EVOLUTION OF KNOWLEDGE OF VIRGIN AND ARABLE FOREST SOILS IN THE FOREST-STEPPE AREA OF THE REPUBLIC OF MOLDOVA

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Abstract

The evolution of the Grey and Brown forest soils genesis from the forest-steppe area of the Republic Moldova knows several hystyorical hypotheses that can be reunited in three groups: 1) primary formation of these soils as a special type, evolved under deciduous forests; 2) secondary formation following the degradation of chernozemic soils and the planting of woody vegetation on these surfaces; 3) their formation from virgin (natural) podzolic soils following the development of the process of substituting the woody vegetation with the grassy vegetation of steppe and meadow. According to recent research, Grey and Brown soils on the territory of the Republic Moldova are polygenetic soils and were formed as a result of going through different phases of pedogenesis: virgin grey and browns soils, formed under deciduous forests → arable grey and brown soils, formed after deforestation and the use of arable land → grey and bronw soils from the stage of evolution towards chernozems, under the secondary steppe vegetation, restored on the former agricultural lands, abandoned during the migration of peoples from east to west → arable leached (cambic) chernozems.

Key words: brown soils, gray soils, genesis, evolution, Republic of Moldova

The development of soil science at the international and national level, the progress of soil knowledge in recent times, determines the need to re-examine and clarify the principles and criteria of soil classification (both upper and lower level), focusing on their concrete properties and the obligatory correct assessment of the factors and processes of pedogenesis that led to the formation or modification of some or other properties.

From the point of view of pedology, life is the sequence of processes of formation and decomposition of organic matter, the intensity and direction of which largely correlate with climatic conditions (Вильямс В.Р., 1949; Florea N., 2005). So, the content and quality of organic matter in soils is one of the main indicators of their genesis, especially in steppe and forest-steppe conditions. The evolution and transformation of soils takes place as a result of the action of climate, biota and human activity. At the same time, it occurs in well-defined directions, the specificity of which is often conditioned by the composition of the parent rock. According to Роде А.А. (1984) two stages of soil evolution and the existence of two basic concepts corresponding to them can be highlighted: 1) soil self-development (ontogenesis) - its formation from the parent rock in conditions of relatively stable equilibrium of soil formation factors (climate, relief and anthropic factor; 2) the actual evolution - the transformation of the mature soil under the influence of the changes of pedogenesis factors.

At present, there are discussions regarding the methods of improving the classification of soils according to their present properties, taking into account the soil formation processes or according to the pedogenesis factors (Полупан Н.И., 1986). When preparing the soil classification, it is necessary to take into account the properties, processes and pedogenesis factors, which corresponds to Dokuceaev's triad (1950): factors - processes - soil profile. The combined method of elaboration of soil classification is characteristic of the Russian naturalistic classification and this classification system best reflects the connection between soils of different taxonomic level (Cerbari V., 2001) and the environmental conditions and their use in the agriculture (Cerbari V. and Leah T., 2020).

The radical change of the concept of classification, nomenclature and scientific notions regarding soils, often makes it impossible to use the materials of previous pedological research. The transition to a completely new classification is not rational. For these reasons, it is currently planned to collect, systematize, analyze and evaluate

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archival and current materials for use in improving the soil classification and grading system. However, it is appropriate that the taxonomic units of soils in the national classification be harmonized with other classifications: Romanian soil taxonomy system SRTS-1980 and SRTS-2000 (Florea N., Munteanu I., 2003), the FAO UNESCO classification in the Legend of "World Soil Map" (1990) and the World Reference Base of Soil Resources (WRB-2006, WRB-2014), as well as to use some standards of these classification systems for the soils of the Republic Moldova. As a result, it was decided that the soils at the type level should be renamed: Brown soils → Brownzems; Grey soils → Greyzems.

