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GENESIS AND EVOLUTION OF FOREST AND ARABLE SOILS FROM CODRI AREA FORMED UNDER DECIDUOUS FOREST VEGETATION

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Abstract

Soils formed under forest vegetation in the forest steppe zone of Russia were named by V. Dokuceaev as gray forest soils, like a transition type of soils from podzols to chernozems. In Moldova these soils formed under forest vegetation in the hilly Moldavian forests areas, named Codri, were also called gray forest soils in spite of the fact that climatic conditions, pedogenesis processes and diagnostic indicators differs from the Russian steppe. Recent soil research have established that in these soils formed in humid warm climate suitable for chernozems formation, podzolic process characterized by the formation of free iron and aluminum sesquioxides is not characteristic. Taking into account the soil formation conditions, processes that formed the investigated soils, their genetic horizons characteristics and color, it is recommended for them to be called brown soils (brunizems).

Key words: *gray soil, brown soil, forest vegetation, genesis, evolution.*

INTRODUCTION

The problem of forest soils genesis in central part of Moldova is one of the most difficult and questionable, due of specific composition of pedogenesis factors in this area. This led to the formation of very complex and polygenetic soil cover in central part of Moldova. The definitive formation of contemporary soils under the deciduous forests occurred in the late Holocene, Subboreal (4600-2500 years ago) and Subatlantic (2500-800 years ago) periods.

According to the results of archaeological research carried out in the territory of Ivancea, Trebujeni and Furceni villages, during the historical period called „culture of farmers" or „Cucuteni - tripole" (5500-2750 BC) here started forest deforestation by humans, and the process continued with interruptions until the invasion of the Huns in 260 year. Released land were used in agriculture (Александровский, 1988).

Romanian historian Xenopol wrote that between high migrations of nations from east to west, after the 260 year when the territory was conquest by nomads, over a period of hundreds and thousands years they attacked and destroying like a grasshopper the local population employed in agriculture of this territory (Xenopol, 2006).

After that most of the arable land were abandoned and were covered with steppe vegetation. Along the way of hundreds years in the extension phase of pedogenesis under restored steppe vegetation, originally soils formed under forest vegetation have evolved in chernozems. However, the largest areas of forest were cut during the years 1800-1950 (Bejan, 2006).

Most of this land hitherto is used as arable and due the anthropogenic pedogenesis phase along more than 100 years soils have not evolved in chernozems. This fact does not correspond to some researchers assertion that as a result of arable use, more than 100 years this soils formed under deciduous forests and evolve in chernozems (Чендев, 2006; Dokuceaev, 1954).

V.V. Dokuceaev named the soils formed under forest vegetation from Russian forest steppe as gray forest soils, and ranked them as a type of transition from podzols to chernozems. Further in the text we call these soils „Grayzems", name used by FAO UNESCO in world soils map legend for called by V.V. Docuceaev and others gray forest soils.

MATERIALS AND METHODS

The research was carried out on the territory of the Institute of Pedology, Agrochemistry and Soil Protection „Nicolae Dimo" experimental field from the village Ivancea, district Orhei. This area, located within 170-210 m absolute altitudes represents scientific interest because here it is known the period of gray soil use in agriculture. On one in the past forest area the grayzems were plowed for about 120 years (120 ± 10 years) period.

In the field was made morphological description of profiles - pairs located opposite to each other in the forest (profile 1 and 51) and in the arable land (profile 2 and 52), located at a distance of approximately 150 m from each other (Figure 1).

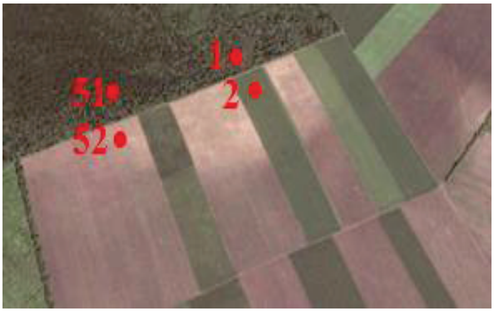

Figure 1. The area (light color) of gray soils (grayzems) in Experimental Station fields:
1 and 51 - soil profiles located in the forest;
2 and 52 - soil profiles placed on arable land.

In the field was determined bulk density and soils penetration resistance. Simultaneously have been collected soil samples for laboratory analysis. To perform the field and laboratory determinations were used nationally approved methods.

RESULTS AND DISCUSSIONS

Area of arable gray soils (grayzems) spread on the studied Experimental Station territory is highlighted on the ortho-photo map by pale color of the land located next to the forest (Figure 1).

