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DYNAMICS OF ECOLOGICAL AND AGRO-ECOLOGICAL INDICES (UNDER CONDITIONS OF PHYSICAL AND CHEMICAL DEGRADATION) OF SOILS RESEARCHED ON THE GENETIC HORIZONS

Olesea COJOCARU, Alina ABRAMOV

Technical University of Moldova, Faculty of Agricultural, Forestry and Environmental Sciences, 50 Mircesti Street, Chisinau, Republic of Moldova

Corresponding author email: olesea.cojocaru@am.utm.md

Abstract

The basic concept of land degradation, as outlined in different definitions, refers to the loss of real or potential productivity and utility of land and the decrease in its quality. Due to various farming methods that decarbonize soil and make it less robust and poor in nutrients, soil is being lost at a rate 10 to 40 times higher than it can be naturally replenished. From the above, many questions arise regarding the sustainability of today's agriculture on the territory of the Republic of Moldova and this is due to several reasons: loss of biodiversity, loss of land quality through the process of soil erosion, pollution from chemical fertilizers and pesticides administered inadequately, non-compliance with the employment contracts, etc. The main purpose consists in the comparative assessment of the indices modified by the agropedogenetic process of the soils evolved under natural and arable conditions, as well as their qualitative state in Tîrnova commune, Dondușeni district. Physical soil disturbance caused by anthropogenic activities, sometimes inappropriate, is a crucial factor in the conservation of soil quality, moisture availability and crop diversity in agroecosystems. However, the development of agroecological technologies and systems that emphasize the conservation-regeneration of biodiversity, soil, water and other resources is an urgent necessity for both urban and rural areas to cope with an increasing range of socioeconomic and environmental challenges.

***Key words**: agroecology, agropedogenetic process, degradation, genetic horizons, natural and arable soil.*

INTRODUCTION

At the beginning of the 21st century it was natural for many scientific researchers to analyse the past and emphasize looking to the future. The continuous destruction of the soil cover over large areas, the pollution of soils, the deterioration of their properties, etc., this is the result of human activity on vast stretches of agricultural land. The influence of man on the soil is manifested in three variants: the modification of only the regimes and/or properties of the soils, the transformation of the structure of the soil profile, or the simultaneous modification of the properties, regimes and composition. Changes in soil properties and regimes are diagnosed by analytical characteristics, soil morphology and, in most cases, by indirect factors such as changes in vegetation. With all the apparent variety of forms of anthropogenic impact on the soil profile (provided that it is completely or partially derogated from), there are only three possible options for modifying its structure: mixing the soil horizon, partial or complete removal of the profile, and unclogging the soil (Cerbari, 2001).

Today, however, we face a two-pronged challenge on the food production front: to increase production at a much faster rate than before to meet the demands of an ever-growing population, and to do so sustainably. The human population is expected to increase from the current 7 billion to approximately 9 billion by 2050 (UNEP, 2013).

As global demand for food, feed, and bioenergy crops increases, many agricultural systems deplete soil fertility, reduce biodiversity, and impact water resources. It is often forgotten that agriculture affects the basis of its own future through land degradation, salinization, over-extraction of water and reduced genetic diversity of crops and animals. These effects have been most severe in developing countries, where agricultural expansion has extended into areas that are not ecologically suitable for crop production. Thus, agroecosystem management is at a crossroads today. We are under serious pressure to increase system productivity to meet increasing needs on the one hand and maintain the sustainability of the production base on the other (Beddington et al., 2011).

The basic concept of land degradation, as outlined in various definitions, refers to the loss of actual or potential productivity and utility of land, and the decrease in its quality. It involves diminishing the inherent capacity of the land to produce economic goods and perform environmental moderating functions. The term is so broad that many land management problems such as desertification, salinization, soil erosion, declining soil fertility, deforestation, biodiversity loss and climate change are described as various facets or indicators of land degradation. However, there is unanimity of opinion that the consequences of land degradation are alarming: lower harvests, reduced availability of clean water, increased vulnerability of affected areas to climate change and, last but not least, food insecurity and poverty (UNCCD, 2011; UNEP, 2013). It is estimated that 12 million hectares of agricultural land, which could produce 20 million tons of grain, are now lost to land degradation each year, adding to the billions of hectares that are already degraded (Bai et al., 2008; Borlaug et al., 2004; Brown, 2007; UNEP, 2013). A rough calculation of current soil degradation rates suggests that we have about 60 years of topsoil left. Because of various farming methods that decarbonize soil and make it less robust and poor in nutrients, soil is being lost at a rate 10 to 40 times higher than it can be naturally replenished (What If the World's Soil Runs Out?).

A new stage in the history of land use appeared spontaneously and was part of a general systemic crisis of the economy of the Republic of Moldova. This fact, especially, was not predicted by agricultural science, therefore, many scientific developments focused on the centralized state management system proved to be of little use in the prevailing new economic conditions of agricultural production and lost their relevance, or needed significant adjustments. In the new economic conditions, a modern level of scientific support for land use is needed, based on the optimization of the relations between economic and natural systems. The agriculture of the Republic of Moldova is on the path of a revolutionary technological modernization dictated by the increase in the price of non-renewable energy resources and their derivatives (mineral fertilizers, including nitrogen, fuels, pesticides, agricultural techniques) in the conditions of the considerable negative impact of technologies based on excessive tillage on the environment, against the backdrop of increased frequency of droughts in recent years. Modern agriculture faces a number of challenges, including those related to climate change. We must recognize that not only climate change influences agriculture, but also vice versa (Boincean et al., 2020).

