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CHERNOZEMS UNDER LONG TERM IRRIGATION

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Abstract. Le but de cet article est de souligner l'impact de l'irrigation à long terme sur les caractéristiques structurelles et la vie dans les Chernozems. Les chercheurs ont été effectués sur deux endroits dans la Plaine Roumaine, sur Chernozems irrigués plus de 30 ans. Sol perturbé (pour l'analyse physique et chimique) et le sol non perturbé (pour l'étude micromorphologique) ont été échantillonnés. Les chercheurs complexes des Chernozems ont montré une corrélation significative entre les valeurs analytiques de la taille et la forme des pores (quantifiée par le but de l'analyse de l'image) et les facteurs générateurs de porosité comme la faune et les processus physico-mécanique (obtenu par les images micromorphologique sur les lames minces). Les données d'analyse d'images obtenues pour la porosité totale ont montré que les deux horizons du sol de la couche arable (Ap et respectivement Apt) étaient modérément poreux (la porosité totale dans Ap était de 0,18 à 0,23 m^2m^{-2}, tandis que dans Apt légèrement diminué à 0,14 à 0,21 m^2m^{-2}). L'impact de l'irrigation a initié également un peu de lessivage de plasma du sol (constituants < 0,002 mm) avec la formation de très fines couches d'argile impurs. L'irrigation à long terme profondément changé l'écologie des Chernozems étudiés, à la suite de réduire les saisons de sécheresse (en appliquant l'irrigation dans les périodes chaudes et sèches) et, par conséquence, la faune est devenu plus actif une période plus longue au cours de l'année. Dans cette environnement compacté, une collaboration mutuelle établie entre les racines des plantes cultivées et la faune du sol: ainsi, la faune étant abondante et très active, enfouit beaucoup de canaux qui sont devenus les chemins préférentiels des racines, et par conséquence une tâche facile pour les racines pour explorer cette environnement compacté. L'irrigation à long terme a lessivé également le $CaCO_3$ au dessous de 125 cm, la limite nécessaire pour les sols classifiés comme Chernozems. Dans cette condition, a été proposée une révision taxonomique.

Keywords: irrigation, image analysis, micromorphology, taxonomy

1. Introduction

Good soil structure means an aggregation process which has positive benefits for plant growth; these benefits arise from the wider range of pore sizes which result from aggregation Gardner et al. (1999).

The image analysis performed on oriented soil thin sections with the help of an image-analyzing computer, allowed to measures and characterizes the pores by their shape and size.

The shape factors ($perimeter^2/4\pi$*aria) afford the division of pores into different shape classes such as: regular (more or less rounded) pores (with shape factor 1 - 2); irregular pores

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(with shape factor 2 - 5); and elongated pores (with shape factor > 5). These classes correspond broadly to the classes defined by Bouma et al. (1977) and Pagliai (1988).

According to the image analysis data, Pagliai et al. (1995) showed that a soil is dense (compact) when the total porosity is less than 0.10 m^2m^{-2}, moderately porous when the total porosity ranges from 0.10 to 0.25 m^2m^{-2}, porous when it ranges from 0.25 to 0.40 m^2m^{-2}, and extremely porous over 0.40 m^2m^{-2}.

The total porosity was subdivided by Greenland (1977) in four classes: fissures (> 500 µm e.d - equivalent diameter); transmission pores (50 - 500 µm); storage pores (0.5 - 50 µm); residual pores (< 0.5 µm).

The activity of fauna (the soil structure architects) have a major influence on the construction and the yearly renewing of the soil environment, but in some horizons (as Apt) the more active compaction process induce the collapse of fauna channels (Răducu, Eftene, 2013).

Earthworms, along with other soil macroinvertebrates, have been defined as the "ecosystem engineers" due to their importance in soil structure formation and maintenance through the creation of continuous macropores (Blanchart et al., 2004; Edwards, Shipitalo, 1998; Castellanos-Navarrete et al., 2012). Earthworms played a key role in enhancing physical soil functions. When conditions were conducible to their proliferation, earthworm activity was a major factor affecting soil structural morphology as confirmed by micromorphological analysis (Castellanos-Navarrete et al., 2012).

