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Research article

The polyphasic evolution of a saline soil

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Abstract. The paper emphasizes the polyphasic evolution of a saline soil and its development towards a zonal soil. Most saline soils have formed in river beds, on parental materials made up of stratified fluvial deposits. Over time, depending on the distance to the river bed and the frequency of flooding, these soils have developed more or less towards the zonal soil. The study plot is located in Bârlad Valley, Bârlad Tableland, where the Tma is 9.3ºC and Pma is 535.5 mm. The soil is an Aluviosol mollic salinic, with relict gleization covering at 60 cm a Chernozem aluvic-salinic, with relict gleization (according to SRTS-2012). In WRB–SR, this soil is classified as a Gleyic Fluvisol. The soil formed in an un-uniform parental material (specific to soils formed in fluvial materials). As a result, the soil profile consists of two main sequences: 1) a sequence (0–60 cm) representing the actual soil (Salinic Aluviosol, with relict gleization) consisting of three pedogenetic horizons that have not sufficiently evolved to become the zonal soil. The differentiation of the horizons of this sequence is due to the cyclic sedimentation processes and, to a lesser extent, to a weak pedogenesis; 2) a second sequence (60–210 cm) representing a soil material consisting of several deposits (stratifications) which: a) had no time to integrate each others and to form a soil; the soil material evolved in marshland being continuously elevated. At a certain moment, the area was drained, and now the horizons constituting the upper part of the buried sequence (60–122 cm) have the appearance of mollic horizons, and the soil trend to developed towards Cernisol (Chernozem respectively); b) are not sufficiently contrasting in terms of texture, so they can be considered as lithological discontinuities and consequently denoted with prefix numbers. The current pedogenetic processes that influence the development of this soil profile (consisting of two overlapped soils) are those of the attenuation of the characteristics inherited from the parental material and those which oriented the pedogenesis throughout the formation of the zonal soil. Land

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reclamation works maintain the tendency of salts to invade the entire profile at a level that does not affects the development of the crop roots..
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Introduction

Most saline soils have formed in river beds, on parental materials made up of stratified fluvial deposits. Over time, depending on the distance to the river bed and the frequency of flooding, these soils have developed more or less towards the zonal soil.

Frequent flooding leads to covering the respective soils with young deposits, keeping them at a low evolutionary level, and the profile morphology highlights the inherited features of parental materials (fluvic deposits).

Most and Hudson (2018) showed that floodplain geomorphology of large lowland rivers is intricately related to aquatic ecosystems dependent upon flood pulse dynamics. They also underlined that floodplain ecosystems along large lowland rivers require hydrologic connectivity for the exchange of water, nutrients, sediments and organisms between river and riparian environments.

Răducu (2015) showed that soils formed into the floodplains developed in un-uniform parent material, and therefore, the soils are stratified and more or less saline.

The group of salt-affected soils includes soils containing soluble salts or their ions in at least one of their horizons in quantities that are above the threshold of toxicity – the maximal permissible concentration of salts that does not suppress plant growth (Pankova et al., 2018).

Combating salinization should, together with other measures for achieving the sustainable intensification of agriculture, be considered as a basis for food security (Vargas et al., 2018).

The aim of the paper is to emphasize the polyphasic evolution of a saline soil and its development towards a zonal soil.

1. Material and methods

The study plot is located in Bârlad Valley, Bârlad Tableland, where the average annual temperature is of 9.3ºC, while the average annual rainfall is of 535.5 mm. The global natural drainage is imperfect. The water table is at 2–3 m depth. The microrelief is represented by a low floodplain, with abandoned meanders. At present the floodplain is embanked, the reclaimed works being combined with drainage and irrigation by sprinkling.

The soil is an Aluviosol mollic salinic, with relict gleization covering at 60 cm a Chernozem aluvic-salinic, with relict gleization (according to SRTS–2012). In WRB–SR, this soil is classified as a Gleyic Fluvisol.