The influence of man on the soil is manifested in three variants: the modification of only the regimes and/or properties of the soils, the transformation of the structure of the soil profile, or the simultaneous modification of the properties, regimes and composition. Changes in soil properties and regimes are diagnosed by analytical characteristics, soil morphology and, in most cases, by indirect factors such as changes in vegetation. With all the apparent variety of forms of anthropogenic impact on the soil profile (provided that it is completely or partially derogated from), there are only three possible options for modifying its structure: mixing the soil horizon, partial or complete removal of the profile, and unclogging the soil (Cerbari, 2001).

The problem of classifying soils transformed under the influence of human activities appeared in the 30s, during the initial period of studying soil cultivation processes (Egorov, 1929; Karpinsky, 1933; Kachinsky, 1930; Krupenikov et al., 1987; Zakharov, 1936). Cultivated soils were classified mainly according to their degree of humification. The study of the genetic profile of cultivated soils was one of the first beginnings of N.L. Blagovidov (Blagovidov, 1954). He proposed the division of soils according to the following criteria: the thickness of the arable layer, the humus content and the main agrochemical indicators. At the same time, due to the increase in the scale of economic activity, the need to develop a classification of anthropogenically transformed soils has become more and more obvious. The classification principles proposed for cultivated soils were not very useful for soils with cardinal profile disturbances, those with radical changes in properties and regimes and, as a result, a change in the direction of soil formation processes.

According to the authors (Shishov et al., 2004), the classification position of anthropogenically transformed soils depends on the morphological structure of the profile and does not depend on the goals and mechanisms of influence. The transformation of natural soils into anthropogenic ones, according to the new classification, can occur in two fundamentally different ways: according to the first way - all typological horizons are completely or partially preserved in the soil profile; and after the second - the anthropogenic transformation of the soils leads to significant changes of the entire profile and the derogation of the typical natural signs.

The classification takes into account all the stages of soil profile transformations, respectively occupying different taxonomic levels in the general hierarchical system of natural and anthropogenically transformed soils (Cerbari, 2001, 2010; Ursu, 1995, 2006) provides for the priority of the background characteristics, therefore, at high levels the soils stand out with a new, different natural system of horizons.

A characteristic feature of all agricultural land soils is the presence of an anthropogenically transformed horizon. The properties of this horizon are different and depend to a greater extent on the nature, duration and intensity of anthropogenic impacts than on the structure of the original soils. The chemical properties of agricultural soils are diverse and depend on many factors. The physical parameters depend on the natural composition of the soils and the applied technologies. This makes it possible to identify such man-made profiles by analogy with natural soils with a similar structure. The presence of a deposit of natural mineral material with a low humus content on the soil surface with a thickness of less than 40 cm serves as the basis for distinguishing stratified soil subtypes into natural soil types. As a result of carrying out agricultural works, soils are sometimes completely or partially devoid of upper typological horizons (Cerbari, 2001; 2010).

Most of the ecological functions of soils are related to their organic matter content, reserves and quality. Humic substances play an important role in ensuring the high biological activity of soils, increasing the resistance between soil and plant to man-made impact. The state of humiferous imbalance of the soils with the factors that determine it, leads to its instability over time and, as a result, the variation of the parameters of the ecological functions. Among the external factors controlling the humus state of the soils, the changes in the parameters of the biological cycle of the plants and at the same time, the exchange of matter and energy are indicated. The density is directly related to the efficiency of the function of the soil organic matter, the moisture capacity, the aeration capacity, the exchange of moisture and aeration, the quality of the habitat of the soil organisms that perform the sanitary function. The optimal ranges of apparent density differ for soils with different granulometric composition through the distribution of soils at a certain range of density with structural variations. The permeability of the humiferous horizon is one of the important characteristics associated with the transport function in the soil layers, as well as the filtration coefficient and porosity (Cerbari, 2010; Ursu, 2006; 2011; 2016).

Soils acquire a morphological structure and properties that have no analogues among natural soils, which leads to a change in their classification position. The quantity and quality of soil property transformations and their morphology differ significantly depending on the level of agriculture, the set of field works and the technologies used. Practically everywhere and at any time, the involvement of the land in the agricultural circulation meant the cultivation of the soil, which was reduced to the following basic operations: derogation, loosening, compaction (in some places), leveling (Krupenikov, 1967; Kudeyarov, 2017) and led to the formation of an agricultural layer in arable and sub-arable horizons.

MATERIALS AND METHODS

The object of the study is the agro-ecopedological research of natural and modified soils as a result of human activity in

Tîrnova commune, Dondușeni district. Studies starting from 2020-2022, which were carried out by the author together with the collaborators of the Institute of Pedology, Agrochemistry and Soil Protection “Nicolae Dimo” on the main types and subtypes of soils spread on the agricultural lands in the researched area (Figure 1).

