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CHANGES OF PHYSICAL PROPERTIES IN SOILS UNDER TRADITIONAL SOIL MANAGEMENT IN ARABLE CROPS, IN THE SOUTHERN PART OF ROMANIA

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Abstract

The last decades made obvious that the life on Earth depends on the health status of our soils. The EU is committed to ensure that land is managed sustainably, and soils are protected or remediated according to their needs. The recently launched EU Green Deal puts soil in the heart of the Farm to Fork and Biodiversity strategies, with important targets to be reached by 2030. Therefore, research on how soil management practices affect the soil quality is required by relevant actors, sectors, and policy fields. The present work presents a comparative study on the changes of physical properties of soils in the southern part of Romania, under two different soil tillage practices: scarification (9 years, at 45 cm depth) and shallow plowing (25 cm) followed by disking. The two soil profiles from Calinesti, Teleorman County and Bucu, Ialomita County, revealed a chromic luvisols (luvisols class) in the Calinesti site and a calcaric fluvisols (protisols class) in the Bucu site. The formation conditions of the two types of soil are quite different in the terms of parental material, climate, vegetation, relief, anthropogenic influence, etc. Following the analysis of the physical properties (bulk density, total porosity, and degree of compaction) of the two soil types, evident differences were found, with implications in the crop yields.

***Key words**: soils physical properties, chromic luvisols, calcaric fluvisols, soil management practices, economic efficiency.*

INTRODUCTION

According to the New EU soil strategy, healthy soils are one essential aspect to meet climate and biodiversity goals under the New European Green Deal. Included in the EU biodiversity strategy for 2030, this initiative has as main goals to protect soil fertility, reduce erosion and sealing, increase organic matter content, identify contaminated sites, restore degraded soils, define what constitutes 'good ecological status' for soils (EC Law, 2021).

The Soil Thematic Strategy for Soil Protection identified two decades ago the key soil threats in the EU as erosion, floods and landslides, loss of soil organic matter, salinization, contamination, compaction, sealing, and loss of soil biodiversity (EC Environment, 2021).

The main physical characteristics of the soil (structure, total porosity and aeration, bulk density, resistance to penetration, permeability) can be influenced by soil mechanical works, which in turn can influence the physical and mechanical characteristics of the soil (consistency, adhesiveness, plasticity, resistance to plowing, etc.) (Dumitru et al., 2011).

Currently, conservative (unconventional) soil works define extremely varied processes, from direct sowing (no-tillage, direct drill) in unprocessed soil to deep tillage without turning the furrow (scarification). Between these two extremes there are different methods, such as: reduced works (classic rationalized), minimum works (with coverage under 30%, minimum tillage), minimum works with vegetable mulch (with coverage over 30%, mulch tillage), sowing on billets (ridge tillage), partial or strip works (strip till, zone till), works with protective layer (cover crops) etc.

By ploughing, the upper horizon is covered, the restored soil layer is brought to the surface and sometimes enriched with nutrients, achieving favorable conditions for germination and growth of plants. At the same time, a loosening of the soil is carried out, its volume is increased by a minimum of 25%, hydrostable aggregates are created especially at bulk density values of 1.1-1.3 g/cm^3.

This volume disappears over time, by natural settlement, when preparing the seedbed or during the vegetation period (Penescu and Ciontu, 2001).

The apparent density or volumetric weight, correlates very well with the total porosity and the degree of subsidence of the soil being conditioned by the texture, content in organic matter and the agrotechnical works executed (Canarache, 1990).

The root system of crop plants develops optimally at specific apparent density values, but these values change over time, either by the natural laying of the soil or by the need for agrotechnical works carried out according to the requirements of each crop.

Even more, the use of nitrogen from fertilizers increases at optimum values of bulk density, while, at low bulk density values (as 1.0 g/cm^3) only 38% nitrogen is used and at higher bulk densities (as 1.4 g/cm^3) only 44% of the total administered quantity is used by plants (Cârciu et al., 2019).

Regardless of the applied technology, by cultivating the land, influences are exerted on the soil that modify the natural balance of the physical, chemical or biological state with repercussions on its fertility.

The impact of agricultural technologies on the soil has become a pressing and topical issue, as it can lead to the degradation of soil properties due to the need to conserve and improve it, including water conservation in the soil.