Soil samples, both disturbed (for physical and chemical analysis) and undisturbed (for micromorphological study), were analyzed according to the standard methods of ICPA-Bucharest (ICPA Methodology-1987).

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 with Documator (20 X) and optical microscope (50–100 X) in PPL (plain polarized light) and XPL (cross polarized light). The terminology used for micromorphological description was according to Bullock et al. (1985).

2. Results and discussions

The studied soil is an Aluviosol mollic salinic, with relict gleization covering at 60 cm a Chernozem aluvic-salinic, with relict gleization (according to SRTS–2012). In WRB–SR, this soil is classified as a Gleyic Fluvisol.

The soil formed in an un-uniform parental material (specific to soils formed in fluvial materials). As a result, the soil profile consists of two main sequences easily distinguish in the field by the color differentiation (Figure 1):

- A sequence (0–60 cm) representing the actual soil (Salinic Aluviosol, with relict gleization) consisting of three pedogenetic horizons that have not sufficiently evolved to become the zonal soil. The differentiation of the horizons of this sequence is due to the cyclic sedimentation processes and, to a lesser extent, to a weak pedogenesis.

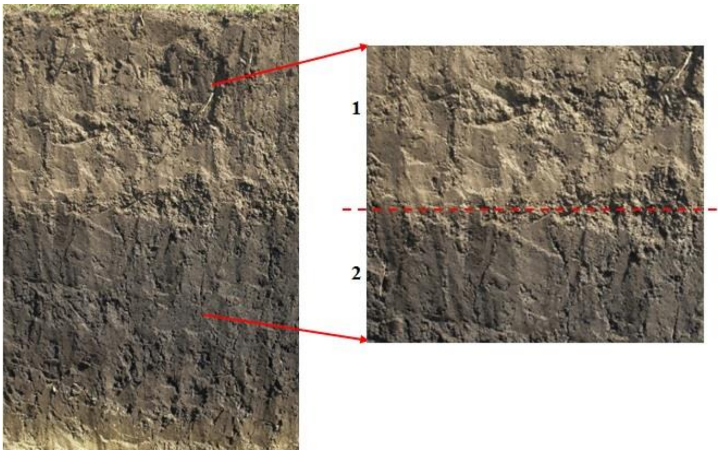

Figure 1: The two soil sequences (the color difference is obvious): 1) Aluviosol salinic, with relict gleization; 2) Buried soil.

- A second sequence (60–210 cm) representing a soil material consisting of several deposits (stratifications) which: a) had no time to integrate each others and to form a soil; the soil material evolved in marshland being continuously elevated. At a certain moment, the area was drained, and now the horizons constituting the upper part of the buried sequence (60–122 cm) have the appearance of mollic horizons, and the soil trend to developed towards Cernisol (Cernozem respectively); b) are not sufficiently contrasting in terms of texture, so they can be considered as lithological discontinuities and consequently denoted with prefix numbers.

The differentiation of the pedogenetic horizons of this sequence is mainly due to the cyclic processes of sedimentation and accretion and, to a lesser extent, to pedogenesis.

These aspects highlight the polyphasic evolution of the soil profile.

2.1. The Salinic Aluviosol, with relict gleization (according to SRTS–2012)

Aluviosol is a young, poorly developed soil which preserved the characteristics inherited from the parent material, i.e. material sorted during fluvial deposition.

Even after cultivation and irrigation, the characteristics inherited from the parental material are still present into the soil profile.

The data of the particle-size distribution (Figure 2) showed medium loamy texture, due to the dominance of coarser fractions (up to 0.002 mm).

The skeleton grains were sorted during deposition, generating some areas with mineral grains of coarse sand size, alternating with areas with mineral grains of loam and fine sand size. In the top horizon, tillage diminishes, to a certain extent, the textural un-uniformity inherited from the parental material.