To identify the role and models of influence of the anthropic factor on soil formation, the potential of an interdisciplinary approach was used, integrating the capabilities of pedological, agroecological, historical sciences, as well as knowledge about the development of technologies and production tools in agriculture, and other types of human activities.

Figure 1. Spatial delimitation of Tîrnova commune, Dondușeni district
Source: https://earth.google.com/web/

During that period, observations were made through systemic physical-geographical methods of spatial positioning of the soil cover and the selection of key polygons in the location of the profiles. As an information base, archival materials available from the town hall of Tîrnova commune were used, covering a total soil surface of 4852 ha, namely: the soil cover, the file of previous pedological researches in different fields, etc.

The researched territory is distinguished by the originality of the ecological conditions that determine the specifics of the formation of a unique complex of the soil cover. The peculiarities of soil formation and evolution in Tîrnova commune take place under the influence of pedogenesis and anthropogenic factors.

In total, 8 soil profiles were placed to assess the thickness of the humiferous layer and 34 samples were taken from the genetic horizons, to determine the physical and chemical properties. The determination of the geomorphological indicators and the physical and chemical properties of the soil was carried out by the methods are presented below. Laboratory analyses were performed according to standard methods meeting the requirements of ISO 17025.

The analysis and determination methods applied were the following: - soil sampling: manual sampling method; - preparing the samples for analysis: by drying the soil samples; - hygroscopic water: by drying in an oven at $t=105^0C$; - granulometric composition: pipette method, soil preparation according to Kacinski, dispersion in $Na_4P_2O_7$ solution (Na pyrophosphate); - granulometric composition: Kacinski method; - density: pycnometer method; - apparent density: cylinder method; - porosity by calculation; penetration resistance: Golubeva penetrometer; - humus content: Tiurin method by burning (quantitative analysis); - the content of carbonates: the gas-volumetric method; - exchangeable calcium content: complexonometric method with trilon B, Tucker; - exchangeable magnesium content: ditto; - current reaction pH (H_2O): potentiometric method; - hydrolytic acidity me/100 g soil: Kappen method.

The comparative method, which consists in studying soil combinations of variable complexity and comparing them with soil-forming factors, including anthropogenic ones, was adopted as the main method in the study presented in the paper.

Through the characteristics of the pedogenetic factors and the key profiles investigated, we performed the diagnosis of anthropogenically transformed soils: composition, diversity, the nature of the relationships between the components, the degree of soil transformation under agricultural influence.

We specify that the diversity of anthropogenically modified soils depends on the amount of soil differences used compared to natural soils, the types and methods of agricultural activity and the technical means used. In anthropogenically transformed soils, signs of various origins are always found, both acquired at various stages of anthropogenic impact and inherited from natural soils.

As a result of a diverse combination of soil formation factors, which vary in a wide range, different soils were formed on the territory of Tîrnova commune, which differ in morphological structure, composition, properties, regimes, functions and ecological potential.

RESULTS AND DISCUSSIONS

In the Republic of Moldova (Ursu, 2016) the role of humus in soil pedogenesis and taxonomy is recognized (used in the classification of chernozems), but humus content is not limited by quantitative indices. In the process of pedogenesis, a chemical substance with a very complicated composition is formed and accumulated in the soil profile, which was called humus. This substance is formed as a result of the interaction of the soil crust with organic residues from the decomposition of organic matter.

The complexity of the structure of the soil cover, the diversity of the destructive influence of natural factors, the intensity of human activity determines the wide development of agricultural land degradation processes. 8 soil profiles were located and investigated in the north-western part of the hilly silvosteppe area of the Northern Plain, district 3 of the typical chernozems of the Bălți Steppe (Figure 2).

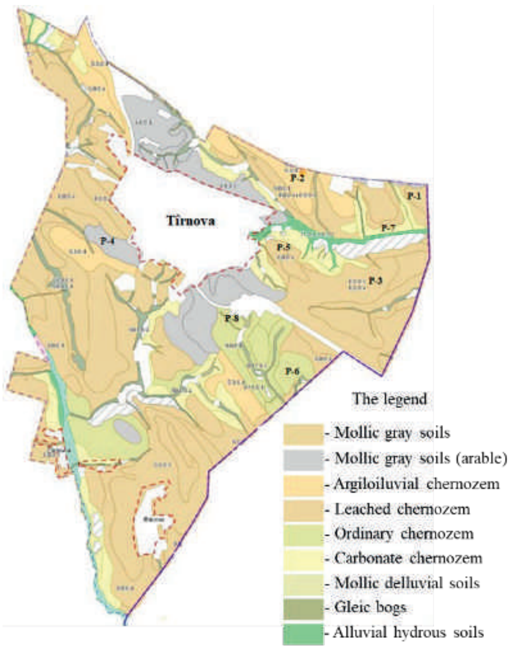

Figure 2. Map of soil types and subtypes with the location of soil profiles in Tîrnova commune, Dondușeni district
Source: Created by authors

Over time, these indices gave way to the taxonomic level, currently being taken into consideration in contemporary classifications. The problem lies in the fact that the humus content is dependent on many factors: phytocenosis (steppe, meadow, forest), grain size composition (clay, loam, sand), the way the soil is used (plantation, pasture, protection strip), the degree of degradation and the method of technogenetic transformation of reclaimed soils (erosion, ploughing, clearing, etc.).