Răducu et al. (2002) showed that in the Apt horizon of tilled plots it can be also noticed a strong reduction of regular and irregular pores, with respect to the upper Ap horizon; since these pores were mainly originated by burrows of soil fauna, their decrees could be ascribed to a collapse due to compaction.

These organisms significantly contributed to soil macroaggregation (> 250 µm) and biogenic macroporosity (≥ 1 mm) through their casting and burrowing activity (Pulleman et al., 2005; Shipitalo and Protz, 1989).

The aim of the paper is to emphasize the impact of the long term irrigation on the structural characteristics and soil life in Chernozems.

2. Material and methods

The researchers had been performed in two sites (Dalga and Perisoru) located in the Eastern part of the Romanian Plain, in Southern Bărăgan Plain, where the climate is temperate continental, and the bioclimate is steppe, on Chernozems irrigated more than 30 years.

The average annual temperature in the firs site (Dalga) is of 10.8°C, while in the second site (Perisoru) is 10.6°C and the average annual rainfall is 480 mm in both sites. The global drainage is good. The water table is at > 10 m.

Undisturbed soil (for micromorphological study) and disturbed soil (for physical and chemical analysis - determined by the standard methods of ICPA-Bucharest) were sampled.

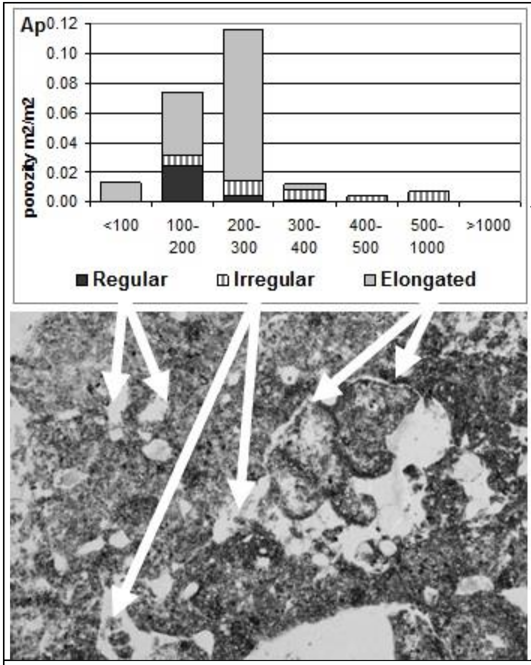
The micromorphological undisturbed samples were air drayed and impregnated with epoxidic resins. After hardening, oriented thin sections (25 - 30 µm) have been made from each sample and studied after words with Documator (20 X) and optical microscope (50-100 X) in PPL and XPL. The terminology used for micromorphological description was according to Bullock et al. (1985).

Image analysis has been performed on soil thin sections with the help of an image-analyzing computer (PC-IMAGE software produced by "Foster Findlay Associates" – London).

The instrument was adjusted to measure pores greater than 50 µm. The pores have been measured by their shape, which is expressed by the shape factor (perimeter^2/4π*aria).

3. Results and discussions

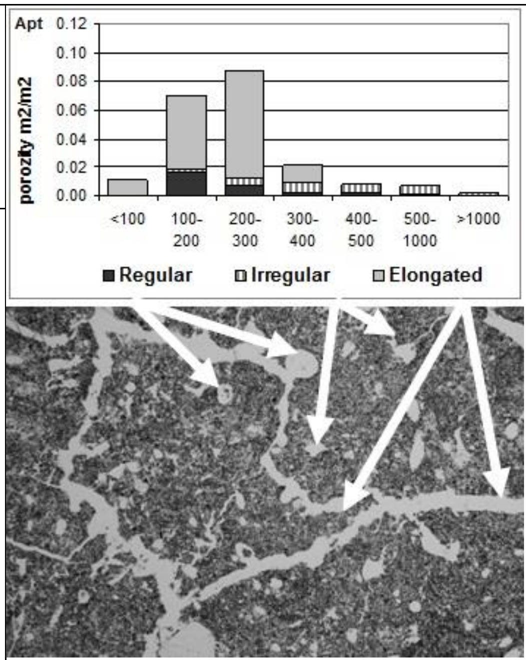
The complex researchers of Chernozem from Dalga showed a significant correlation between the analytical values of the pore size and shape (quantified by the aim of the image analysis) and the generating factors of porosity as fauna and physico-mechanical process (obtained by the micromorphological image on the thin sections).