MATERIAL AND METHOD

The paper describes formation of the grey and brown soils, virgin and anthropically modified from the forest-steppe of Northern, Central and Southern Moldova.The properties of these soils were evaluated based on the research materials of pedological cartography, carried out in the last 30 years by the Institute of Pedology, Agrochemistry and Soil Protection "Nicolae Dimo". When conducting research in the field, laboratory and office, the research methods and criteria for evaluating soil properties published in several sources were used (Florea N., *et al,* 1987; Monitoringul..., 2010; Self-evaluation guide, 2018; Cerbari V., 2008; Егоров В.В., *et al,* 1977; Теории и методы физики почв, 2007; Мировая реферативная база ..., 2018).

The characteristic of the properties of the grey and brown forest soils was performed based on the data obtained for the soil profiles researched for different purposes in the 2007-2020 period on the Northern Moldavian Plateau and the Dniester Plateau. In 2007, the virgin and arable greyzioms were researched on two monitoring polygons (arable greyziom and virgin greyziom), located on the Northern Moldavian Plateau (Edineț district) with semi-temperate climate (humidity coefficient after Ivanov-Vashotsky, K = 0.7-0.8). In 2020, the virgin and arable greyzems from the northwestern part of the Plateau (Briceni) and from the Nistru Plateau (Rezina) formed in conditions of practically humid temperate climate (K = 0.9-1.0). were researched.

The north-western part is characterized by absolute heights within 242-284 m and a wetter climate than in the other administrative districts, located on the plateau in its central and southern part. The Dniester plateau, being in direct contact with the Eastern European plain, is characterized by a more continental climate, colder and absolute heights in the limits of 271-351 m.

RESULTS AND DISCUSSIONS

According to the Legend of the World Soil Map, FAO UNESCO (1990) soils named in the Republic of Moldova – Grey forest soils have been renamed Greyzems. These soils, initially formed under forest vegetation (regardless of their current use under forest or arable land) are spread on the Northern Moldavian Plateau and on the Dniester Plateau. Small areas of these soils can be spread on the „Codrii" Plateau and other heights. The spread of these soils can be appreciated, more precisely, in the process of conducting large-scale pedological research in the field and laboratory. The study of the genesis of grey soils is associated with the names of Докучаев В.В. and Коржинский Д.С., quoted by Виленский Д.Г. (1957); Вильямс В.Р. (1949); Талиев В.И. (1992); Тюрин И.В. (1930).

Dokuceaev determined the greyzem as a zonal type of soil formed in the climatic and vegetation conditions characteristic for the forest-steppe zone (Докучаев В.В., 1949). The formation of three subtypes of greyzems explained by Dokuceaev is manifested by the gradual decrease of the influence of the podzolic process of pedogenesis from north to south, from the area of coniferous forests with podzolic soils to the area of deciduous forests. The scientist highlighted the following soil subtypes: "light grey northern soils and grey (transitional) soils". In the last group of soils Dokuceaev included dark grey soils, recently called in the Republic of Moldova typical grey and molic grey (Ursu, 2011).

The hypothesis put forward by Коржинский Д.С., quoted by Виленский Д.Г. (1957) predicts the secondary origin of grey soils as a result of the oscillation of the southern and northern boundary of the forest-steppe and the manifestation of degradation and progradation of grey soils. At present, it has been proven that these oscillations did take place, but they were not large and influenced the progradation (Lupașcu Gh., *et al,* 1998) or the regradation of soils on relatively small surfaces.

The theory of genesis of greyzems was also developed by Талиев В.И. (1992), who assumed that the grey soils came as a result of the progradation of podzolic soils under the influence of grassy meadow and steppe vegetation. The massive existence of the progradation of chernozems in the grey soils was noted in the work *"The oscillation of the boundaries between the forest and steppe in the Holocene"* (Гроссет Г.Э., 1961; Хотинский Н.А.,1986).

Greyzems were formed as a result of the natural intercalation of the secondary podzolic process of pedogenesis under the action of

microorganisms with the chernozemic process of humus formation under grassy vegetation (Вильямс В.Р., 1949).

