time, the so-called subsoil or sub-humus layers are already in their natural structure in a natural compacted state. The seed bed is formed as a result of the influence of sowing aggregates, and it also depends on the type of soil. The subsoil which located under the humus horizon is also like something the information carrier and is formed itself both natural compaction and also external influence on level of yield.

Given the stringent requirements for working on the fields of the HMTM and in connection with the relevance of environmental problems, more and more attention is required to this aspect [2]. Over the course of several years, while carrying out work on scientific grants, we conducted relevant comprehensive studies on the development of AES in relation to HMTM [3-5]. It should be noted that in the conditions of a free market, the example of Estonia, the motivation of farmers can be completely different when purchasing a particular machine compared to the requirements for agro-ecology, and this situation can unfortunately continue until the results when the land use is quite profitable at last.

At all events, farmers should keep in mind that environmental requirements are becoming stricter over the years. Therefore, sooner or later, they should have in their arsenal an appropriate method of assessment, so that everything that is acquired would benefit both the household and nature.

It should be borne in mind that during many years of researches and as a result of participation in scientific grants of the European Union we have been found that it is possible to confine ourselves to only five basic diagnostics indicators of the physical condition of the soil: density (Mg m^{-3}), hardness (MPa), humidity (g g^{-1}%), humus content (%) and structure (relative. units) [6-8]. All five indicators can be ranked at two extreme levels - the optimal (X_o) and the worst (X_w), as well as at the third intermediate level - sparing X_s (from an agro-ecological point of view - the maximum permissible) Naturally, all intermediate levels characterized by the corresponding digital indicators are between these extremes. Thus, it is possible to determine analytically the corresponding degrees (levels) H_i of the state of a given soil agro-ecological system before mechanical impact, after it and also follow the dynamics of the aftereffect, i.e. how and by what regularity the process of self-healing occurs. For analytical calculations, the above can be described using a simple well-known expression, having the equation [9]:

$$H_i = \frac{X_o - X_i}{X_o - Xw} \qquad (1)$$

At the same time, it is possible to clearly characterize the each part of degrees of the soil physical properties. The main thing is that the scientific results become more comprehensible and illustrative.

The specific feature of our methods is that we have been tried to obtain adequate answers to the questions related corresponding levels of AES. Based on the above, the goal of our research was to develop a new system for assessment of AES., evaluation of the result of soil physical properties through such an important indicator as AES., which is the definitive result of the evaluation of agricultural technology, in general the soil physical properties particularly.

The novelty of these theoretical studies is the choice of the most informative diagnostic indicators, so that their quantity would be minimal and sufficient to obtain the necessary amount of reliable information and that its necessary representative would be provided for a comprehensive assessment of the level of AES.

Materials and Methods

For practical calculations by the formula (1), it is possible to determine the indicator X_w in two ways: 1) in the laboratory; 2) on the field [8], for example, taking into account the identification of the limiting value of the density of the soil, it is better to use a laboratory method where a oedometer is used [10]. On the field, you can also find somewhere sections of multiple wheel passes along the same track in the form of run-down spontaneous field roads.

To determine the limiting value of soil moisture, it is not difficult to find such an early spring period when all soil pores are filled with water. In the laboratory, the same thing can be created at any time.

Taking into account the humus content, one should find such places on the field with a low-power humus horizon (in conditions similar to Estonia), where, when ploughing, a subsurface soil layer is turned inside out. After cultivation and get the opportunity to take soil samples for laboratory analysis.

With regard to the structural nature of the soil, here first of all it is necessary to agree on which method of the many well-known ones should be chosen in order to obtain a reliable result for practical purposes. For example, we use a technique that is widespread in the Scandinavian countries [11,12]. According to this technique, soil structure is determined by wet sieving through special sieves with sieve sizes of 5 mm (for example, US sieves - 4.75 mm) and 2 mm. The third element is the base, with the same dimensions as the sieve, where eventually the soil that passes through the two-millimetre sieve is poured. The whole larger fraction of the soil that remains on the top (5 mm or with a sieve from the USA - 4.75 mm) is considered not-agronomy valuable structural aggregates. The soil fraction that passed through a sieve with a sieve size of < 2 mm is also considered the same. Therefore, the agronomy valuable fraction will be that soil which, during the sieving process, remained on a sieve with a mesh size of 2 mm, i.e. between with soil fraction sizes 2 and 5 mm. As a result, we will have the following series for us: (< 5 mm); (2 - 5 mm); (> 2 mm) [10,13].

In order to somehow evaluate the structure of the soil, we used the well-known ratio: (2 - 5)/[(< 5) + (> 2)] = Kstr [13,14]. As a result, we get for practice the desired indicator - the structural coefficient Kstr. Analyzing the obtained simple ratio, it is clear that if its numerator and denominator are equal to each other, then the value of Kstr = 1. Therefore, we will have an optimal indicator of soil structure. The worst indicator Kstr will occur during soil compaction and its value will approach zero [13].

