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AGGREGATE STABILITY AS A SOIL QUALITY CRITERION

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Introduction

Soil quality is one of the most significant factors for high agricultural productivity and sustainable agriculture. From physical standpoint the "soil quality" could be characterised with the soil physical conditions and properties satisfying plant requirements for water, air and mechanical resistance and favouring root growth and normal physiological functions.

This aspect of soil quality consideration is especially significant and actual for now modern mechanised agriculture. At this type of agriculture soils are subjected to an "aggressive" form of use. Often this leads to loss of organic matter and nutrient content, acidification and severe destruction of soil aggregates. The consequences are soil compaction and deterioration of other significant soil properties.

Most of the Bulgarian cultivated soils are characterised by poor soil structure of the arable layer. This accounts for unstable physical conditions for root development. The main reason is the destruction of the soil aggregates by human-induced activities that cause the diminishing of the soil organic matter. These effects are aggravated by the mechanical impacts of the heavy machinery and cultivation at unsuitable soil moisture conditions (Dilkova *et al.,* 1998).

The influence of these two factors on the soil physical properties of the arable layer is expressed practically through the instability of the soil structure during the vegetation and hence in deterioration of soil porosity determining drainage aeration and plant available water capacity. Both these mean deterioration of soil quality and the productive capacity.

To maintain good aggregate stability of the arable layer usually it is recommended to enrich the soil with organic matter by manuring and crop incorporating residues (Lal, 1998; Swindale, 1998). Many investigations show that the soil aggregation and water stability of the soil aggregates depends on the banding of mineral particles with organic matter through R_2O_3 and especially through amorphous oxalate-extractable iron (Kemper and Kosh, 1966; Hamblin and Greenland, 1977; Tisdall and Oades, 1982).

The model experiments show that the extraction of amorphous oxalate-extractable iron (Fe_o) is the reason for the lost of the water stability of the soil aggregates (Giovanini and Sequi, 1976). Among the three main aggregation factors humus, clay and amorphous oxalate-extractable iron, the most variable is the organic matter. It could be regulated by manuring and other means in order to maintain a good ratio between organic matter, clay and Fe_o for high aggregate water stability and high soil quality.

The objectives of this study are: a) to evaluate the limiting factors for the stability of soil structure in the pedogenetically different soil units in Bulgaria. This could make possible to distinguish the soils in which the main limiting factor is the organic matter content; and b) to corroborate the usage of aggregate stability as a stationary soil quality criterion.

Materials and Methods

The arable layers of representative soil profiles have been used in this study. The profiles inlude: one Vertisol, one Vertic Chernozem, one Haplic Luvisol, three Eutric Planosols and four Distric Planosols. The respective layers of genetically analogous soils from virgin lands have been used to compare the results (Figure 1).

