

Changes in micromorphological features of semidesert soils in the southeast of European Russia upon the recent increase in climate moistening

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Abstract

In the past 30 years, a definite trend towards an increase in climatic humidity and a rise in the groundwater table has been observed in the southeast of European Russia. Stationary studies at the Dzhanybek Research Station in the north of the Caspian Lowland prove that these climatic changes have been reflected in soil microfeatures. A comparison of soil thin sections taken in different times: in the 1950s, 1960s, 1970s, 1982, and 2002 from the same soils has been performed. No considerable changes in the soil properties took place in 1950s through 1970s, when the climatic parameters were relatively stable. From 1982 to 2002, when a significant rise in the climatic moistening and in the depth of the groundwater took place, certain changes in the soil microfeatures took place. These include the activation of humus accumulation and biogenic structuring, the eluviation of the silty clay-humus matter, the development of solodic features, gleyization of the soil mass, and the accumulation of coal-like particles. In the case of salt-affected soils, the development of hydrogenic accumulations of gypsum and carbonates took place.

Key Words

Climate change, soil forming processes, hydromorphic features, biological activity, decalcification

Introduction

In the European part of Russia, the driest landscapes are found in its southeastern part. Geomorphologically, this area is delineated as the Caspian Lowland, an ancient accumulative plain of marine genesis. Geobotanically, it belongs to the subboreal desert steppes and northern deserts (Safronova 2002). Since the end of the 1970s, an increase in the degree of climatic moistening has been observed in the southeast of European Russia (Sotneva 2004; Sapanov 2007). In absolute values, these changes are not very considerable: annual precipitation has increased by 50 mm, and the potential evaporation during the summer season has decreased by 70 mm. However, arid and semiarid ecosystems are very sensitive to such changes. Under conditions of a generally low natural drainage, the increase in climatic moistening leads to a simultaneous rise in the groundwater level (Sokolova *et al.* 2000; Sapanov 2007) (Figure 1). These changes have already been reflected in the character of vegetation in the northern part of the Caspian Lowland. The results of geobotanical research at several key plots demonstrate an increase in the portion of mesophytic species (Novikova *et al.* 2004). What are the effects of the increased moistening of the climate and the rise in the groundwater level on the soils? In this paper, we try to estimate them on the basis of micromorphological data obtained at the Dzhanybek Research Station of the Russian Academy of Sciences in different years.

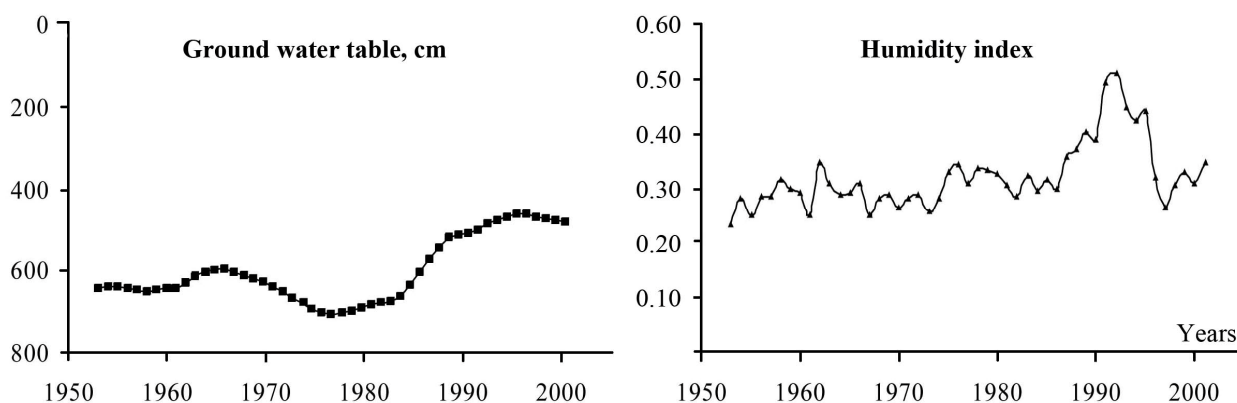


Figure 1. Dynamics of the groundwater table and humidity index in the northern part of the Caspian Lowland. The values have been smoothed by the moving 5-year averages (Sapanov 2007).