The history of this arable soil area formation is the next. In the 1852 the Ivancea village territory was bought by Armenian Karabet Arakelean Balioz (Голуб, Сорочинский, 1950). He cut in the years 1860-1880, the forest on the today arable sector for commercial purposes. The investigated soil profiles are shown in Figure 2.

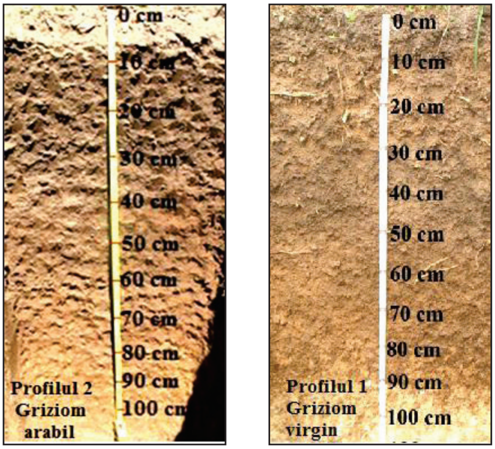

Figure 2. Profile composition of forest and arable gray soil (grayzems)

Forest grayzem has the next profile type: *AEhţ (0-9 cm) → AEH (9-21 cm) → BEhtw (21-34 cm) → Bhtw (34-51 cm) → BCtw (51-80 cm) → BCtwk (80 -100 cm) → BCK (100-120 cm).* This soil (profile 1) is characterized by clear differentiation profile. In the range of 0-34 cm depths is highlighted three horizons:

AEhţ, AEH and BEhtw with medium texture and low compaction, which is located below the iluvial-cambic compacted horizon (Table 1 and Table 2).

The layer 0-30 cm of arable soil consists from the first three forests soil horizons with genetic material mixture: AEhţ, AEH and BEhtw. Under these layers is located the iluvial-cambic very compacted horizon identical to his forest soil horizon analog. Significant changes in profiling occurred just artificially created only arable layer. The arable layer lost its favorable glomerular - grained structure and the resistance to compaction. It became rough and very compacted, the color from gray changed into red-brown (Table 1 and Table 2).

Some characteristics of grayzems in central part of Moldova have been described by V.V. Dokuceaev, who was amazed by the high content (7-10%) of organic matter in the layer 0-8 cm (Dokuceaev, 1950).

There are three hypotheses on the origin of gray soils genesis:

1. The hypothesis of V.V. Dokuceaev who consider gray forest soils primary origin as a result of soil formation process under deciduous forest vegetation.
2. S.I. Korjinskii's hypothesis regarding grayzems formation as a result of chernozems degradation under deciduous forest vegetation as a result of forest invasion in the steppes during the colder and wetter Holocene.
3. V.R. Viliams's hypothesis, that the gray soils were formed as a result of podzolic soils developed under the influence of steppe vegetation as a result of the steppes invasion in the forests during the drier Holocene.

Subsequent research confirmed that all three hypotheses have the right to life; only the last two are individual cases. So then, grayzems or soils appointed by the V.V. Dokuceaev gray forest soils are formed as a result of the podzolic pedogenesis process and the humus accumulation process merge.

The profiles of these soils may show inherited traits or characters that were formed as a result of iron and aluminum sesquioxides iluvial process from higher in a lower horizon in the water-soluble chelat forms. So it is necessary to assess under what conditions were formed grayzems in central part of Moldova.

This dilemma can only be solved by highlighting the process that led to their profile textural differentiation: soil spodic process, lessivage or argillic alteration *in situ*. To answer this question has been researched forest and arable soils in the territory village Ivancea, Orhei district and have used the results of previous research on this territory, made in Lysimeter (Грати, 1977). Based on the research results from stationary placed in forestry soils in the village Ivancea were made the following conclusions:

1. Under the forest toward the autumn is used all available soil moisture reserves. Autumn-winter precipitation are only enough to wet the soil to a depth 150 cm. As a result, at this depth in spring is observed maximal moisture deficit and carbonates accumulation.
2. In early spring the soil moisture in 0 - 100 cm layer is equal to field capacity, but the rapid rise of temperatures and intensive use of water by forest vegetation leads to available water reserves depletion in June - July in this layer, which confirms contrast humidity regime in these soils.

For the most part of the year the soils in the forest are well aerated and aerobic processes dominate in their profile, which does not favor the evolving gleic soil process (minerals mass reduction processes) in the superficial horizons (prerequisite for the development of podzolic soil process).