Through agricultural works performed within conventional technologies, various changes take place, such as: the appearance and formation of crust, reduction of mesofauna, mineralization of organic matter, compaction, which lead to negative phenomena (acceleration of erosion, reduction of humus content, etc.).

Adopting good agricultural practices, especially on the soil management, is a key factor in granting food, clean water, feed, energy, safe climate, diverse ecosystem services and biodiversity, etc. for future generations.

The present work presents a comparative study of physical and hydrophysical properties of soils in two locations in Romania, under two different soil tillage practices and the implications on the crop yields.

MATERIALS AND METHODS

Physico-geographical conditions

The experiment was conducted in two different locations, in Southeastern part of Romania, in Călinești area Teleorman County on a chromic luvisols (Figure 1) and in Bucu area, Ialomița County, on a calcaric fluvisols, as illustrated in Figure 2. The technology applied in the two reference areas was different, in terms of soil mobilization and seedbed preparation but also the imputations used.

Figure 1. Călinești area

Figure 2. Bucu area

Soil analysis

The samples were analysed in INCDPA Bucharest laboratories. Soil samples were dried at room temperature; soil subsamples were homogenized, milled, and sieved through a 250 µm sieve.

The following analytical methods were used to determine the chemical properties:

- organic matter (humus): volumetric determination (Walkley-Black humidification method, STAS 7184/21-82);
- $CaCO_3$ (carbonates): gasometrical method (Scheibler calcimeter, SR ISO 10693: 1998, %);

- the nitrogen content, by calculation, based on the humus content and the degree of saturation with bases (IN = humus x V/100);
- mobile phosphorus content (Egner-Riehm-Domingo method and colorimetric molybdenum blue, Murphy-Riley method ascorbic acid reduction);
- mobile potassium content (Egner-Riehm-Domingo extraction and flame photometry);
- pH (potentiometric method in aqueous suspension at soil/water ratio of 1/2.5 - SR 7184 /13-2001);
- hydrolytic acidity, extraction with sodium acetate at pH 8.2;
- degree of bases saturation V% (Kappen Schoffield method).

The following physical characteristics were determined:
- determination of granulometric fractions;
- pipette method, for fractions ≤ 0.002 mm;
- wet grinding method for fractions of 0.002-0.2 mm and dry grinding method for fractions > 0.2 mm; the results are expressed as a percentage of the material remaining after pretreatment;
- bulk density (BD): The known volume of metal cylinders (100 cm^3) at the instant soil moisture (g/cm^3) - total porosity (PT): by calculation (% by volume -% v/v);
- aeration porosity (PA): by calculation (% volume -% v/v);
- compaction degree (GT): by calculation (% by volume -% v/v), where: PMN - minimum required porosity, clay of the sample is calculated with the formula PMN = 45 + 0.163 A (% by volume -% v/v); PT = total porosity (% v/v); A - clay content (% w/w);
- hygroscopicity coefficient (HC): drying at 105°C of a pre-moistened soil sample at equilibrium with a saturated atmosphere with water vapor (in the presence of 10% H_2SO_4 solution) - % by weight (% w/g);
- wilting coefficient (WC, %, g/g), calculated based on hygroscopicity coefficient;
- field water capacity (FWC, % w/w), calculated based on Dumitru et al. (2009) formula, considering clay content (%), silt content (%), bulk density (g/cm^3), and layer depth (cm);
- useful water capacity (UWC, % w/w) is calculated as the difference between field capacity (% w/w) and wilting coefficient (% w/w);
- total water capacity (TC, % w/w) is determined as the report between total porosity (% v/v) and bulk density (g/cm^3).

For the complete soil characterization, in terms of both the physico-chemical properties of the soil and physico-geographic conditions in which the soil was formed, soil properties are represented as symbols grouped in ecopedological indicators, according to the methodology in force (ICPA, 1987; Munteanu and Florea, 2009).

According to the available data, the main physical-geographical conditions of the two testing sites are illustrated in Table 1.