Thus, regarding the genesis of Greyzems (grey soils) within the forest-steppe of Moldova, several hypotheses were exposed:

- primary formation as a special type of soil, developed under deciduous forests (Докучаев В.В., 1949).
- secondary formation following the degradation of chernozem soils and the planting of woody vegetation on these surfaces (Виленский Д.Г., 1957).
- their formation from virgin (natural) podzolic soils following the development of the process of substituting woody vegetation with steppe and meadow grassy vegetation (Вильямс В.Р., 1949).

According to the Russian Pedological Dictionary (Роде А.А., 1984), the "*podzolic process*" means the alteration (decomposition) of primary and secondary minerals under the influence of microorganisms, organic acids formed by the decomposition of organic residues, and the movement of decomposition products, mainly in the form of solutions and partial in the form of colloids at the bottom of the soil profile or it outside. The definition of the podzolic process of pedogenesis is analogously presented in the World Reference Base of Soil Resources, WBR-2014.

The authors are of the opinion that the following processes participate in different proportions in the formation of the profile of grey and brown soils: podzolic, *"in situ"* alteration, (cambic) and leaching. Under conditions of percolative or periodic percolative hydric regime, a soil profile is formed with eluvial horizon in the upper part and iluvial in the middle and lower part of these soils. The different correlation of the podzolic process, the leaching, the *"in situ"* alteration and the humus accumulation process leads to the formation of greyzems and brownzemas with different properties. In colder or wetter climates (humidity coefficient according to Ivanov-Vâsoțchii, K=0.8-1.0) under the deciduous forest the podzolic process becomes more intensive and a typical, rarely - albic greyzem is formed (Briceni, Ocnița, Edineți, Dondușeni, Soroca, Rezina, Șoldănești districts). In conditions of warm climate and moderate contrast (K = 0.7-0.8) in deciduous forests with developed grassy vegetation, typical greyzems are formed, rarely dark or molic (Ursu A., 2001).

In contrasting thermal conditions, characteristic of the loamy-sandy soils on the „Codrii" Plateau (altitude 200-400 m) and the clayey-loamy soils of the hilly periphery of the Codrii (altitude 170-200 m), brown soils are formed, mainly under the action of alteration process "in situ" and leaching.

Historically, it is considered that the best climatic conditions for the beginning of soil profile differentiation were formed in the Holocene between 6000-8000 years ago, characterized by comparatively humid and warm climate that led to the manifestation in the soils under the forests of the eluvial-gleyic process of Fe and Al migration (Александровский А.Л., 1988; 2006). It should be noted that the eluvial-gleyic process of Fe and Al migration on the profile of grey and brown soils in the Republic of Moldova often manifests itself in weak form and without an aggressive action of acidity (typical brownzems and greyzems) that or formed under the weak action or moderate acidity in the northern part of the forest-steppe zone. In some cases, the increased acidity in the AE horizon of the virgin grey soils under the deciduous forest forms conditions of pronounced manifestation and podzolic process (migration of soluble Fe and Al).

There is an obvious parallel between the factors of climate, vegetation and soil. In areas with a wetter climate, the processes of leaching, debasification and soil acidification, migration of colloids intensify (Mihalache M., 2014). On the areas with semi-temperate climate, a grassy steppe vegetation develops, which favors the formation of the chernozems. In areas with humid climate, the dominant vegetation is the forest, and the characteristic soil is greyzem or brownzem. Climatic factors, through the conditions of temperature and humidity, have the greatest importance in the process of formation and evolution of soils in the forest-steppe area, as they are related to the water and thermal regime of soils and the intensity of biological processes. The appreciation of the role of the physico-chemical processes that take place in the soil depends on the knowledge of the climatic factors characterized by the conditions of temperature and humidity (Хотинский Н.А., 1986). The influence of climatic conditions can be characterized by the annual humidity coefficient after Ivanov-Vâsoțchii (K), which is the ratio between the sum of annual rainfall and the amount of evaporability in the same time interval, which can have the following values:

- 1.0 - 0.7 - for forest-steppe;
- 0.7 - 0.5 - for the steppe;
- 0.5 - 0.3 - for the dry steppe area.