Lysimeter waters reaction in almost all investigated soils is neutral or slightly alkaline; it can be explained by the fact that litter is rich in calcium. The concentration of iron and aluminum in the Lysimeter waters on the profile of both forest and arable soil is low and stable, and decreases sharply in parental rock. The lack sesquioxides increasing in Lysimeter waters, after this are going through the eluvial horizon, doubts the presence of podzolic process in investigated soils and the existence of clay films on the pores walls and in the microcracks iluvial horizon, confirms the existence of lessivage process of colloidal particles from top to down in the profile. Gray soil textural differentiation of the profile is linked to the intensity of two processes: eluvial (lessivage) process and strong argillic alteration *in situ* in the middle part of profile.

From the materials presented in the monograph written by V. Grati (1977) is resulted that soils formed under forest vegetation in central Moldova differ from soils called gray forest soils from Russian steppe zone by the lack or very weak development of podzolic process and it's replacing with the lessivage process with comparatively low intensity.

In the textural differentiation of the soil profile in this area plays a key role clay alteration process *in situ* of Btw horizon mineral part.

Although listed findings show that soils in the hilly part of Codri area differ clear from all points of view to those called grayzems or gray forest soils, V. Grati has not proposed revision of their taxonomy. Research by us research findings largely confirmed V. Grati.

The specific properties of investigated soils are shown in Tables 1 - 3. The BCk and Ck horizons were considered as part of the weakly amended mineral part of the soil profile by iluvial processes and alteration *in situ*. As a result of textural differentiation (Canarache,

1990) and argillic alteration coefficients calculating we find the following:
- forest soils have medium differentiated profile and arable land are poorly differentiated textural as a result of argillic alteration *in situ* process intensification in the arable layer;
- iluvial-cambic horizons of soils studied is characterized by high clay content predominantly colloidal;
- loss of clay in eluvial horizons (AEhţ, AEH, BEH) in grayzems from the forest are about 9 times less than its accumulation in iluvial-cambic horizons, that confirms the leading role *in situ* alteration processes in the texture differentiation of their profile.
Low and very low textural differentiation of profile in studied agricultural soils is due to the *in situ* alteration process intensification in the upper part of the profile as a result of their hydrothermal regime change, weak acid reaction and eluvial-iluvial process stopping.
A key indicator of the studied soils genesis is their total composition, because it reflects the result of the pedogenesis process. Forestry soils are characterized by a little enrichment with silicate in eluvial (soil from forest) and posteluvial horizons (arable layer of agricultural soils). At the same time it detects a higher content of iron and aluminum compounds in iluvial-cambic horizons as a result of alteration processes and their leaching from above horizons.
Generally, studied soils profiles differentiation in terms of the genetic horizons chemical composition is low as a result of hydrothermal warmly and contrast regime. Data on the non - silicate iron compounds content in investigated soils confirming their weak or moderate accumulation in the iluvial - cambic horizon Btw, as a result of clay co-migration from the AE to Btw horizon. Brown color of the horizons of forest soils is due to iron oxides.
So now, research results confirm that the textural differentiation of forest soils in central part of Moldova occurred as outcome of argillic alteration *in situ* in the central part of their profile and the weak or moderated process of clay and free sesquioxides co-migration (lessivage) from the horizon AE to Btw and not podzolic process characteristic for gray forest soils (grayzems). Forest soils in this area climate are more correctly to be called *brown* or *brunizems.*
The soil cover in the hilly Codri Plateau in Central Moldova, depending on the stage of the recent and previous pedogenesis and can consist of brown forest soils, brown arable soil, brown arable at different stages of transition to chernozems, cambic chernozems, cambic postarable chernozems at different levels of transition to brunizems as a result of the long pedogenesis under the secondary forests of originally formed chernozems.

Table 1. Physical and chemical properties of the forest (profile 51) and 100 years arable (profile 52) grayzems