Materials and methods

The Dzhanybek Research Station is found in the northern part of the Caspian Lowland on the Volga–Ural interfluvium with absolute heights about 26–28 m a.s.l. This is the area with the semiarid subboreal climate. Annual precipitation is about 250–350 mm, and potential evaporation reaches 1000 mm. The entire territory is a virtually non-drained flat composed of homogeneous heavy loams of the Khvalyn (Late Pleistocene) transgression of the Caspian Sea. The groundwater table at the beginning of the 21st century is found at the depth of 4–5 m (Figure 1). The soils are developed from the brown loesslike calcareous loams underlain by clays with interlayers of sands at the depth of more than 15 m.

Local soils and vegetation have complex patterns related to the redistribution of precipitation (mainly, snowmelt runoff) by the elements of the well-pronounced microtopography (Rode and Pol'skii 1963). The microhighs with a relative elevation of up to several decimeters receive only atmospheric precipitation; the soil thickness under them contains a considerable amount of salts. These elements are occupied by solonchakous solonetztes under sparse semidesert vegetation (Figure 2). The presence of the solonetzic (natric) horizon with a very low water permeability specifies the nonpercolative soil water regime and the absence of salt leaching. Salts precipitate from the soil solutions in the subsurface horizons. At the depth of 20–30 cm, the content of soluble salts reaches 1.5–2.5%. The accumulation of calcium carbonates is observed below the solonetzic horizon, in the layer of 30–50 cm (6% CaCO₃). The gypsum content in the layer below 30 cm reaches 3–6%. The humus content is low (<2%). Saucer-like local microlows receive additional water owing to the surface redistribution of precipitation. Dark-colored chernozem-like soils with a periodically percolative water regime are developed in the microlows under forb–grassy steppe communities. These soils are free from soluble salts and gypsum; the accumulation of carbonates is seen from the depth of 50–70 cm (up to 5–6% CaCO₃). The humus content reaches 4–6%. On the microslopes between microhighs and microlows, light chestnut soils with different degrees of solonetzicity are developed under *Agropyron–fescue* dry-steppe associations.

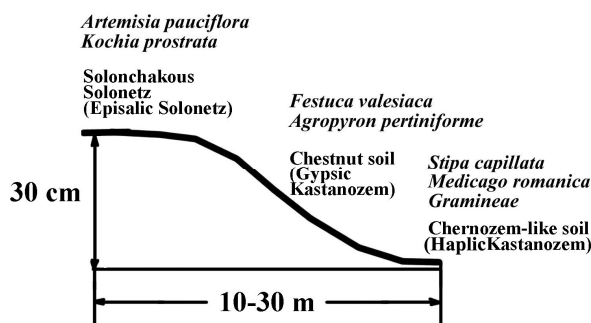


Figure 2. Soils and vegetation along a typical microcatena in the Dzhanybek area. Soil names according to the WRB system (2006) are given in parentheses.

A comparative study of the microfabrics of solonetztes and chernozem-like soils was performed on the basis of thin sections prepared from undisturbed micromonoliths of the main genetic horizons (Gerasimova *et al.* 1992; Stoops 2003). Samples taken in 1982 and 2002 were obtained from the same soils in the pits located at very close distances (<30 m) from one another. Micromorphological descriptions of soils of the station for the earlier periods were taken from the works of Pol'skii (1958), Yarilova (1966), and Tursina (Bazykina 1978).

Results

Soil micromorphological features in the period of the relatively stable climate (1950s–1970s)

This period was characterized by the stability of micromorphology of solonetztes and dark-colored chernozem-like soils. The latter soils had the high content of clayey-humus plasma in the upper horizon, the high compactness of angular blocky aggregates, the high interaggregate porosity in the middle-profile horizons, and the even distribution of micrograined calcite and high compactness of the silty-plasmic material in the lower-lying calcareous horizons.