This paper explores in detail the description of soil types and subtypes in Tîrnova commune, Dondușeni district, as well as the physical and chemical properties in ensuring the protection of agricultural crops and the maintenance of soil fertility in the future, with the aim of obtaining optimal harvests of good quality products. It is argued that since biodiversity-mediated renewal processes and ecological services are largely biological, their persistence depends on the maintenance of biological integrity and diversity in agroecosystems, ensuring the protection of crops and the conservation of exploited soil fertility. Physical soil disturbance caused by anthropogenic activities, sometimes inappropriate, is a crucial factor in the conservation of soil quality, moisture availability and crop diversity in agroecosystems.

The formation and evolution of soils in Tîrnova commune, Dondușeni district takes place under the influence of the natural factors of which they are a part: relief, parent rock, groundwater, climate, vegetation and animal kingdom. In the present time, human activity in agriculture has intensified. Deforestation, excessive use of arable soils on slopes has led to the increase of eroded soil surfaces, landslides.

The anthropic factor in combination with the natural conditions determines both the intensity and the direction of the solification processes, as well as the evaluation degree of the degradation processes of the soil cover of the municipality.

According to the geomorphological districting of the Republic of Moldova, the territory of Tîrnova commune is located in the northern part of the undulating plain of Bălți. As a solification factor, the relief represents the space on which the pedogenesis process takes place and influences soil formation both directly through the nature of the surface deposit, which results from the process of disaggregation-alteration, geological erosion and its age, and indirectly through the modification of local climate elements and especially the thermal regime and vegetation.

According to the agroclimatic districting of the Republic of Moldova, the territory of Tîrnova commune is part of the climatic district - 1A, which is characterized by a moderately continental climate with a short and comparatively warm winter, with a long and hot summer.

The climate of the commune is influenced by three types of major factors: solar radiation, the circulation of air masses and the underlying surface.

Tîrnova commune is located in the northern agroclimatic region. The sum of active temperatures (average daily temperature >10°) is equal to 2899°C, the amount of precipitation - 420-460 mm, the hydrothermal coefficient (CHT, the ratio of the sum of precipitation and the sum of positive temperatures, during the period with temperatures >10°) varies between 1.2-1.0, which ensures optimal humidity for agricultural development. But there is a trend of increasing air temperature in recent years, which indicates the occurrence of climate change. This would condition some impediments in crop growth.

Next, we present the succinct characteristic of the morphological peculiarities, composition and properties of the main types and subtypes of soils spread on the agricultural lands in Tîrnova commune.

Mollic gray soil (Profile 1): formed on water basins and slopes with a height of 240-250 m above sea level. The main genetic characteristic of these soils is the process of podzoling and humus accumulation. The effervescence from HCl-10% occurs in the transition horizon BC or in the parent rock C. Neoformations in the form of silicon oxide (SiO_2) occur in the lower part of the A horizon, sesquioxides in the form of mildew in the B horizon. In the upper part of on the profile parallel to the podzoling process, the leaching of the humus-iron films on the quartz particles in the lower part takes place.

The studied mollic gray soil is characterized by a profile of the type: *Ahp1-AEh-EBhtw-Btw-BCtwk-Ck.*

Ahp1 (0-10 cm) - humus-cumulative, wet, arable, dark gray color, glomerular-powdery structure, weakly compact, loamy-clay, contains many roots, slow transition to the next horizon.

AEh (10-30 cm) - light gray eluvial horizon with brown shades, wet, clay-depleted, weak eluvial, nuciform structure - glomerular, loamy-clay, porous, medium and fine pores, compacted, roots of grasses, trees and shrubs, contains quartz particles (SiO_2), clear transition to the next horizon.

EBhtw (30-56 cm) - transitional horizon from eluvial to illuvial, light gray with brown tint, wet, loamy-clay, clay-enriched, nut-prismatic structure, compacted, fine and small pores, tree roots, passage clear to the next horizon.

Btw (56-74 cm) - the clay-illuvial horizon, wet, dark brown with reddish shades, glomerular-nut-shaped structure, in the lower part prismatic, loamy-clay, weakly porous, fine and small pores, compact, contains quartz particles (SiO_2) and enriched with sesquioxides of Fe_2O_3, gradual transition to the next horizon.

BCtwk (74-104 cm) - transitional to the parent rock strongly modified by "in situ" alteration and illuviation processes, dry, light brown to yellow color, poorly developed structure, very compact, effervescence appears from HCl-10% being present white carbonates, loamy-argillaceous, contains iron concretions, clear transition to the next horizon.

Ck (104-160 cm) - parent rock, yellow color with very weak brown shade and white carbonate veins, structured, loamy-clay, weakly porous, very compact, contains iron concretions.

The thickness of the humiferous layer of soft gray soils is 74 cm, being considered with a moderately deep humiferous profile.