a

b

Figure 1: Ap horizon of Dalga-Chernozem: a) Image analysis: soil porosity (characterized by size and shape); b) Microscopic observation: pores generated by the biological activity (reflected by their shape).



a

b

Figure 2: Apt horizon of Dalga-Chernozem: a) Image analysis: porosity (characterized by size and shape); b) Microscopic observation: pores generated by physico-mechanical processes and biological activity (both reflected by their shape).

The image analysis data (Figure 1 a and 2 a) obtained for the total porosity in Dalga Chernozem showed that both soil horizons of the arable layer (Ap and Apt respectively) were moderately porous.

The total porosity in Ap horizon was 0.23 m^2m^{-2} (Figure 1 a), while in Apt slightly decreased to 0.21 m^2m^{-2} (Figure 2 a).

The porosity (according to the pore size) in Ap horizon was dominated by the pores with 200 - 300 µm equivalent pore diameter. Among them, elongated pores were the most frequent, followed by the regular and the irregular pores. In the case of 100 - 200 µm size class, the proportion of the different types of pores was relatively balanced, except for the irregular pores which were lower. The irregular pores became dominant in the size class of 400 - 500 µm and 500 - 1000 µm respectively.

In what concerning the correlation between the pore shape and the generating processes of the poral space (Figure 1 b and 2b), the micromorphological observation on the thin sections reveals that Ap porosity was mostly biological and relatively well preserved, even in the conditions of a tilled layer:

- irregular pores were dominant in the areas with collapsed chambers and channels (burrows) filled with coprolites (casts) generated by macrofauna (earthworm) activity and partially integrated in soil matrix; and also the vughy (voids with the irregular walls) generated by mezofauna activity.
- regular pores (with rounded shape) were generated mainly by plant roots growth and also by mezofauna burrowing.
- elongated pores were dominated by the fissures (generated by the physico-mechanical processes of cracking) and by fine semicircular fissures which delimitate the biological pedofeatures from the surrounding matrix.

In what concerning the pores characterized on their type, the image analysis of the Ap horizon showed the dominance of the transmission pores (50-500 µm), while the storage pores (0.5 - 50 µm) drastically reduced. The fissures (> 500 µm) mentioned at a relatively high values.

In the Apt horizon, the fissures (> 500 µm) became dominant, having the higher values. The storage pores (0.5 - 50 µm) has relatively the same values with that ones in the upper Ap horizon, while the transmission pores (50-500 µm) drastically decreased in this horizon (comparing to the top Ap horizon).

Dalga Chernozem was relatively well structured by the high biological activity, which added to the porous system (generated by physico-mechanical processes), numerous and continuous bio-pores (channels or burrows), which represent the path for cultivated plant roots, and further, the development of abundant rooting.

In the more compacted Apt horizon, the number of the roots decreased, in accordance with the collapse of the biological pedofeatures. Thus underlines once again that fauna is the soil structure architect.

Comparing both Chernozems (from Dalga and Perisoru), some important differences could be outlined.