The soil fauna activity is very high and mixed the matrix of each horizon.

The bioaccumulation is relatively low, plant debris are rare and very small.

Calcium carbonate appears sporadically in the first 0-60 cm as micro-nodules (< 1 mm Ø) located into the voids (some of which contain very fine veins of Fe oxy–hydroxides).

As a consequence of drainage, the gleization is relict, being emphasized by the presence of amorphous pedofeatures, mainly nodules (which seems to be rather strongly weathered skeleton grains).

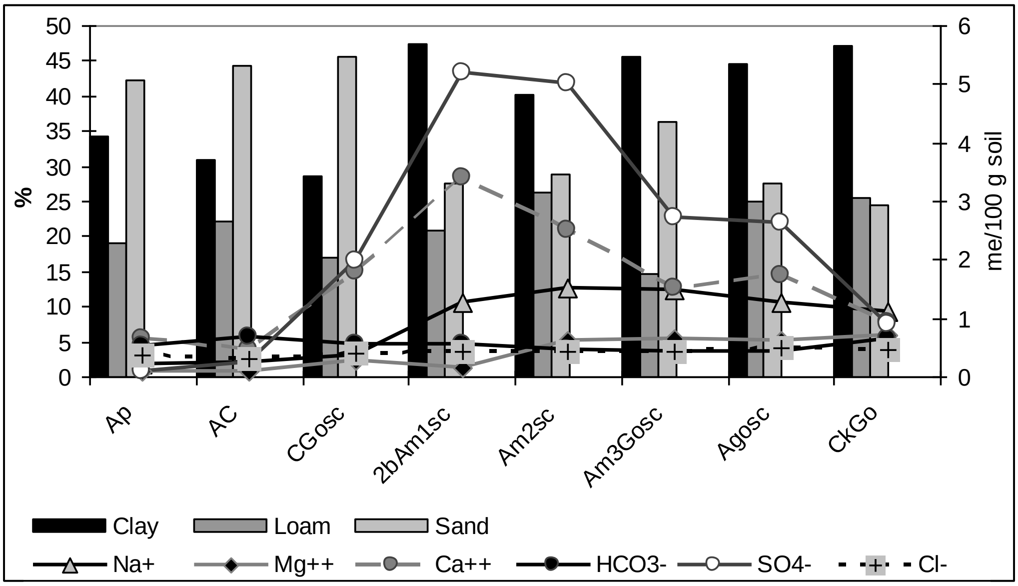

Figure 2: The particle size distribution and the dominant salts in the soil profile

2.2. The buried soil (Chernozem aluvic-salinic, with relict gleization – according to SRTS–2012)

This has a very well developed mollic epipedon (60–158 cm), the humus being very high, even higher than in the upper Aluviosol. This makes the structure well developed, with greater porosity, specific to the Am (A mollic) horizons.

The data of the particle-size distribution (Fig. 2) showed that buried soil is more clayey than the upper soil sequence. All the stratifications of the buried soil have the clay content over 40%, the texture being loamy-clayey and medium clayey-loamy.

Into the Am2sc (78–95 cm) and Am3Gosc (95–122 cm) horizons, some pedofeatures formed, featuring a more developed horizons: namely very fine feri-humo-clayey illuvial coatings deposited on the walls of few pores from Am2sc horizon (78-95 cm); and very fine illuvial coatings with good orientation of clay have been observed in some pores of Am3Gosc horizon (95-122 cm).

Under a higher magnification (16X), the illuvial coatings from Am2sc horizon (78–95 cm) are masked by the blackish organic plasma (very abundant in the horizon).

These pedogenetic characteristics highlight the evolution trend of the buried soil, while the presence of the illuvial coatings (both clayey and consisting of melanized organic matter) suggests that dry periods were longer than those with moisture excess.

The morphological observation in the field and their analytical data emphasized the presence of gypsum and salts (more easily soluble than gypsum), as well as of calcium carbonate.