It is characterized by the following data of physical and chemical properties: the density on the profile is between the values of 2.51-2.71 g/cm^3, and the apparent density depends mainly on the degree of loosening of the soil and has values from 1.19-1.50 g/cm^3 being uncompacted on the surface and compacted in the adjacent horizons, the porosity varies between the limits of 57.8-39.1% v/v being very high on the surface and low in the transition horizon to the parent rock, the resistance to penetration varies with values between 10 kgf/cm^2 giving the possibility of normal penetration of plant roots and 23 kgf/cm^2 with a moderate limitation, the texture is loamy-clay homogeneous on the profile. The results of the undertaken research demonstrate that the resistance to compression and cutting of the soil increases as the soil moisture is reduced below 14% and decreases with the increase of its moisture to values above 28%. The humus content in the arable layer is 3.94%, and with depth it gradually decreases between the values of 3.64-0.83%. The sum of exchangeable cations in the arable layer is 25.2 me/100 g soil. Ca^{2+} cations predominate considerably over Mg^{2+} cations in a ratio of 3:1. The degree of saturation with bases is 86%. Carbonates are detected in the BCk passage horizon and Ck parent rock in amounts of 1.0-1.4%, but their maximum can be even more. The soil reaction in the upper horizons is neutral (pH = 6.9), and in the underlying ones weakly alkaline. Knowing the hydrolytic acidity of the soil is of particular practical importance for determining the soil's need for improvement, which is 4.0 me/100 g of soil, being considered low. The granulometric composition of the soil is loam-clay (47.70-44.76% physical clay fraction).

The following describes the post-forest arable soil, formed after the anthropic deforestation of the forest and its use for arable land.

The arable mollic gray soil, weakly eroded (Profile 4): is located on slopes with a slight inclination (4-6°). It was lost as a result of erosion up to half of the A horizon, being the most fertile and it has a humus-cumulative depth of 65 cm. It is characterized by the following data of physical and chemical properties: the density on the profile is between the values of 2.60-2.68 g/cm^3, and the apparent density depends mainly on the degree of loosening of the soil and has values from 1.3-1.61 g/cm^3 being uncompacted on the surface and very compacted in the adjacent horizons, the porosity varies between the limits of 49.9-39.5% v/v being medium on the surface and very low in the transition horizon to the parent rock, the resistance to penetration varies with values between 5 kgf/cm^2 giving the possibility of normal penetration of plant roots and 22 kgf/cm^2 with moderate and high compaction towards the depth, the texture is loamy-clay homogeneous on the profile with values of 52.07-77.69%, the humus content in the 0-30 cm layer varies between 2.51-1.67%, and in the post-arable layers it decreases to 0.94% in the 60-80 cm layer. Carbonates occur in the BCk and Ck horizons, with values in quantity of 1.8-17.4%, with maximum values in the parent rock. The reaction of the soil solution is moderately acidic, passing with depth from moderately alkaline to alkaline (5.6-8.6%). The hydrolytic acidity is 3.5 me/100 g of soil. The granulometric composition is loam-clay (52.07%) and clay-clay (in the parent rock 77.69% physical clay fraction). Such a texture is favourable for the growth of field crops and they have a high fertility, if the arable layer is theirs it is structured and loose. The work on the slightly eroded soft gray arable soil, loamy-clayey, is required to be carried out at the humidity that corresponds to its friable state (the state of humidity at which the soil crumbles easily). This type of soil is relatively resistant to drought as a result of the high capacity to accumulate water during the cold period of the year. However, the water regime of clay-clay soils with a compact arable layer is partially unfavourable. Therefore, the preventive recovery of the physical quality state of the destructured and compact arable layer is absolutely necessary to be carried out until the implementation of the agricultural system.

Argiloiluvial chernozem (Profile 2): formed under abundant grass vegetation that was replaced by forest vegetation after its destruction or deforestation. This soil is of polygenetic origin, formed in the process of solification under forest and steppe vegetation. The characteristic process of this soil is the accumulation of humus and podzolization of the profile. Effervescence is more commonly observed at the appearance of the parent rock.

Argiloiluvial chernozem is characterized by a profile of the type: *Ahp-Ah-Bht1-Bht2-BCk-Ck* (Figure 3).

Ahp (0-20 cm) - humus-accumulative horizon, arable, wet, gray-dark color with whitish shades from silicon oxide (SiO_2) particles, glomerular-powdery structure, loose, porous, loamy-clay, roots of in plants, clear transition by color and structure.

Ah (20-40 cm) - humus-cumulative horizon, the color is darker, almost black with whitish shades from the particles of silicon oxide (SiO_2), wet, glomerular-nut-shaped structure, the faces of the structural granules are glossy, poorly compact, fine pores, clay-loamy, roots from plants, transition to the next horizon clear by color.

Bht1 (40-60 cm) - argiloiluvial horizon, dark brown color, wet, glomerular-prismatic structure, the faces of the granules are glossy, compact, in the lower part on the brown tone black humus leaks from the Ah horizon (from the decomposition of the roots) can be observed, clay-loamy, clear transition to the next layer. This horizon is a relict of the pedogenesis stage of the soils under the forest.

Figure 3. Profile of argiloiluvial chernozem
Source: Created by authors

Bht2 (60-80 cm) - argiloiluvial, dark brown color, dry, glomerular-prismatic structure, compact, loamy-clay, clear transition to the next horizon.