In the solonetztes, the uppermost horizons had the low content of peptized humus-clayey plasma and plant debris; their platy peds had no intraped differentiation of plasma. The solonetzic horizons had a typical angular-blocky structure with an increased content of clayey plasma and a relatively small amount of thin clay stress cutans on ped faces. The subsolonetzic horizons had the high inter- and intraggregate porosity and

the specific rounded aggregates. The pores in the lower-lying gypsiferous horizons contained dense infillings composed of very fine (0.02 mm) lens-shaped and irregular-shaped gypsum crystals. These infillings were also preserved during the next period.

Soil micromorphological features in the period of changing climate (1982-2002)

In the **dark-colored chernozem-like soil**, a general increase in the degree of biogenic aggregation and in the amount of plant tissues of different degrees of decomposition took place. This attests to the enhancement of humus accumulation processes and is related to a greater phytomass production and a higher activity of the soil biota in the comminution and transformation of plant residues and the soil structuring. An increase in the density of forb–grassy vegetation specifies the rise in the soil porosity and some loosening of the middle-profile horizons with the development of specific pedogenic structure. The increasing porosity of the middle-profile horizons favors the leaching of carbonates under conditions of a more pronounced percolative water regime of the soil. The processes of decalcification are diagnosed by the appearance of carbonate-free zones around intraped pores in the middle-profile horizons. The high degree of optical orientation of clayey plasma in the middle-profile horizons of the chernozem-like soil should be noted. It may be due to the recent physicomorphological processes, or be inherited from the former stage of the enhanced salinization. A common micromorphological feature typical of both the dark-colored chernozem-like soil and the solonchakous solonetz is the abundance of fine-dispersed charred plant tissues (coal-like particles). Their formation takes place upon incomplete mineralization of plant tissues under conditions of the increased surface hydromorphism related to the recent rise in precipitation.

In the **solonetz**s, the following changes took place in the recent past (1982–2002). In the above-solonetzic horizons: (1) the content of clay particles somewhat decreased; (2) the amounts of plant tissues of various sizes, flocculated humus particles, and iron concentrations increased; (3) an indistinct platy structure was transformed into a clearly pronounced lens-shaped structure with a definite differentiation of particles within the lens-shaped aggregates (with the accumulation of clay particles at their lower sides at the expense of clay depletion from the upper parts of the aggregates); and (4) recent gypsum concentrations appeared around the roots. In the solonetzic horizons: (1) the content of clayey plasma somewhat increased, (2) the angular blocky structure became more pronounced, and (3) the degree of optical orientation of the clayey plasma in the intraped mass increased. At the same time, no fresh illuviation clayey coatings appeared on pore walls. In the saline subsolonetzic horizons: (1) the degree of compaction of the pseudosandy salt-bearing material increased, (2) the degree of the soil impregnation with fine-grained calcite (micrite) increased, and (3) the amount of gypsiferous infillings in the pores also increased, and the gypsum crystals became larger (Figure 3).