Table 1. Main physical-geographical conditions

Location	Geology and lithology	Climatic factors	Groundwater	Soil types
Calinesti (altitude: 75-80 m)	N-V Burnaz plain, on the Moesic Platform, sedimentary deposits -fluvio-lacustrine deposits over which loess and löessoid deposits	*min. t.*>-30°C *January av.* -2- -3°C *max. t* >40°C *July av.* > 23°C *aagr* - 125-127 kcal/cm^2 *aaat* - 11 °C - 12.0°C *dwf* - 190-210 d *aar* - 500-550 mm	3-5 m in river meadows, 5-15 m in most interfluves	typical luvosols (and mollic)
Bucu (altitude: 15-20 m)	The Ialomița meadow; covered with fluvial and swampy deposits, that consist predominantly of clays (sandy or loessoid), fine and coarse sand, homogenized with gravel	*min. t.*>-30°C *January av.* -2- -4°C *max. t* >38°C *July av.* 22 - 23°C *aagr* - 125-127 kcal/cm^2 *aaat* - 10.8 °C - 11.0°C *dwf* - 190-210 d *aar* - 400-500 mm	1-2 m in the spring 2-3 m during summer and autumn	fluvisols and gleysols

min. t. - minimum temperature; January av. - average temperature in January; max. t - maximum temperature; July av. - average temperature in July; aagr - annual average global solar radiation; aaat - average annual air temperature; dwf - days without frost/year; aar - average annual rainfall

RESULTS AND DISCUSSIONS

Soil characterization

A. Călinești location

- Soil type: Chromic luvisols
- Landscape: plain
- Use: arable, sunflower
- Parent material: loessoid deposits
- Groundwater: > 10 m

Figure 3. Călinești soil profile

Morphological characterization of the Călinești soil profile

The analytical data for chromic luvisols from the studied area are presented in the Table 2.

A_0 (0-32) cm, medium clay, color 7.5 YR 2/2 to the wet material and 7.5 YR 3/3 to the dry material, well developed grainy structure, aggregates crumble easily, unassembled when moist, friable in the dry state, poorly plastic and adherent, gradual passage.

AB (32-56 cm), dusty clay, color 7.5 YR 3/2 at the wet state material and 7.5 YR 4/3 at the dry state material, well developed polyhedral structure at the top of the horizon and medium polyhedral developed at its base, the aggregates crumble easily, not smooth when moist, friable in the dry state, weak plastic and adherent, weak compaction.

Bt_1 (56-135 cm), uniform color in shades of 7.5 YR 3/2 at the wet state material and 7.5 YR 3/3 at the dry state material, the structure is medium and large prismatic, clay-clay texture; the material is hard in the wet state and hard in the dry state, moderately plastic and adherent, weakly compact and weakly cemented.

Bt_2 (135-180 cm), medium clay, uniform color in shades of 7.5 YR 3/3 at the wet material and 7.5 YR 4/4 at the dry material, the structure is medium and large prismatic, frequent fine cracks, the material is hard when moist and hard when dry, residual neoformation is observed in the form of clay films on the faces of the structural aggregates.

C_k (>180 cm), medium sandy clay, uniform color in shades of 7.5 YR 4/4 in wet and 7.5 YR 5/4 in dry, unstructured, friable in wet, moderately cohesive in dry, has rare grains of sand, rare spots of $CaCO_3$, strong effervescence.

Table 2. Characteristics of the chromic luvisols, Calinesti area

Horizon	Ao	AB	Bt_1	Bt_2	C
Depth (cm)	0-32	32-56	56-135	135-180	> 180
Coarse sand (2-0.2 mm)	14,8	5.1	6.4	5.3	26.5
Fine sand (0.2-0.02 mm)	26.6	21.8	20.8	11.5	19.5
Dust (0.02-0.002 mm)	28.6	41.7	28.6	38.5	18
Clay (< 0.002 mm)	30	31.4	44.2	44.7	36
Soil texture	silt	silt loam	silty clay loam	silty clay loam	sandy loam
Soil reaction (pH)	5.7	5.9	6.2	6.5	7.2
Humus content (%)	3.2	2.8	1.7	0.8	0.8
Apparent density (g/cm^3)	1.26	1.31	1.46	1.47	1.39
Total porosity (%)	52.5	50.6	46.5	43.0	46.7
Degree of compression GT (%)	-6	1	15.3	17.7	4
Carbonates (%)	0	0	0	0	4.7
Degree of saturation with bases V (%)	72	74	78	80	-
Total content of nitrogen IN	2.3	2.07	1.32	0.64	-
Mobile P (ppm)	34	31	26	24	-
mobile K (ppm)	184	165	132	117	-
Wilting coefficient (%)	10.2	10.8	11.7	11.8	-
Field capacity (%)	18.5	19.6	21.2	21.5	-
Useful water capacity (%)	8.4	8.8	9.6	9.8	-
Total water capacity (%)	41.6	38	32	29	-
Humus reserve (t/ha)	129	88	196	53	-

B. Bucu location
- Soil type: calcaric fluvisols
- Landscape: meadow
- Use: arable, sunflower
- Parent material: alluvial deposits
- Groundwater: > 2.5 m

Figure 4. Bucu soil profile

Morphological characterization of the soil profile from Bucu area
The analytical data for the clacaric fluvisols from the Bucu area are presented in the Table 3.