BCk (80-110 cm) - transitional horizon, yellowish-brown color, dry, unstable nuciform-glomerular structure, loamy-clay, compact, very small pores, the presence of carbonates is observed, clear transition to the next horizon.

Ck (110-130 cm) - parent rock, yellow color with whitish tint from carbonates, dry, unstable structure, compact, loamy-clay.

The thickness of the humiferous layer of the argiloiluvial chernozem is 80 cm and is considered moderately humiferous.

It is characterized by the following data of physical and chemical properties: the density on the profile is between the values of 2.61-2.65 g/cm^3, and the apparent density has values from 1.22-1.43 g/cm^3 being loose on the surface and compacted in the adjacent horizons, the porosity varies between the limits of 53.1-46.2% v/v being high on the surface and medium in the transition horizon to the parent rock, the resistance to penetration varies with values between 5 kgf/cm^2 giving the possibility of normal plant root penetration and 20 kgf/cm^2 with a moderate limitation. The humus content in the arable layer is 3.23%, and with the depth it gradually decreases between the values of 2.58-1.03%. The sum of exchangeable cations is 28.2-21.5 me/100 g of soil. Of the cations, those of Ca^{2+} predominate. Carbonates occur in the BCk horizon and the Ck horizon with values of 9.7-10.3%. The soil reaction in the arable layer is moderately acidic pH=5.6, which in the underlying layers is weakly acidic with values of 5.8-6.1, and in the BC horizon and the C horizon weakly alkaline (pH=8.2-8.3). Hydrolytic acidity – 3.0 me/100 g soil. The granulometric composition is loamy-clay homogeneous on the profile (55.91-59.17% physical clay fraction).

Leached chernozem (Profile 3): was formed under active vegetation and climate conditions, which favoured the intensification and deepening of mineral matter transformation processes. They are spread in the silvosteppe - the transition zone between the chernozem steppe and the forest zone, which is characterized by a rich grassy vegetation, on Quaternary loessoidal deposits. Currently, the original appearance of the silvosteppe is preserved only in isolation and on small areas, as over time its structure has been anthropically modified. The effervescence starts from a depth of 90 cm. Carbonates are in the form of pseudomycelia, but accumulations of bieloglasca.

The leached chernozem is characterized by the following type of profile: *Ahp-Ah-Bhw1-Bhw2-BCk-Ck*.

Ahp (0-36 cm) - arable humus-accumulative horizon, dark gray color with a brown tint, dry, loamy-clay, glomerular-bulky structure with transition to prismatic, very porous, poorly compacted, a lot of roots and organic remains, the transition to the next layer is clear.

Ah (36-51 cm) - dark gray color with brown shades, wet, loamy-clay, grainy-nut-shaped structure, small and medium aggregates, compacted, porous, small, medium and fine pores, some thin roots, transition to the next gradual horizon.

Bhw1 (51-71 cm) - dark brown color, loamy-clay, nut-shaped to granular structure, very compact, small and fine pores, few roots, rarely insect holes, transition to the next layer gradually.

Bhw2 (71-90 cm) - light brown color, wet, loamy-clay, poorly structured, crumbles into nut-shaped and grainy aggregates, very compact, small and fine pores, gradual transition to the next horizon.

BCk (90-150 cm) - carbonate illuvial horizon, yellow color with brown shade and white carbonate mycelia, rare concretions, loamy-clay, unstructured, very compact, fine pores, some pits emerge, transition to the next horizon gradually.

Ck (150-180 cm) - yellow color, with white pseudomycelia, less carbonate neoformations than in the BC horizon, unstructured, loamy-clay, compact, small and fine pores, a lot of crotovines.

The thickness of the humiferous layer is 90 cm and is considered moderately humiferous.

It is characterized by the following data of the physical and chemical properties: the density on the profile is between the values of 2.61-2.63 g/cm^3, and the apparent density has values from 1.31-1.54 g/cm^3 being weakly compacted at surface and flattened to very flattened in the adjacent horizons, the porosity varies between the limits of 48.1-36.2% v/v being medium on the surface and low to very low in the transition horizon to the parent rock, the resistance to penetration varies with values between 12 kgf/cm^2 with a weak limitation of plant root penetration, up to 28 kgf/cm^2 with a moderate to very high limitation. Hygroscopic water has values of 5.0-4.5% and is formed by the condensation of vapours around soil particles until the free energy on their surface is satisfied. It is closely related to the soil particles, in contact with the solid phase. The content of humus in the arable layer is 3.56%, and with depth it gradually decreases between the values of 3.50-0.87%. The sum of exchangeable cations is 29.6-27.9 me/100 g soil. Carbonates occur in the BCk horizon and the Ck horizon with values of 14.2-18.8%. The soil reaction in the arable layer is slightly acidic pH = 6.1, and in the BC horizon and the C horizon slightly alkaline (pH = 8.3). Hydrolytic acidity - 1.93 me/100 g soil. The granulometric composition is homogeneous loamy clay on the profile (57.85-50.38% physical clay fraction).

Ordinary chernozem (Profile 6): formed under the grassy steppe vegetation and is characterized by a deep humiferous profile with moderate humus accumulation. Carbonates accumulate in the Bh1 horizon in the form of pseudomycelia, and in the Bh2 horizon often also in the form of whitewash.

