The Development of Chernozems on the Dniester—Prut Interfluve in the Holocene

F. N. Lisetskii, P. V. Goleusov, and O. A. Chepelev
Belgorod State National Research University, ul. Pobedy 85, Belgorod, 308015 Russia
E-mail: liset@bsu.edu.ru
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Abstract—The development of forest-steppe and steppe chernozems on the Dniester—Prut interfluve in the Holocene was studied on the basis of data on the paleosols buried under archaeological monuments of different ages. The parameters of the mathematic models of the development of the soil humus horizons in different subtypes of chernozems were calculated. They were used to determine the rate of this process and the age of the soils formed on the surface of Trajan’s lower rampart. The climate-controlled changes in the character of the soil’s development in the Late Holocene were differently pronounced in the different subtypes of chernozems. The suggested differentiation of the trends in the development of the humus horizon in the studied chernozems corresponds to the differences in the soil-forming potential of particular areas (as judged from the energy consumption for pedogenesis).

Keywords: soil and time, rate of pedogenesis, models of soil development, soil chronosequences chernozems, archaeological monuments of the Holocene monuments, the Holocene, soil chronosequences, soil chronofunctions
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INTRODUCTION

As stated by the European Thematic Strategy for Soil Protection [45], the climate changes recorded in many parts of the world during the period of instrumental measurements pose certain risks for soils and the environment and may intensify the processes of soil degradation. The soil—climatic interactions in the ecotone areas, including the transition between the forest-steppe and steppe, are of particular interest.

The Dniester—Prut interfluve is found on the southwestern part of the East European Plain. The genesis and geography of the soils in this vast area have been studied in detail in Moldova [22, 38] and the Trans-Dniester part of Odessa oblast in Ukraine [35, 43]. However, the history of the pedogenesis in the Holocene and the rates of the particular soil processes in this region are insufficiently studied.

The first results of the regional pedochronological investigations were obtained for Trajan’s ramparts—a fortification system, some part of which (the rampart and the ditch) is still well preserved. In different years, special pedogenetic studies were conducted on Trajan’s lower rampart (LTR) along three segments: near the Prut River (not far from the Kolibash settlement [21]), to the east of the settlement of Vadul-lui-Isak [17], and near the western shore of Lake Sasyk [11]. The LTR’s length reaches 126 km, so we can compare the newly formed soils on the top of the rampart with the different background soils, including ordinary [21], calcareous [17], and southern [11] chernozems. The composition of the microelements in the buried soils in the steppe (under the LTR) and in the forest-steppe (under the Kopach kurgan constructed about 4000 years ago) was examined [9]. The soil buried in the third century BC was studied in the area of the ancient settlement of Kodry [1]. The soil buried 2350 ± 50 yrs ago (cal. 2400 ± 50) was investigated under the LTR in the upper reaches of the Dniester, and the soils formed in the area of the antique town of Nikonii were also studied [27]. In recent years, newly formed and buried soils have been studied on the right bank of the Zbruch River in Ukraine (the rampart under which these soils were buried is also called Trajan’s rampart) [12].

The paleogeographic reconstruction of the climate changes on the basis of the spore—pollen diagrams obtained for twelve settlements of the Neolithic and Eneolithic (Copper Age) periods [20] has shown that the phase of the Holocene climatic optimum in in the forest-steppe of the Dniester—Prut interfluve was in the Late Atlantic—Early Subboreal period (6000–4200 yrs ago). The most considerable aridization of the climate occurred 4200–3700 yrs ago, and better climatic conditions were established in the Late Subboreal Period (3300–2800 yrs ago).

In the Holocene, the studied region was subjected to considerable climate fluctuations accompanied by corresponding changes in the character of the pedogenesis. The complicated history of the development of human cultures with specific impacts on soils also has to be taken into account.
We studied the surface soils of different ages developed on the archaeological monuments within the Dniester–Prut interfluve in order to reveal the climatic conditions of their development in the Late Holocene.

OBJECTS AND METHODS

Field investigations were performed on the Dniester–Prut interfluve, a part of the Danube–Dniester interfluve in Moldova, and in the southwest of Ukraine. According to the soil-geographical zoning, this region is specified into three provinces: the northern Moldavian forest-steppe province (39% of Moldova), the southwestern province of the northern steppe, and the Danube province of the southern steppe (Fig. 1).