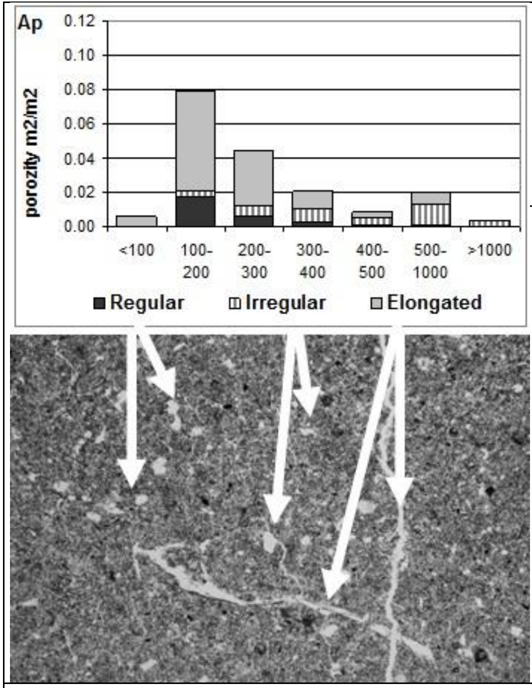
On the general background of a considerably smaller total porosity in Perisoru (comparing to Dalga), a clear dominance of the fissures (elongated pores) is looming (both in Ap and Apt). Thus, the image analysis data of Perisoru Chernozem (Figure 3 a and 4 a) showed that the total porosity in Ap was 0.18 m^2m^{-2} (Figure 3a), while in Apt drastically decreased to 0.14 m^2m^{-2} (Figure 4a).

The porosity (according to the pore size) in Ap horizon was dominated by the pores with 100 - 200 µm equivalent pore diameter. Elongated pores were the most abundant, being succeeded by the irregular and the regular pores respectively. In the pore size classes of 200 - 300 µm and 300 - 400 µm, the proportion of the different types of pores was relatively balanced. The irregular pores became dominant in the size classes of 400 - 1000 µm.

The structure and the poral space characteristics (quantitatively highlight by the imagine analysis – Figure 3 a and 4 a) strongly correlated with the number and the distribution of the coprolites and biogenic channels, as well as the fissures (qualitatively emphasized by the aim of the micromorphological imagines on the thin sections – Figure 3 b and 4 b).

The micromorphological observation pointed out the dominance of the fissures both in Ap and Apt horizons, but these fissures (clearly different from the Apt Dalga-Chernozem – Figure 2 b) are very fine, circular and/or semicircular, and delineated the biogenic pedofeatures (coprolites, casts and pedotubuls generated by macro- and mezofauna) from the surrounding matrix.

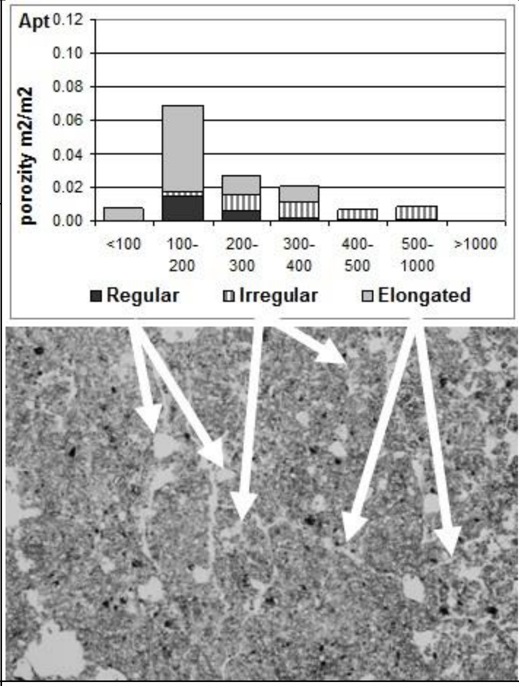
Even if the pedofeatures collapsed and integrated into the matrix, as a result of a very active process of compaction, the fine cracks developing around them showed their presence.



a

b

Figure 3: Perisoru-Chernozem. Ap horizon: a) Image analysis: soil porosity (characterized by size and shape); b) Microscopic observation: pores generated by the biological activity and by the physico-mechanical processes (both reflected by their shape).



a

b

Figure 4: Perisoru-Chernozem. Apt horizon: a) Image analysis: soil porosity (characterized by the size and shape); b) Microscopic observation: pores generated by the biological activity (reflected by their shape).

In this way, the image analysis data obtained for the pores grouped according to their type, showed that the transmission pores (50-500 µm) are the most frequents in Ap horizon, while the fissures (> 500 µm) had the highest values in the more compacted Apt horizon.