This soil is characterized by a profile of the type: *Ah1-Ah2-Bhk1-Bhk2-BCk-Ck*.

The obtained data show us that the ordinary chernozem under steppe grassy vegetation positively influences the soil properties, maintaining the hydrothermal regime and the biological cycle of substances, forming a state of favourable physical and chemical quality. The possibility of accumulating relatively large amounts of water from precipitation in the soil is a positive factor that contributes to reducing the risk of soil erosion.

The depth of the humiferous profile with a humus content of more than 1.0% of the ordinary chernozem is 120 cm, being considered as a strong deep humiferous profile.

It is characterized by the following data of physical and chemical properties: the density on the profile is between the values of 2.62-2.66 g/cm^3, and the apparent density has values from 1.18-1.44 g/cm^3, being uncompacted on the surface and weakly compacted in the adjacent horizons, the porosity varies between the limits of 54.9-47.8% v/v being medium on the surface and low to very low in the transition horizon to the parent rock, the penetration resistance varies with values between 8 kgf/cm^2 having a normal penetration of vegetation roots, up to 17 kgf/cm^2 with a moderate limitation from 60 cm. Hygroscopic water has values of 4.53-4.24%. The humus content in the Ah1 horizon is 3.33%, and with depth it gradually decreases between the values of 2.83-1.12%. The sum of exchangeable cations is 28.1-24.4 me/100 g soil. Ca^{2+} ones predominate in a ratio of 3-5:1 compared to Mg^{2+} cations. Carbonates appear in the Bhk1 horizon (4.6%) and gradually increase with depth with values of 7.3-18.9%, their maximum amount is found in the Ck horizon. Soil reaction in the city. Ah1 is neutral pH = 7.0, and towards depth it goes from weakly alkaline to moderately alkaline (pH=7.8-8.7). The granulometric composition is homogeneous loamy clay on the profile (52.45-55.65% physical clay fraction).

Carbonate chernozem, slightly eroded (Profile 7): it is formed under the conditions of the xerophytic steppes. The diagnostic criterion of this soil is the appearance of carbonates on the surface. Carbonates are found in the form of mildew and mycelium in the upper layers and whitewash in the lower ones. For the carbonate chernozem, the claying of the upper part of the profile is characteristic, because a higher content of physical clay is observed, compared to the lower horizons and the parent rock. The weakly eroded carbonate chernozem following the washing of half of the Ahk horizon has a humifer profile thickness of 60-70 cm. It is characterized by a profile of the type: *Ahkp-ABhk-Bhk-BCk-Ck*.

Ahkp (0-18 cm) - the recently arable layer, humus-cumulative horizon, gray color with a slight brown shade, moist, loamy-clay, poorly developed glomerular structure, porous, medium pores, many roots and plant remain, carbonates are found under form of mycelium, transition to the next clear horizon.

ABhk (18-40 cm) - the lower part of this horizon unaltered by plowing, dark-gray color, wet, loamy-clay, glomerular-granular structure, porous, large and medium pores, worm and insect holes, often thin roots, carbonates meet in the form of mycelium, passing to the next slow horizon.

Bhk (40-70 cm) - continuation of the humiferous profile, gray color with a brown tint, wet, loamy-clayey, glomerular-granular structure, porous, medium pores, thin roots, pits, wormholes, carbonates occur as mycelium, moving to the next horizon gradually.

BCk (70-80 cm) - significantly modified by the pedogenesis process, light-brown color with a yellowish tint, dry, carbonates in the form of pseudomycelia and white whitish spots and concretions, small and fine pores, weakly compacted, crotovine, transition to the next horizon gradually.

Ck (80-150 cm) – loessoidal deposits, yellow color, loamy-clayey, dry, small and fine pores, carbonates in the form of vines.

Research results have shown that the physical and chemical properties of arable carbonate chernozem degrade as the intensity of the anthropogenic factor increases.

Mollic diluvial soil (Profile 8): formed at the foot of the slopes and in the valleys in the process of accumulation of recent pedolite deposits (soil material of diverse texture and degree of humification), as a result of the intensification of the erosion process on the inclined slopes, under the influence weak water table, the level of which is found deeper than 2-3 m from the ground surface. As a rule, glaze pears appear in the lower part of the profile. The diluvial process is better expressed than the solification process. Over time, the diluvial soil includes two superimposed profiles: one belonging to the original soil, and the second - to the contemporary diluvium, which is distinguished by the decrease towards the surface of the humus content and, often, by the increase of the carbonate content.

It is characterized by an undifferentiated profile in genetic horizons, consisting of pedolite layers of the type: *Ih-IIh-IIIh-IVh-Vhg*.

Ih (0-37 cm) - dark gray color, moist, loamy-clay, poorly compacted, granular-glomerular structure, roots, porous, medium and small pores, no carbonates, gradual transition to the next layer.

IIh (37-58 cm) - black color, weakly compact, wet, glomerular-granular structure, loamy-argillaceous, differs from the superficial layer, lacking carbonates, transition to the next layer gradually.

IIIh (58-90 cm) - dark gray color with a brown tint, wet, weakly pronounced structure, loamy-clay, lacking carbonates, transition to the next clear layer.