Gypsum (CaSO4 • 2H2O) occurs from the top horizon of the buried soil, 2 bAm1sc (60–78 cm), in the form of lenticular crystal concentrations, well developed (rarely) and anhedral crystals (predominantly). The crystals habitus and the size of the crystals depend on the pore sizes and shapes, as well as on the speed of the crystal growth from the soil solution.

Gypsum rosettes (representing clusters of gypsum lenticular crystals) were also observed into the larger voids of the soil fragments (observed by the aim of stereomicroscope) and in the thin sections (observed by the aim of optical microscope).

Gypsum presence into the soil is also emphasized by the analytical data that showed SO42- values ranging from 0.10 me/100 g soil (in the top horizon) to 1.98 me/100 g soil (in the deeper horizon of the upper soil sequence). In the buried soil, the registered values decrease with depth: from 5.20 me/100 g soil (in 2bAm1sc – 60–75 cm) to 2.72 me/100 g soil (in the bottom profile).

Besides the gypsum, efflorescences of salts (more soluble than gypsum) were also observed in all the horizons of the buried soil, located on the pore walls.

The Na+ values (Fig. 2) are relatively low and decreased with depth in the upper soil (0.21 – 0.36 me/100 g soil), while into the buried soil, the values also showed a decreasing tendency with depth (0.28 – 1.47 me/100 g soil).

Cl- values (Fig. 2) are also relatively low, ranging from 0.37 to 0.39 me/100 g soil in the upper soil, while into the buried soil the values are a bit higher (0.42–0.51 me/100 g soil).

In this respect, the decreased order of the cations (Fig. 2) is Ca > Na > Mg, while the anion decreased order is HCO3- > SO42- > Cl-.

The presence of HCO3- in the higher quantity determined the increased of soil alkalinity, emphasized by the higher values of pH (7.72 – 8.28). The HCO3- anion formed with the bivalents cations undissociated salts that do not participated to the exchange reaction and decreased effective ionic concentration of the bivalents cations from the soil solution, which induce soil alkalinity.

Calcium carbonate has an ascending appearance, starting with 60 cm depth, after which it disappear and reappear at 160 cm depth. In terms of habitus, CaCO3 is micro- and cryptocrystalline and is present both in the soil matrix and in the form of small nodules. Besides these, micro-nodules were also observed in the bottom of soil profile, formed by sparite, which appear to be substitutions/re-crystallizations of some shell fragments.

The analytical data also showed low content (3.2%) of calcium carbonate at 158–172 cm depth, which increased to 16.5% into the bottom soil profile (172–210 cm).

The relict gleization is emphasized by the presence of amorphous pedofeatures, mainly nodules (formed by Fe ◎ Mn ◎ melanized organic matter) and sporadically concretions, either intact or strongly fragmented.

The current pedogenetic processes that influence the development of this soil profile (consisting of two overlapped soils – bisecvum) are those of the attenuation of the characteristics inherited from the parental material and those which oriented the pedogenesis throughout the formation of the zonal soil.

Land reclamation works maintain the tendency of salts to invade the entire profile at a level that does not affects the development of the crop roots.

Conclusions

The study of the polyphasic evolution of a saline soil leads to the following conclusions:

- The studied soil is a bisecvum consisting of an Aluviosol which covers at 60 cm a Chernozem.
- Even after cultivation and irrigation, the characteristics inherited from the parental material are still present into the upper Aluvial soil profile.
- Calcium carbonate appears sporadically in the upper Aluvial soil; and more abundant in the bottom part of the buried soil.
- Gypsum ($CaSO_4 \bullet 2H_2O$) occurs only into the buried soil.
- Efflorescences of salt (more soluble than gypsum) were also observed in all the horizons of the buried soil.
- At present, the pedogenetic processes mitigate the un-uniformity inherited from the parental material and oriented soil development throughout the formation of the zonal soil.

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