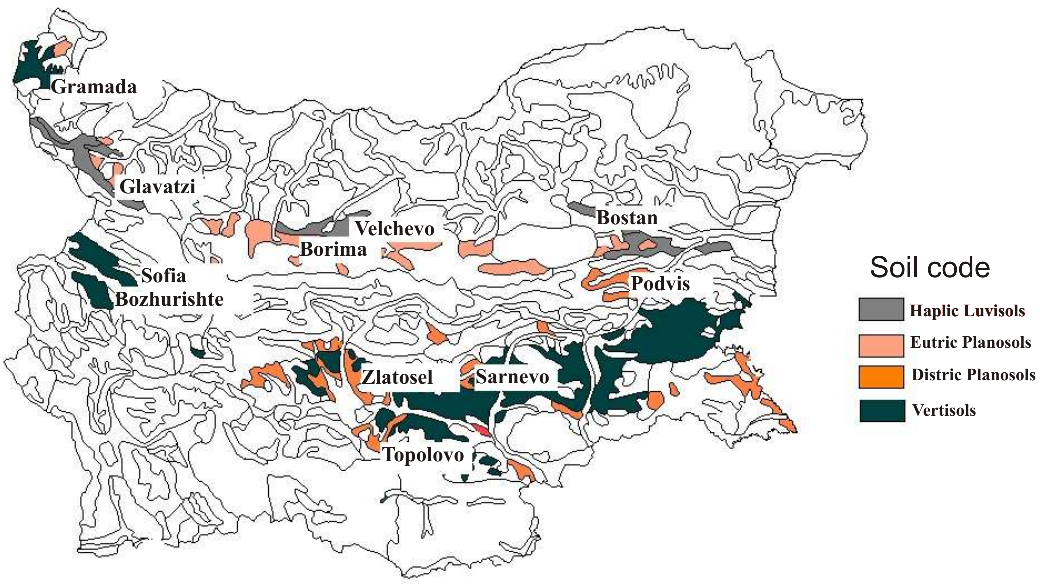

Figure 1. Scheme of studied sites.

The following characteristics have been analysed: soil particle size distribution (Katchsinski, 1958), organic matter content (OM) (Tjurin, 1965), bulk density at field capacity or close to that (100 cm^3 ring samples), soil aggregate stability (Vershinin and Revut, 1952), expressed by the ratio (MWDR) of the mean weight diameters of the aggregate after and before wet sieving, pore size distribution (suction plate method), and amorphous, oxalate-extractable aluminium (Al_o) and iron (Fe_o) compounds (Tamm, 1934).

The correlation analysis and simple regression models have been used to relate the aggregate stability with the organic matter, clay content, oxalate-extractable iron (Fe_o,) and with the ratio OM/(Fe_o*Clay). The classifications made by Dregne H. and T.G. Boyadgiev (1983), Hall *et al.,* (1977), and Kramer (1969) have been used for qualifying the present status of the physical properties.

Results and Discussions

The data in Table 1 and Figure 2a confirm that the water stability of the aggregates increases with increasing of soil organic matter content and with OM/clay ratio (Figure 2b). Their dispersion is high and show that the content of organic matter is not the only one aggregation factor (Tisdall and Oades, 1982; Dilkova *et al.,* 1998c).

Table 1. Mean values of the physical and chemical properties of the 0-25/30 cm layers of the studied soils.

Soil groups (FAO)	Horizons	Clay %	ρ_b g/cm^3	AWHC %	OM %	Fe_o %	OM/Fe_o	MWDR
Vertic	A (virgin)	49	1.18	24.9	3.91	0.57	6.9	0.43
Chernozem and Vertisol	A (arable)	47	1.21	16.8	3.01	0.71	4.2	0.18
Haplic	A_1A_2 (v.)	19	0.97	31.1	3.43	0.88	3.9	0.50
Luvisol	A_1A_2 (a.)	22	1.30	23.0	2.46	0.90	2.7	0.12
	A_2l (v.)	19	1.21	27.8	2.70	0.92	2.9	0.45
	A_2l (a.)	23	1.52	25.2	2.58	0.82	3.1	0.13
Eutric	A_1A_2 (v.)	16	1.28	27.6	3.32	0.57	5.8	0.74
Planosols	A_1A_2 (a.)	18	1.41	24.9	1.88	0.71	2.6	0.26
	A_1A_2 (v.)	19	1.30	28.5	2.85	0.77	3.7	0.36
	A_1A_2 (a.)*	21	1.03	26.8	4.00	0.88	4.5	0.36
Distric	A_1A_2 (v.)	18	1.16	29.7	3.41	0.58	5.9	0.46
Planosols	A_1A_2 (a.)	28	1.26	15.5	1.53	0.67	2.3	0.22
	A_2l (v.)	18	1.38	19.2	1.42	0.65	2.2	0.41
	A_2l (a.)	20	1.41	9.8	1.14	0.82	1.4	0.23

* case with manure applied in the arable layer

In a previous study (Dilkova, *et al.,* 1998c) statistically proved predictive models were obtained for MWDR with the ratio total carbon/clay for virgin Eutric Planosols, Vertic Chernozems and Vertisols and with organic carbon, extractable with mixed solution (sodium pyrophosphate & sodium hydroxide) for Distric Planosols.