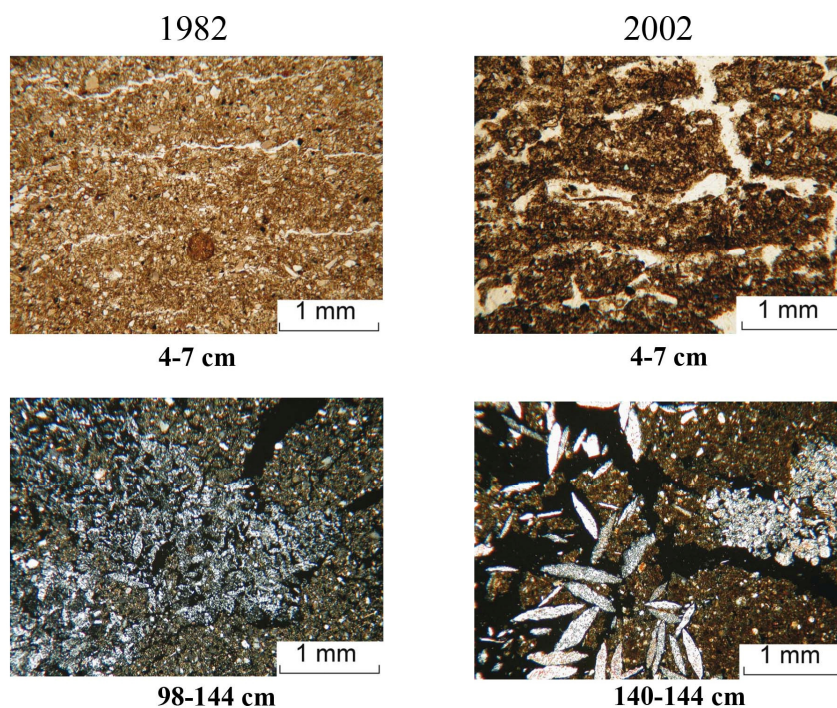


Figure 3. Enhancement of the accumulation of humus and biogenic aggregation in the surface horizons (upper line, N II) and of the hydrogenic accumulation of gypsum (the appearance of large gypsum crystals) in the lower horizons (lower line, N X) in the solonetzs during the 20-year-long period (1982–2002).

Conclusion

The revealed changes in the microfabrics of studied soils make it possible to assess the trends of pedogenic processes related to the recent rise in the atmospheric precipitation and in the groundwater table. In 1982-2002, the activation of humus formation, biogenic structuring, eluviation of silty-clay-humus matter, solodic process, gleyization, and accumulation of coal-like particles (charred plant detritus) took place. In the solonetzic horizons of solonetztes, some re-organization of the clayey coatings with their inclusion in the intraped mass was observed. In the subsolonetzic horizons, the compaction of the pseudosandy salt-bearing mass, the accumulation of fine-grained calcite (micrite), and large gypsum crystals took place. The identified micromorphological changes are concordant with changes in the factors of soil formation observed in the last decades.

Acknowledgments

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References

- Bazykina GS (1978) The change in agrophysical properties of solonchakous solonetztes of northern Caspian Lowland due to amelioration. In 'Issues of Soil Hydrology and Genesis' pp. 5-31. (Nauka: Moscow).
- Gerasimova MI, Gubin SV, Shoba SA (1992) 'Micromorphology of Soils in the Main Natural Zones of the USSR'. (ONTI: Pushchino).
- Novikova NM, Volkova NA, Khitrov NB (2004) The vegetation of the solonetz complex in the protected steppe plot of the northern Caspian Lowland. *Arid Ecosystems* **10**, 9-18.
- Pol'skii MN (1958) Agrophysical properties of solonchakous solonetztes as the target of amelioration. In 'Scientific Bases for Land Improvement in Semideserts of Northwestern Caspian Lowland'. pp. 58-73. (Izd. Akad. Nauk SSSR: Moscow).
- Rode AA, Pol'skii MN (1963) The water regime and balance in the virgin soils of semidesert complex. In 'The Water Regime of Semidesert Soils'. pp. 5-83. (Izd. Akad. Nauk SSSR: Moscow).
- Safronova IN (2002) Phytoecological mapping of the northern Caspian Lowland. In "Geobotanical Mapping". pp. 44-65. (BIN RAN: Saint-Petersburg).
- Sapanov MK (2007) The synchronism in the changes of the Caspian Sea level and ground water table in the northern Caspian Lowland in the second half of the XXth century. *Izvestiya RAN. Geographical Series* **5**, 82-87.
- Sokolova TA, Sizemskaya ML, Sapanov MK, Tolpeshta II (2000) Variations in the content and composition of salts in the soils of the solonetzic complex at the Dzhanybek Research Station during the last 40-50 years. *Eurasian Soil Science* **33**, 1166-1177.
- Sotneva NI (2004) The dynamics of climatic conditions at the Dzhanybek Research Station in the northern Caspian Lowland in the second half of the XXth century. *Izvestiya RAN. Geographical Series* **5**, 74-83.
- Stoops G (2003) Guidelines for Analysis and Description of Soil and Regolith Thin Section, 184 p. (Soil Science Society of America: Madison, Wisconsin, USA).
- Yarilova YeA (1966) The peculiarities of micromorphological features of solonetztes in the chernozemic and chestnut zones. In 'The Micromorphological Method in the Research into Soil Genesis', pp. 58-75. (Nauka: Moscow).