Regarding the application of formula (1) as a percentage of humus (according to Kieldal), taking into account the conditions of Estonia, it will be necessary to select its extreme values from the results of studies in connection with the poorest or infertile and richest humus content of the soil (Table 2).

Similarly, to assess the degree of change in soil condition (H_i) in terms of soil humidity, here all current and extreme values should be considered to calculate according to Field Capacity (Table 2).

Results and Discussion

Having, as a result, the required minimum number of informative diagnostic indicators, we made an attempt to find the possibility of assessing the aftereffect caused by the running systems and working bodies of HMTM. Initially, it should be established which of the considered diagnostic indicators: density (Mg m^{-3}), humidity (g g^{-1}%), humus content (%) and structure (relative units), can cause the greatest losses at the worst level productivity (rel. units). For Estonian conditions, yield is most affected by both density and humidity, provided that the remaining necessary agricultural requirements (fertilizer, plant protection, etc.) are met. Moreover, with the latter both deficiency and excess affect. This can be most easily and accurately determined in the laboratory by the (Reppo) method of guttation [17].

After conducting special laboratory experiments with method guttation of the plants, obtaining the relative values of plant's guttation for each diagnostic characteristic considered separately, comparing it with the yield (in relative units), we can calculate the value of the complex indicator Eq to assess the level of AES of the soil as if sparing the impact of HMTM on the soil, and with a negative impact, taking into account the after-effect. The mentioned complex indicator Eq is calculated by the formula:

$$E_Q = \frac{1}{1-K_h}\left[\left(\frac{1-K_a}{1+S/A}\right)+\left(\frac{1-K_S}{1+W_F/S}\right)+\left(\frac{1-K_W}{1+A/W_F}\right)+\left(\frac{1-K_G}{1+S/H_G}\right)\right] \qquad (2)$$

where K_a is the relative productivity of the test culture during soil compaction; K_S - relative productivity of the test culture with a deterioration in soil structure; K_G is the relative productivity of the test culture with a decrease in the natural fertility of the soil; K_W - relative productivity of the test culture when the soil moisture condition worsens (deviations from "physical ripeness"; in Estonia -

towards moistening); K_h is the smallest yield (in relative units) at the extremely deteriorated soil condition, which is assumed to be 0.2 (as applied to the conditions of Estonia). In some conditions, this boundary may be even slightly higher due to the adaptive ability of the culture relative to the negative impact; S is the degree of deterioration of soil structure; A is the degree of soil compaction; H_G - degree of decrease in natural soil fertility; W_F is the degree of deterioration of soil moisture conditions or water content, i.e. deviations from the boundary limits of its "physical ripeness".

In order to make specific calculations for the given integrated information system using formulas (1) and (2) and give an appropriate assessment, we obtained the following criteria-based evaluation indicators (Table 1). The calculation results for a comprehensive express diagnostics of the AES according to the formula (2) are shown in table 1. Moreover, to obtain reliable results (Table 2), it is enough to calculate the desired above degrees: A, S, H_G and W_F, we can limit ourselves to field experiments. When determining the relative yield by the guttation method [17], it is necessary to have the appropriate laboratory support and know the methodology for conducting experiments with gutting plants (Reppo method). It should be noted at the same time that there is a fairly reliable and with a high coefficient of determination direct correlation between relative guttation and relative productivity with the same soil state, which makes it possible to predict the expected yield of crops.

Designation of levels	Degrees of the most informative characteristics				Complex
	Structure, S	Natural fertility, H_G	Soil compaction, A	Soil physical maturity, W_F	Indicator E_Q
Sparing	0.38	0.37	0.24	0.33	0.20
Negative	0.85	0.89	0.81	0.83	0.83
LSD at P ≤ 0.05	0.02	0.18	0.09	0.05	0.03

Table 1: *Relative values of the relevant diagnostic indicators for a comprehensive AES of soil.*

				Level and quantity		
No.	Designation of parameters	Indicator	Unit	Sustainable*, negative (X_i)	Optimum (X_o)	Worst (X_h)
1	2	3	4	5	6	7
1	Structure	K_{str}	Rel. unit	0,77* 0,49	1,00	0,40
2	Humus content	H_s	%	4.8* 1,5	8.0	0.7
3	Soil bulk density (void ratio (ε)** ε = (δ-γ)/γ); (δ - soil specific density) δ = 2,56 Mg m^{-3})	γ	Mg m^{-3}	1,34* (0,91)** 1,64 (0,56)**	1,20 (1,13)**	1,79 (0,43)**
4	Relative soil moisture content from its field capacity (FC)	X·FC	-	0.8* 0,5	1.0	0.4

Table 2: *Sustainable and negative values for a comprehensive AES (H_i) for the soil physical properties and for humus content.*
LSD (05): 1) when assessing the elements of soil structure according to the methodology of the Scandinavian countries - 0.06 rel. units; 2) when assessing the content of humus - 0.36% (by Kieldal); 3) when assessing the bulk density - 0.04 Mg/m^3; 4) when assessing relative soil moisture content from field capacity FC - 0.08FC.
Note*: field capacity (FC) for medium Estonian soils is 18 (g g^{-1}%).*