A good relationship was found also between water stability of soil aggregates and the ratio of the organic matter content/amorphous (oxalate-extractable) Aluminium (Al_o) in some virgin soils: $MWDR=a_o+a_1(OM/Al_o)$ (Dilkova, *et al.,* 1998a). All these relationships outlined the tendencies and could serve as predictive models for soil units, which they concern. The variety of the models could be explained with the omission of some aggregation factors as well as with correlation between some of them (Table 2).

In this study is estimated more completely the influence of the three aggregation factors - amorphous oxalate-extractable iron, organic matter, and clay content, on the aggregate stability of virgin and arable layers. Best prediction of MWDR is obtained by the regression model with the ratio $OM/(Fe_o$*clay) (Figure 2c). The advantage of this regression is that it has higher coefficient of determination compared to the others and involves the data from arable and virgin layers.

Table 2. Correlation coefficients of MWDR with the organic matter (OM), clay, oxalate-extractable aluminium (Al_o) and iron (Fe_o) content of the arable and virgin 0-25/30 cm layers (n=37).

	OM	Clay	Fe_o	Al_o
Clay	0.31			
Fe_o	-0.07	-0.05		
Al_o	0.37	0.62	0.38	
MWDR	0.27	-0.43	-0.43	-0.43

The conclusion is that the values between 0,20 and 0,50 of the ratio OM/(Fe_o*clay) (Table 3), characterise good and very good aggregate stability (Figure 2c), while the values below 0,20 and especially below 0,10-0,15 could be accepted as critical accounting for low aggregate stability.

Table 3. Classification of the aggregate stability and soil quality physical indicators.

MWDR		OM/(Fe_o*Clay)		BD g/cm^3		PAWC %	
	assessment	**mean**	**Min-max**	**mean**	**Min-max**	**mean**	**Min-max**
<0,25	poor	0.11	0.05-0.30	1.29	0.97-1.63	21.3	9.8-34.0
0,25-0,50	good	0.21	0.09-0.58	1.20	0.97-1.67	26.1	9.1-33.8
>0,50	very good	0.36	0.21-0.58	1.25	1.01-1.43	26.6	21.2-36.4

The idea to investigate soil aggregate stability as a soil quality indicator stems from its influence on important soil physical properties for plant growth such as soil compaction and available water holding capacity (AWHC) (Table 1, Figure 3). As it could be seen (Figure 3), the aggregate stability of cultivated soils is lower and accounts for higher bulk density and lower AWHC than at virgin soils.

The critical values of the aggregate stability for the bulk density and plant available water capacity (AWHC) are 0,25-0,30. It should be noted that at virgin conditions these values are typical for the illuvial and transitional horizons, while under cultivation they are anthropogenic features of the arable layers.

It could be concluded that the studied arable soils are with low water stability of the structure along the whole profile. The manuring of the arable soil layers (e.g. the case marked with * in Table 1) increases significantly OM, diminishes the bulk density and restores the aggregate stability to the level of the corresponding virgin analogue.

The results of the study give grounds to conclude that the soil enrichment with the organic matter by manuring, plant residues incorporation, grassland crop rotation favour the soil aggregate stability and physical conditions when the other two factors (clay and amorphous oxalate-extractable iron) are not limiting.