The contemporary soils of the forest-steppe of the Republic Moldova are mostly polygenetic, as they were formed by evolving through different phases of pedogenesis as a result:

- global climate change during the Holocene and the change in their results of vegetation types, biological processes of soil formation;
- the anthropic impact and its particularities in different periods of time and climatic zones on the evolution of soils;
- permanent invasions of nomadic peoples over the territory of Moldova for many centuries ago, deforestation, destruction of the local population of farmers and conversion of arable land, formed by deforestation, in meadows covered with steppe vegetation. Under the action of the secondary steppe vegetation, the soils have progressed into chernozems, because the climatic situation on the entire territory of the Republic Moldova corresponds to their formation (Крупеников И.А., 1967; 2008).

The beginning of the formation of the soil cover on the territory of Moldova refers to the border between the Pleistocene and Holocene. After this time, as a result of climate change and geographical areas, the soils of the forest-steppe of Moldova have gone through a series of development stages, which were most prominently reflected in their profile during the transition periods of areas, for example, from the cold steppe to the forest or from the forest to the semi-wet or semi-arid steppe. In the Middle Holocene (8000-4000 BC) or in the 6th-2nd millennium BC), in the warm and humid Atlantic period, the territory of today's Moldova was practically completely covered by deciduous forests. The cooling of the climate at the end of the Holocene (2nd millennium BC) and the anthropogenic factor led to the reduction of forest areas, the formation of forest-steppe and steppe areas (Александровский А.Л., Жариков С.Н., 1991).

An important role in the reduction of forested areas during this period was the deforestation of forests by humans and the use of land cleared from under the forest in agriculture. However, some secular forests, both in the area of grey soils and in the area of brown soils, on the Moldova's territory have been preserved until now.

The results of the research carried out on the territory of Orhei district are interesting for this reason (Адаменко О.М. *et al,* 1996). It was found that on this territory during the boreal period (9200-8000 BC) areas occupied by steppe vegetation predominated. In the Atlantic period (8000-4600 BC), as a result of the warmer and wetter climate, the surface of the forests expanded considerably and probably the whole territory of today's forest-steppe was forested. The subatlantic period (2500-800 BC) is considered a comparatively wet period of the Holocene. During this period in Central Moldova continues to expand the area of forests dominated by oak. At the same time, towards the end of this period, a decrease of the forested areas is observed as a result of the anthropic activity of centuries.

The "current" brown soils from the periphery of "Codrii" refer to the soils whose genesis is determined by the contrasting climatic conditions existing today in the respective place. Later, under the Holocene deciduous forest, it was closest to the surface, and this soil was named brown soil after its brown color (Адаменко О.М. *et al,* 1996; Гроссет Г.Э., 1961).

The researched soils in the hilly area of Codrii from Central Moldova, according to their morphological characteristics and color, largely coincide with the fossil soil, formed in the Holocene on this territory (Cerbari V., Lungu M., 2011; Cerbari V., *et al,* 2017). It can be assumed that these soils reached maturity in the subatlantic period, especially in the relatively short time segment of 700 years of cooling and humidification of the climate, during the so-called "short glaciation period" of XIII-XIX. Currently these soils are renamed brownzems (brown soils) by the authors of this work, and not grey, as they have been called so far by Грати В.П. (1975, 1977).

The intensive anthropogenic impact on the forest soils in the forest-steppe area of Moldova began in the middle of the 4th millennium, when the Cucuteni-Tripoli culture of farmers was established on the territory of Moldova, which lasted until the second millennium BC. After the second millennium and until the beginning of our era there was no permanent agriculture on the territory between the Prut and the Dniester, the nomadic population came engaged in livestock.

A revival of agriculture on this territory occurred from the beginning of our era and lasted until the fourth century, when Dacia was occupied by the Romans, and in the Crimea and the lands of the Black Sea coast was formed the state of the Ostgos. In the fourth century of our era (e.n.) the Huns destroyed the state of the Ostgos and all the native population on the territory of today's Moldova. Permanent agriculture on the territory between the Dniester and the Prut practically disappeared until the 14th century, when in 1350-1400 the principality of Moldova was formed (Xenopol A.D., 2006).