The value of relative guttation (relative yield) [15] under the sparing mode of exposure varied for all diagnostic indicators (A, S, H_G, W_F) within the range of 0.90 ... 0.94 rel. units (LSD (05) = 0.10 rel. units) Under negative impact, the most noticeable effect on the indicators of relative productivity was during soil compaction (K_a = 0.60, LSD (05) = 0.12 rel. units), with deteriorating conditions moisture (K_W = 0.64, LSD (05) = 0.11 rel. units) and with a decrease in the natural fertility of the soil (K_G = 0.61, LSD (05) = 0.10 rel. units), while as with a deterioration in soil structure, a similar decrease in the relative yield of a guttated plant was not so significant (K_S = 0.82, LSD (05) = 0.11 rel. units). As can be seen from table 1, the more gentle the effect of MBTS on the soil will be, the lower values of EQ we will have and vice versa.

Since express diagnostics of the mechanical effect of HMTM on the soil cannot be presented in addition to the above diagnostic parameters without determining the soil hardness, i.e. penetration (cone) resistance, it will be useful to emphasize that the soil hardness is closely dependent not only on soil density, but also on its moisture content. It is well known that a penetrometer is not suitable for obtaining reliable results at all soil moisture. For example, in dry soil you can drive through the field even with a tank and it is impossible to catch a tangible negative result, and vice versa in waterlogged soil we are already dealing with a danger to HMTM in terms of bearing capacity [2] and even more so, the penetrometer will not even show any noticeable hardness values.

We support the well-known point of view that soil hardness can be adequately measured with soil moisture within 0.7FC - 0.9FC (FC - Field Capacity), in other words, soil moisture content should be 70% - 90% or 0.7 - 0.9 of field capacity (FC). If, for example, for average Estonian soils, the field capacity is 18%, then this value is equal to 18% or 1.0, then the relative soil moisture content 0.7 will correspond to the actual moisture content of 12.6% and accordingly 0.9 will correspond to - 16.2%.

For the purpose of rapid assessment of AES usually often resort to the use of a penetrometer, which greatly facilitates and accelerates the determination of the presence of a level of soil compaction.

Despite the fact that the search for the relationship between the hardness or penetration (cone) resistance of the soil and its density is somewhat risky [4,10], nevertheless, we came to the conclusion that, subject to a relatively narrow moisture regime within (0.7 ... 0.9) FC, a reliable relationship can be obtained with the number of measurements n > 10. This dependence in the presence of a compacted layer or sole of the soil [10,16,17] differs in comparison with the absence of such a sole. For light soils in Estonia, in this case sod-podzolic sandy loamy soils, these dependencies have the following equation:

- the absence of a compact-pan:

$$\gamma = 0.09\, p_i + 0.92 \qquad (3)$$

In the presence of a compact-pan:

$$\gamma = 0.95 e^{0.07 p_i} \qquad (4)$$

Where γ - soil bulk density (Mg m^{-3}); p_i is the current value of soil hardness (MPa).

If to calculate the negative impact of HMTM is done in the presence of a compact-pan, where in fact, that after the direct passage of the HMTM wheels there will not be a significant difference between the results of penetration resistance of the soil and subsoil [17], i.e. when penetrating into the soil the cone tip of the penetrometer then we get (for example the results: 7 kg cm^{-2}, 6 kg cm^{-2} and 8 kg cm^{-2}). Thus, the arable soil and subsoil layers are as homogeneous in their state after the negative influence of HMTM. After calculations the bulk density through above penetration data (7; 6; 8) by formula (3) we get the following series of soil bulk densities: 1.55 Mg m^{-3}, 1.46 Mg m^{-3}, 1.64 Mg m^{-3}. Therefore, it is possible to take corresponding results as a real which was to be proved. If to compare with optimum level of bulk density (Table 2) you can see that according above bulk densities the soil compaction increased by 55%, 46% and 64% respectively.

Conclusion

From the obtain results we can conclude the following:

1. A number of diagnostic indicators have been proposed, such as: bulk density ($Mg \cdot m^{-3}$), water content ($g\ g^{-1}$%), humus content (%), and soil structure (in relative unity), which are fairly representative and can be completely limited to an adequate assessment of the purpose of rapid assessment of AES, as a result, to predict machine degradation of soils;
2. An analytical approach and an appropriate integrated indicator E_Q were developed to assess the level of the soil agro-ecological state, while the HMTM has a sparing effect on the soil in comparison with the negative impact. This approach also makes it possible to investigate the corresponding level concerning after-effect;
3. The soil penetration resistance allows to accelerate obtaining adequate results of soil compaction. According example of medium Estonian soils the impact of HMTM on soil was estimated. The permissible values of soil penetration or cone resistance (MPa) in ploughing and subsoil layers were determined using the taking into account the different impact of HMTM on soil. Also, with a relatively narrow range of soil water content, which corresponds to its physical maturity, the necessary empirical dependence of the transition from the results of penetration resistance to the corresponding results of soil bulk density was obtained.

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