Ap (0-16 cm), dusty sandy clay, moderately developed grayish structure, brown with shades of 10 YR 3/2 to wet and dark brown 10 YR 5/4 to dry, reawakening, weak biological activity, non-plastic, non-adhesive, frequent fine pores, very frequent thin roots from cultivated vegetation, gradual passage, hardpan 18-26 cm;
Ao (16-28 cm), medium sandy clay, poorly developed grainy structure, strongly tanned, yellowish brown with shades of 2.5 Y 4/3 at wet and 2.5 Y 5/4 at dry, frequent fine roots, strongly tanned, clear wavy passage.
AC (28-46 cm), sand-fine clay, light brown with shades of 2.5 y 4/4 to wet and yellowish brown 2.5 y 6/4 to dry, very friable, unstructured, non-plastic, non-adhesive, frequent coarse pores, frequent fine roots, weak effervescence in the lower half of the horizon, gradual passage.
C_1 (46-82 cm), sand-clay coarse, light yellowish with shades of 2.5 Y 5/3 at wet and 2.5 Y 6/6 at dry, unstructured, reaven, very friable, frequent CaCO3 pseudomyceles, strong effervescence, clear straight passage.
C_2 (82-115 cm), sand-clay coarse, light yellowish with shades of 2.5 Y 5/3 at wet and 2.5 Y 6/6 at dry, unstructured, reaven, very friable, frequent $CaCO_3$ pseudomyceles, strong effervescence, clear straight passage.

Table 3. Characteristics of the calcaric fluvisols, Bucu area

Horizon	Ap	Ao	AC	C_1	C_2
Depth (cm)	0-16	16-28	28-46	46-82	82-115
Coarse sand (2-0.2 mm)	9.8	10.2	14.1	14.5	18.4
Fine sand (0.2-0.02 mm)	40.9	36.7	45.9	50.3	48.7
Dust (0.02-0.002 mm)	30.8	34.5	28.4	24.9	20.4
Clay (< 0.002 mm)	18.5	18.6	11.6	10.3	12.5
Soil texture	sandy loam	sandy loam	loamy sand	sand	sand
Soil reaction (pH)	7.2	7.2	7.4	8.1	8.4
Humus content (%)	2.16	2.07	1,21	0.37	-
Bulk density (g/cm^3)	1.52	1.53	1.63	1.64	1.44
Total porosity (%)	42	42	38	36	43
Degree of compression (%)	12	13	19	22	7
Degree of saturation with bases	94	96	98	100	100
Total content of nitrogen IN	2.03	1.98	1.18	0.37	-
Mobile P (ppm)	14	13	9	7	-
Mobile K (ppm)	112	87	67	45	-
Wilting coefficient (%)	3.9	4,2	4.6	4.5	-
Field capacity (%)	7.1	7.7	8.5	8.2	-
Useful water capacity (%)	3.2	3.44	3.9	3.7	-
Total water capacity (%)	42	29	45	49	-
Humus reserve (t/ha)	34	97	65	-	-

Aspects regarding the soil physical and hydrophysical properties

In Călinești experimental plot, the chromic luvisols was cultivated mainly with sunflower, and the soil works were represented by scarify-cation, each year in the last 9 years. At 45 cm the hardpan layer was found. The soil activity was more intense, with lumbricides (*Lumbricus terrestris*) present until 60 cm. The crop residues were found in the top 40 cm of the surface, fact which improved the soil physical indicators, as bulk density, total porosity, and compaction degree, as illustrated by Figure 5.