The studied aspects points out that the soil fauna activity (the soil architects and builders) had a majored influence on the construction and the renewing of the poral space of the soil, but in the Apt horizon, the compaction is more active and induce the collapse of the channels generated by the fauna and consequently stressed the roots development.

In both Apt horizons of Dalga Chernozem the Perisoru Chernozem respectively, the physico-mechanical porosity (creaking) became dominant generating elongated pores. Thus, in Apt horizon of Dalga Chernozem dominated the wide interconnected cracks, while in Apt horizon of Perisoru Chernozem, fine semicircular fissures were prevailing.

In the more compacted horizons of the Perisoru Chernozem, the mezofauna became more active than normal in a Chernozem, generating more loose zones with small coprolites and a vughy structure.

Thus, in the more compacted soil, mezofauna being better adapted to these conditions takes over the macrofauna task: to compensate the collapse macrofauna pedofeatures and to improve the long term irrigated soil environment.

The long term irrigation deeply changed the ecology of the studied Chernozems, as a result of the reducing of the drying seasons (by applying irrigation in the hot dry periods) and consequently, the fauna is more active a longer period during the year.

In the more compacted Chernozem from Perisoru, long term irrigation reduced the drying periods of the year, favoring the fauna activity and consequently helping the roots to explore the soil (the channel burrowing by soil fauna being the preferred root path). In this way, in a compacted environment, a mutual collaboration established between the crop roots and soil fauna: thus, fauna being abundant and very active, burrowed many channels, which became the preferential roots path, and consequently an easy task for roots to explore such a compacted environment.

The irrigation impact also initiated a slightly leaching of soil plasma (constituents < 0,002 mm) with the formation of very fine impure clay coatings on the pore walls.

The Chernozems are soils easy to classify. One of their requirements is the presence of "the Cca horizon or of the friable powder concentration of $CaCO_3$ (secondary carbonates) in the first 125 cm" (SRTS-2012). Their classification problem appears when the limit of $CaCO_3$ horizon is below 125 cm (when the soil must be classified as Phaeozem - soil specific for the more humid zones).

Under the long term irrigation, in Perișoru Chernozem, the $CaCO_3$ leached below 125 cm. In such a case it is out of question to classify this soil as Phaeozem. In this condition, a taxonomic revising is proposed.

Conclusions

The following **conclusions** can be drawn:

- under the corroborated impact of the irrigation with tillage, Dalga Chernozem is relatively well structured and has an abundant porous system as a result of an intense biological activity, which add to the poral system created by creaking, numerous and continuous biopores, favoring the development of an abundant rooting.
- in Perișoru Chernozem the moderate-strong compaction was observed in all the studied profile, biogenic porosity formed by channel and chambers being collapsed and under integration into the A horizon (Ap and Apt respectively), but the intense activity of mezofauna improved the rizosphere microenvironment, generating loose zones (with small coprolites and vughy structure).
- the biogenic pedofeatures, although weak preserved, emphasized an intense fauna activity which continuously build valuable aggregates (bio-aggregates and bio-pores) improving the soil aeration and the bio-geochemical process in the soil.
- the researchers indicate a significant correlation between the soil porosity measurement by image analysis (according to their shape and size) and the generating processes of the poral space emphasized by the micromorphological observation on the thin section image (according to the biogenic pedofeatures shape and location).
- the image analysis data of the total porosity showed that the soil in Dalga Chernozem was moderately porous (the total porosity in Ap was 0.23 m^2m^{-2}, while in Apt slightly decreased at 0.21 m^2m^{-2}), while in Perisoru Chernozem the porosity was lower (0.18 m^2m^{-2} in Ap, and 0.14 m^2m^{-2} in Apt).
- the micromorphological observations on soil thin sections pointed out the dominance of the porosity generated by soil macro- and mezofauna, more preserved in Ap and

more collapsed in Apt horizon, under the compaction processes (more intense in Perisoru Chernozem comparing with Dalga Chernozem).

- in the more compacted Chernozem from Perisoru, long term irrigation reduced the drying periods of the year, favoring the fauna activity and consequently helping the roots to explore the soil (the channel burrowing by soil fauna being the preferred root path).

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