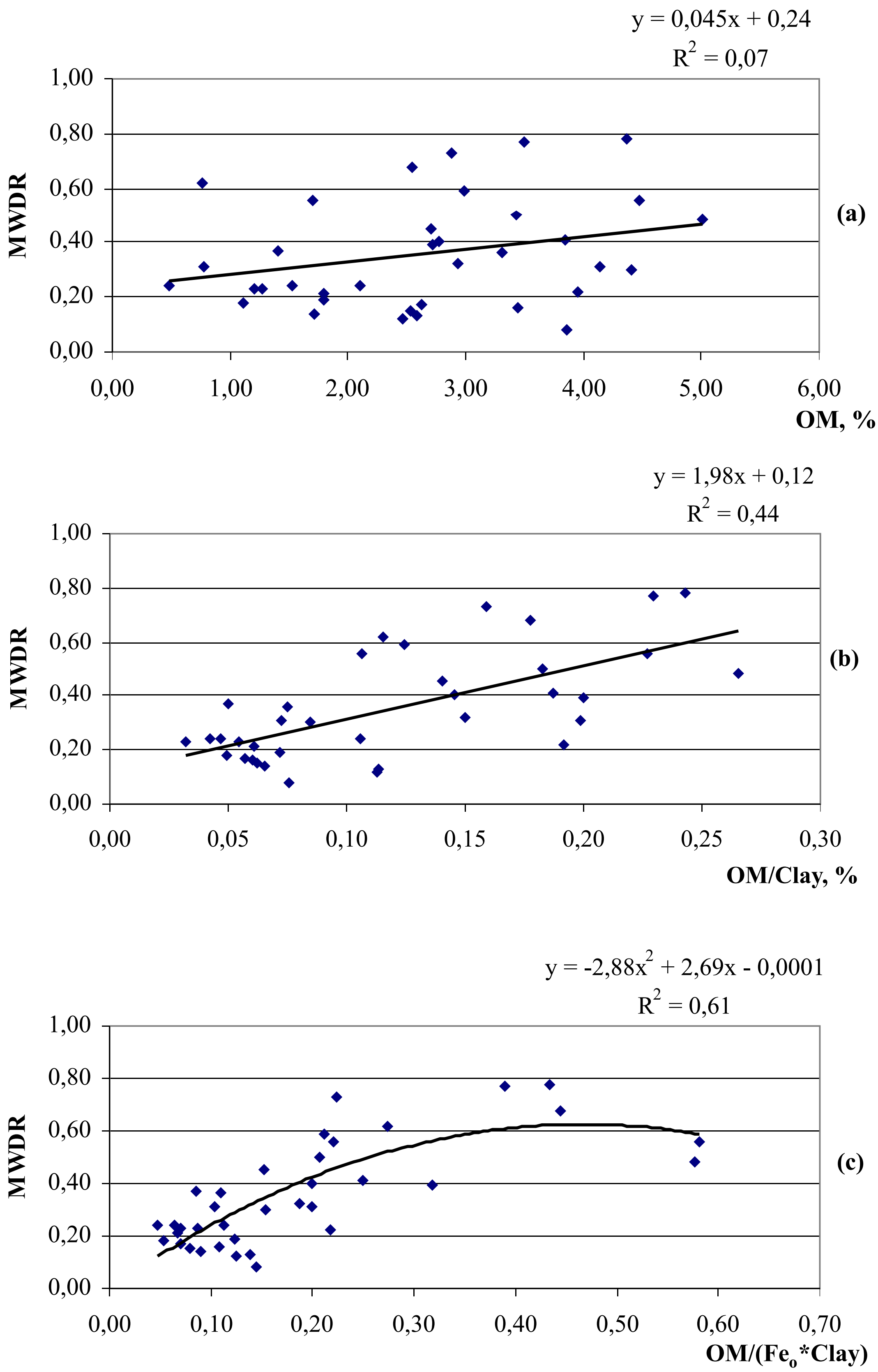

Figure 2. Relationships between MWDR and organic matter content (OM), OM/clay and OM/(Fe_o*clay)