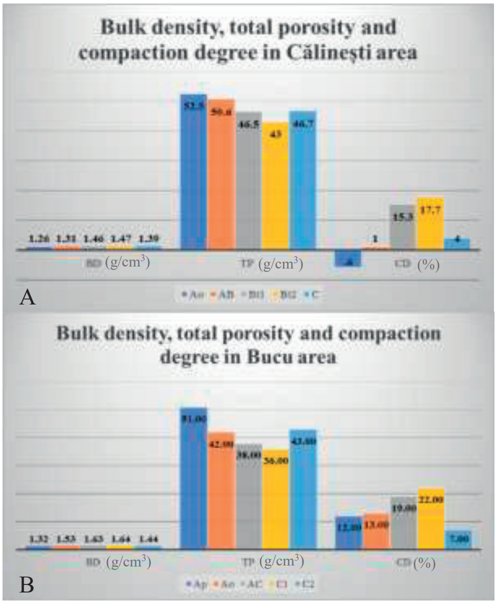

Figure 5. The soil physical properties in Călinești (A) and Bucu (B) experimental fields

The better water infiltration capacity, proved by the four hydrophysical indicators, as wilting coefficient, field water capacity, useful water capacity and total water capacity (Figure 6), is confirmed by the absence of puddles on the surface of the soil, even short time after rains. All these factors contribute to an increased sunflower production, higher than the average production, usually around 3600 kg/ha.

At Bucu experimental plot, also cultivated with sunflower, the soil works on calcaric fluvisols were represented only by superficial ploughing (max.15 cm). Due mainly to the lack of water, the works of soil mobilization were of poor quality and had as result the formation of hardpan below 13-15 cm. Due to the water weak infiltration and unfavorable soil physical characteristics, the root system was poor, and was formed above the hardpan.

In addition, puddles could be observed at the surface of the soil.

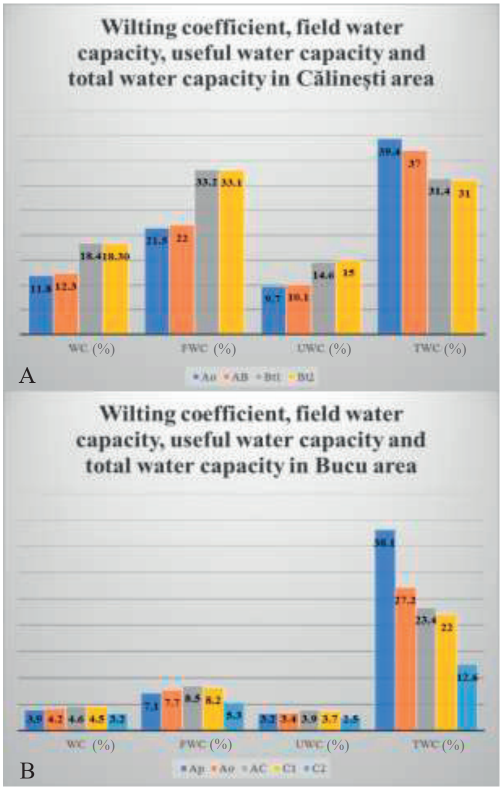

Figure 6. The soil hydrophysical properties in Călinești (A) and Bucu (B) experimental fields

Being a soil with a generally coarse texture, poorly supplied with nutrients, with low activity of the soil fauna, the sunflower yields were low, below 1000 kg/ha.

Previous studies showed that the root system develops optimally at bulk density values ranging from 1.0-1.4 g/cm^3. In Bucu area, the values higher than 1.53 g/cm^3 proved the difficulty of root system to develop. The values of the compaction degree (CD) change over time, either by natural laying of the soil or due the agrotechnical works carried out according to the requirements of the crop, but the obtained values proved that Bucu soil has a higher compaction degree, which is unfavorable to sunflower plants.

CONCLUSIONS

Two locations with different physical and geographical conditions were studied, which resulted in two types of soil, classified in different soil classes, namely: protisols (calcaric fluvisols) and luvisols (chromic luvisols).

In the conditions of the chromic luvisols from Călinești, mobilized by scarification for 9 years, without plowing, it was found that the physical properties of the soil were much improved, without puddles, a very favorable aerohydric regime resulted, the activity of the soil fauna intensified, which led to an increase in production per unit area.

In the conditions of the calcaric fluvisols from Bucu, worked superficially up to 15-17 cm, due to the accentuated compaction, the root system of the plants was restricted, weak infiltration of water, the appearance of the crust on the surface, which lead to low yields, under 1000 kg/ha.

The hydrophysical properties of the two soil types are very different, considering the values of total water capacity (TWC) and useful water capacity (UWC), hence the resistance of plants to drought in certain vegetation periods was much low in Bucu area.

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