IVh (90-140 cm) - brownish color, glomerular structure, loamy-clayey, reash, lacking carbonates, weakly compacted, clear transition to the next layer.

Vhg (140-170 cm) - yellowish-brown color, dry, loamy-clayey, hard, compact, lacking carbonates, weakly glazed.

The thickness of the humiferous layer is 170 cm.

It is characterized by the following data of physical and chemical properties: the density on the profile is between the values of 2.63-2.71 g/cm^3, and the apparent density has values from 1.23-1.50 g/cm^3 being loose on the surface and compacted in the adjacent layers, the porosity varies between the limits of 53.2-44.0% v/v being very high on the surface and becomes low with the depth, the resistance to penetration varies with values between 8 kgf/cm^2 having a normal penetration of plant roots, up to 20 kgf/cm^2 (in layer IIh) with a high resistance to penetration, and in the other layers it is medium. Hygroscopic water has values of 4.6-4.2%. The humus content in layer Ih is 4.10%, and with depth it gradually changes between the values of 3.0-2.9% (in layer IIh and IIIh), and in layer IVh it is 4.51%, which suddenly down to 2.96%. The sum of exchangeable cations is 33.9-27.6 me/100 g soil. The reaction of the soil in layer Ih is neutral, and towards the depth in the following layers it is weakly alkaline (pH = 7.4-7.7). The granulometric composition is homogenous loamy clay on the profile (56.78-51.23% physical clay fraction).

The qualitative state of the soils is evaluated by their creditworthiness. Soil quality is the comparative assessment of soils, their fertility according to their objective properties and the productivity of agricultural crops.

The vertical stratification of the soils is very well expressed. Thus, the gray soils are spread at altitudes above 220 m, the chernozems - 150-220 m, and the chernozemoid and alluvial soils are found in meadows and valleys. Creditworthiness by soil quality, i.e. the quality of soils, their potential fertility in relation to natural conditions and the requirements of different crops, of agricultural land was 81 points in 2015 (out of 100 possible points) - a pretty good indication, but this it differs depending on the type of soil, cultivated plants and human activities, a fact that has been shown to constitute 73 points in 2022.

According to the data from the archive, in 1990 the proportion of humus in the soil for the Dondușeni district was 4.1%.

However, according to the 2015 and 2022 Land Cadastre data regarding the characteristics of soil quality in the total surface area of Tîrnova commune soils, the following is highlighted: in 2015, there were 1055 ha of slightly eroded soils, 344 ha of moderately eroded soils, and 12 ha of heavily eroded soils; and in 2022 - slightly eroded soils 1589 ha, - moderately eroded 436 ha, - strongly eroded 109 ha. We notice that their figure has increased drastically in the category of slightly eroded soils with 534 ha, moderately eroded with 92 ha and strongly eroded with 97 ha. Thus, we observe that the surface of soils subject to degradation processes as a result of inappropriate human activities has increased over the course of 7 years by 723 ha. If the average creditworthiness in 2015 was 81 points, then in 2022 it is valued at 73 points, 8 points less.

CONCLUSIONS

The formation and evolution of soils in Tîrnova commune, Dondușeni district takes place under the influence of the natural factors of which they are a part: relief, parent rock, groundwater, climate, vegetation and animal kingdom.

According to the geomorphological districting of the Republic of Moldova, the territory of Tîrnova commune is located in the northern part of the undulating plain of Bălți. Under the action of external climatic agents, rocks undergo certain physical and chemical transformations, which condition the formation of soils with a certain composition, morphology and certain physical and chemical properties.

According to the agroclimatic districting of the Republic of Moldova, the territory of Tîrnova commune is part of the climatic district - 1A, which is characterized by a moderately continental climate with a short and comparatively warm winter, with a long and hot summer. The climate of the commune is influenced by 3 types of major factors: solar radiation, the circulation of air masses and the underlying surface.

According to the geobotanical districting of the Republic of Moldova, in the past there were forests with meadow steppes on the territory of Tîrnova commune. These forests have been preserved fragmentarily on the territory of the commune. In addition to forest vegetation, meadow, meadow and aquatic vegetation are also widespread. The builder of the forests was the pedunculated oak mixed with the wild cherry, sage, Tatar blood, dove, etc.

According to the pedo-geographic districting of the Republic of Moldova, the territory of Tîrnova commune is located at the connection line of districts no. 1 and no. 3, that is why soils specific to both districts are spread here (soft gray soils, agriloiluvial, leached chernozems). There are also soils specific only to the undulating Plain of Bălți (ordinary and carbonate chernozems).

8 soil profiles were located and investigated in the north-western part of the hilly silvosteppe area of the Northern Plain, district 3 of the typical chernozems of the Bălți Steppe. The dynamics of the ecological and agroecological indices (in the conditions of physical and chemical degradation) of the investigated soils on the genetic horizons vary according to the type and subtype of the soil.

Anthropogenic changes, as a result of the expansion of human settlements, significantly affected the relief and the soil cover because the need for pastures, hayfields and cultivated land required the deforestation of forests, and through this, the processes of washing, seepage and torrentiality found an unprotected land in in the face of accelerated erosion, which ultimately led to a decrease in the quality of the environment and the expansion of the affected areas.

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