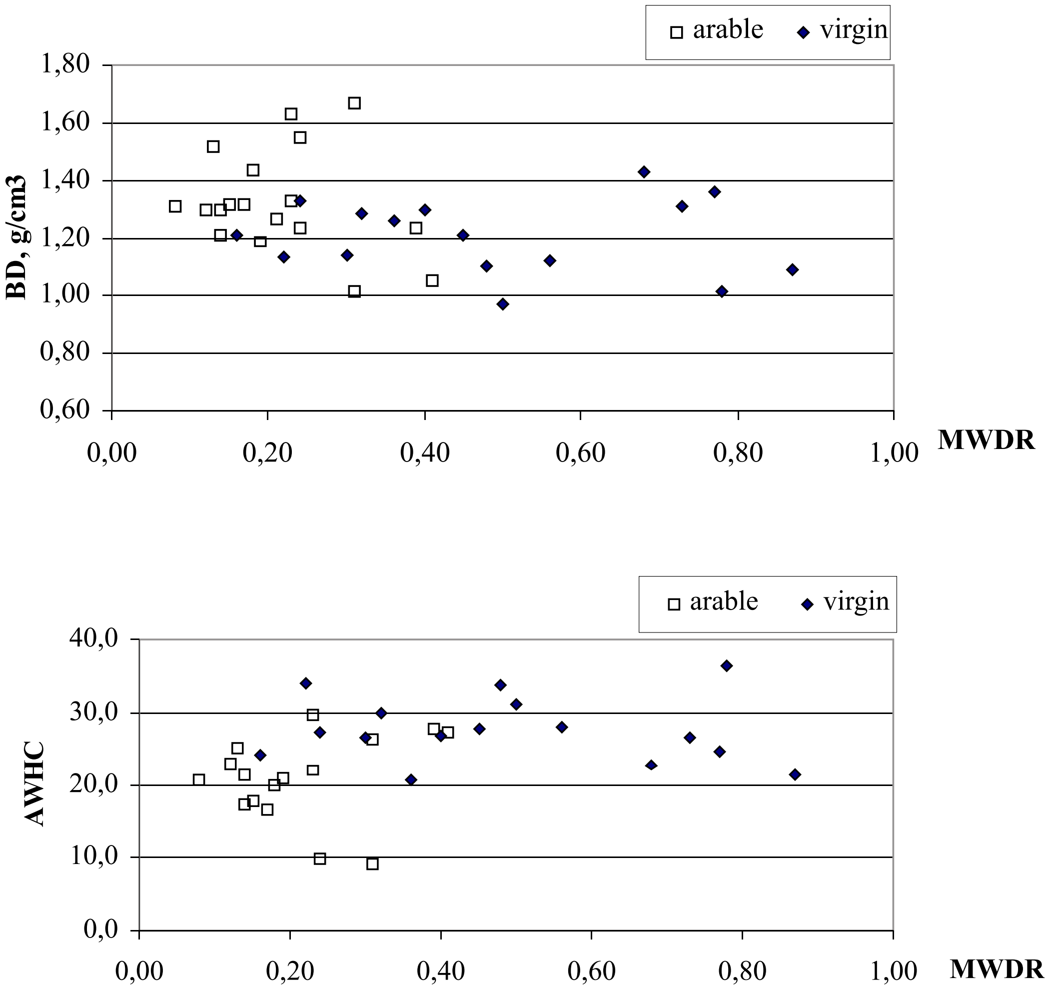

Figure 3. Bulk density (BD) and plant available water holding capacity (AWHC) of 0-25 cm soil layers in relation to MWDR.

Conclusions

The significance of the organic matter, amorphous oxalate-extractable iron and clay content for the soil water aggregate stability of the upper 0-20/30 cm layers of the virgin and cultivated Vertisols, Haplic Luvisols, and Planosols have been studied.

It has been found that the soil aggregate stability is an important factor for the agronomic physical properties: bulk density and the plant available water capacity. All these results permit us to classify the aggregate stability (MWDR) as poor, good and very good when the MWDR is less 0.25, 0.25-0.50 and more than 0.50, correspondingly, and to propose it as a soil quality criterion.

The ratio OM/(Fe_o*clay) is proposed as a new complex factor of the aggregate stability. The usage of this criterion will allow the identification of limiting factors and will help to elaborate appropriate recommendations for implementation of manuring and other agricultural techniques in order to maintain good water stability of soil aggregates and high quality of the soil.

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