Greyzems and brownzems are polygenetic soils that were formed as a result of going through different phases of pedogenesis; after their use in agriculture they were abandoned during the great migrations of nomadic peoples.

According to recent research (Cerbari V., *et al,* 2017), these soils have gone through the

following phases (stages) of pedogenesis: 1) virgin greyzems and brownzems, formed under deciduous forests → 2) arable greyzems and brownzems, formed after deforestation → 3) greyzems and brownzems in the stage of evolution towards chernozems under the secondary steppe vegetation, restored on the former agricultural lands, abandoned from agriculture during the migration of nomadic peoples from east to west → 4) leached chernozems (cambic) arable.

In northern Moldova the most common are the typical greyzems. Illuvial horizons are formed as a result of the combination of the podzolic process with the alteration of the material of this horizon "in situ" (Рябинина Л.Н., 1968). The classification of the soils from central "Codrii" at the level of genus, species and variety of soil, allowed the agronomic grouping of the soils, the appreciation of their suitability for different use. Of particular interest is the description of stagno-gleyic phenomena located in the lower part of the profiles of some gray forest soils (Валтянский Д.М., 1979). Stationary research in lysimeters on so-called grey soils (territory of Ivancea commune, Orhei district) and brown soils (Codrii Plateau) in the forest and on the arable lands was carried out by Грати В.П. (1977).

It is necessary to mention that the research carried out later (Cerbari V., Lungu M., 2011) confirmed that the soils on the territory of Ivancea commune are brown and not forest grey, as Грати В.П. (1977) called them.

A basic task of current research has been to highlight the change in greys and brown soils as a result of arable use and change in the phases of pedogenesis. Anthropic transformation of soils is a major change as a consequence of substantial anthropogenic intervention on environmental conditions through land improvement works and, implicitly, on the process of pedogenesis as a result of mechanical interventions that strongly change the soil profile, due to improper use of the soil which led to the intensification of degradation processes (Leah T., Cerbari V., 2020).

CONCLUSIONS

On the Northern Moldavian Plateau and the Dniester Plateau the textural differentiation of the profile of greyzems and brownzems occurred under the action of the podzolic soil formation process as a result of the formation of aggressive acidity in the AE horizon of the soil, which largely ensured the process of mineral alteration of Fe and Al and their migration on the soil profile in the form of water-soluble organo-mineral compounds, in conditions of percolative or periodic percolative water regime of the soil during the warm period of the year.

Aridity and contrasting hydrothermal regime of the soils is the main cause of browzems formation under the deciduous forest. The predominantly weak textural differentiation of the brownzem profile takes place under the action of the "*in situ*" mineral alteration process and the weak leaching of the colloidal material, formed in early spring, in the short periods with percolative humidity regime.

Greyzems and brownzems can be divided by highlighting the process that dominates at the textural differentiation of their profile: spodosolification or argillic alteration "in situ" and leaching.

In the field, the grey and brown soils differ in the following: the typical virgin grey soils are characterized by a grey color of the eluvial horizon and a dark brown color of the illuvial horizon, as a result of covering the soil particles with organo-mineral films of iron chelates, carbonates are leached deeper 100-120 cm; typical virgin brown soils are characterized by brown-grey color of the eluvial horizon and brown or reddish-brown of the illuvial horizon, carbonates appear deeper than 70-100 cm.

ACKNOWLEGMENTS

The paper was developed within the State Program for 2020-2023: Project 20.80009.7007.17 "Assess-ment of soil condition of the Republic of Moldova in agrogenesis conditions, improvement of the classification system, development of the methodological-informational framework for soil monitoring and expanded reproduction of fertility (STARCLASSOL)". Stage of 2020: Study of the genetic peculiarities of brown and gray soils in natural and arable regime for the improvement of their classification system.

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