The specific features of the forest-steppe chernozems in Moldova are mainly related to the climatic conditions of this region: this is the most strongly moistened and the coldest part of Moldova. The zonal vegetation is represented by oak forests and rich meadow steppes. Ordinary chernozems of the warm facies (with the mycelial form of carbonate accumulations) are formed in the Trans–Dniester part of Odessa oblast and on the southern branches of the Southern Moldova Upland. The Danube province of the warm southern European facies of chernozems is specified by the very dynamic (pulsating) carbonate accumulations, the strongly varying depth of the effervescence, the high clay content in the upper soil horizons, the high biological activity and intensive mineralization of the organic debris, and by the considerable biological transformation of the soil mass [35].

The modern chernozems of Moldova represent the final (for the present time) thirteenth stage of the pedogenesis in the Quaternary period. The climate of this stage is generally similar to the climate of most of the previous stages. This conclusion is based on the results of the study of loess–paleosol sequences in the Danube reaches in Moldova, where twelve buried paleosols of the Pleistocene are distinguished in the 30-m-high sediment column; all of them are of the chernozemic type [47].

It should be noted that the soils on the Dniester–Prut interfluve have been subjected to anthropogenic influence long ago. The optimum moistening of this territory in the southwestern part of the Russian Plain favors the formation of forest vegetation; however, the economic activity of humans favors the considerable transformation of the forest vegetation.

It is supposed that the earliest agriculture in Europe appeared in the Balkans in the middle of the 7th millennium BC; in the area of modern Romania and Moldova, the first farmers appeared about 8000 yrs ago [33, 37].

Paleobotanical investigations in the Neolithic and Eneolithic settlements on the Dniester–Prut interfluve [44] have shown that the native farmers used cereals, which were transported from their initial source in Middle Asia via the Balkans in the 6th millennium BC. In the southern part of Moldova (in the deposits of the Yalpuh floodplain), the first clear traces of the farming activity date back to the end of the Atlantic period (AT-3): 5550 ± 70 yrs ago (cal. 6400 ± 70 yrs ago) [6].

The historical-cultural individuality of the separate regions on the Dniester–Prut interfluve should be noted. The anthropogenically disturbed surfaces and soils of these regions have different ages. Thus, the monuments of the Linear Pottery culture (6th–5th millennium BC) are found in the forest-steppe zone in the central part of Moldova. The monuments of the Bug–Dniester culture (from the middle of the 6th to the beginning of the 4th millennium BC) are only found in the upper reaches of the Dniester River, whereas the monuments of the Tripolye (Cucuteni–Trypillian) culture (5400–2750 BC) are present to the north of Chisinau (530 and 123 ancient settlements belonging to this culture are known in the forest-steppe areas of Moldova and Odessa oblast, respectively). The distribution patterns of the archaeological monuments of different ages in the subzones of ordinary and southern chernozems are generally similar, though some differences should be noted. In the Eneolithic Period (4th–3rd millennia BC), the Gumelnitsy crop farming and stock breeding tribes developed the land in the modern Odessa oblast near the Danube River. There were more than 230 settlements in the Trans–Dniester region of Odessa oblast in the Bronze Period, and 66% of them were in the subzone of southern chernozems. Many antique settlements (from the 6th century BC to the 4th century AD) appeared near the Dniester estuary and in the lower reaches of the Danube River. Younger monuments of the Balkan–Danube culture (the 10th–11th centuries AD) are found in Budzhak oblast (an historical oblast on the Danube–Dniester interfluve near the Black Sea). Monuments of the Golden Horde Period (the 13th–14th centuries AD) are also present in this area.

We studied six archaeological objects (ancient settlements) in the forest-steppe zone, 25 archaeological monuments in the steppe zone, and several plots at Trajan’s and Zmiev ramparts (Fig. 1). The names of the archaeological monuments are given according to manuals [2, 8]. New soils are mainly developed from pedolithic sediments—cultural layers overlying the background natural soils—one grassy steppe vegetation.

The organic carbon content in the soil samples was analyzed by Tjurin’s method; the group composition of the humus, by the method of Kononova and Bel’chikova; the total nitrogen (N) content, by Kjeldahl’s procedure; the CO₂ of carbonates, by the acidimetric method; the available phosphorus, by Machigin’s method; and the soil particle size, by the pipette method.