Horizon and the depth, cm	The faction, %			Textural differen-tiation index	Coeffi-cient of argillic alteration	Bulk density g/cm^3	Fe_2O_3 total, %	pH	$CaCO_3$, % g/g	Humus content, %
	<0.0001 mm	<0.001 mm	<0.01 mm							
Forest loamy-clay grayzem (profile 51)										
Ahţ 0-8	11.4	23.4	43.9	1.0	0.9	0.84	3.82	6.8	0.0	8.63
Aeh 8-21	12.2	23.8	43.7	1.0	0.9	1.22	3.56	5.0	0.0	2.65
EB 21-30	15.4	28.4	48.4	1.2	1.0	1.38	4.17	5.4	0.0	1.87
Btwh 30-50	28.5	37.5	58.4	1.6	1.4	1.64	4.80	5.3	0.0	1.14
Btw 65-80	29.4	39.4	60.8	1.7	1.5	1.64	5.13	6.9	0.0	0.68
BCtwk 80-00	26.8	35.0	57.6	1.5	1.3	1.57	4.83	7.7	16.7	0.58
BCk 100-120	14.8	27.9	53.6	1.1	1.0	1.46	3.98	7.8	22.3	0.52
Ck 130-150	14.2	27.1	49.3	1.1	1.0	1.46	3.98	8.0	24.7	0.47
Arable loamy-clay grayzem (profile 52)										
Ahp1 0-30	14.9	33.1	50.8	1.0	1.2	1.44	3.85	6.5	0.0	2.23
Bhtw 30-50	26.9	37.7	58.7	1.1	1.4	1.60	4.89	5.6	0.0	1.25
Btw 50-72	28.1	38.7	60.2	1.2	1.4	1.61	4.83	6.1	0.0	0.73
BCtwk 72-90	24.3	34.0	57.8	1.0	1.3	1.55	4.55	7.8	16.4	0.68
BCk 90-110	14.8	27.8	51.4	0.8	1.0	1.46	4.19	8,1	23.0	0.58
Ck 130-140	14.5	27.3	49.3	0.8	1.0	1.45	3.92	8.1	23.4	0.34

Table 2. Main physical properties of forest (profile 1) and arable (profile 2) grayzems

Horizon and the depth, cm	The faction, %		D	DA	PT, % v/v	AH	CH	Moisture content in the field 14.05.2015	Resistance to penetration, kgf/m^2
	<0.001 mm	<0.01 mm	g/cm^3			% g/g			
Profile 1. Gray forest soil (grayziom)									
AEhţ 0-9	24.6	42.4	2.48	0.86	65.3	7.8	9.2	-	3
AEh 9-21	25.6	44.0	2.61	1.27	51.3	7.4	7.8	-	7
BEhtw 21-34	34.6	54.2	2.66	1.45	45.5	7.6	8.4	-	14
Bhtw 34-51	40.8	61.5	2.70	1.62	40.0	8.5	10.2	-	24
BCtw 51-80	40.7	60.9	2.71	1.61	40.6	8.0	10.0	-	-
BCtwk 80-00	35.3	55.6	2.72	1.60	41.2	6.5	7.9	-	-
Ck 100-120	32.4	50.5	2.73	-	-	6.2	7.5	-	-
Profile 2. Arable gray soil (grayziom)									
Ahp1 0-10	31.5	55.9	2.59	1.38	46.7	3.8	7.8	17.9	12
Ahp1 10-20	32.0	56.2	2.60	1.55	40.4	3.8	7.9	20.2	19
Ahp2 20-35	32.9	56.3	2.62	1.57	40.1	4.0	8.7	21.6	21
Bhtw 35- 50	41.8	62.2	2.69	1.61	40.1	7.0	12.2	23.2	26
BCtw 50-80	41.1	61.9	2.72	1.62	40.4	6.7	12.0	23.0	-
BCtwk 80-100	38.0	58.0	2.73	1.59	41.8	6.6	10.5	20.8	-
Ck 100-120	35.2	55.1	2.73	-	-	6.5	10.4	20.8	-

Note: *D - density; DA - bulk density; PT - total porosity; AH - hygroscopic water; CH - coefficient of hygroscopicity.*

Table 3. The chemical characteristics of forest and arable gray soils (grayzems)

Horizon and the depth, cm	pH (H_2O)	$CaCO_3$	P_2O_5 total	Humus	N total	C : N	P_2O_5	K_2O	$N\text{-}NH_4$	$N\text{-}NO_3$
		% g/g					mg/100 g sol			
Profile 1. Gray forest soil (grayziom)										
AEhţ 0-9	6.3	0	0.17	8.72	0.411	12.3	3.4	28	-	-
AEh 9-21	5.5	0	0.11	3.21	0.181	10.3	2.3	14	-	-
BEhtw 21-34	5.6	0	0.10	1.31	0.078	9.7	1.0	12	-	-
Bhtw 34-51	5.2	0	0.08	1.16	0.073	9.2	0.4	10	-	-
BCtw 51-80	5.7	0	-	0.76	-	-	-	-	-	-
BCtwk 80-00	7.5	7.7	-	0.63	-	-	-	-	-	-
Ck 100-120	8.1	19.4	-	0.47	-	-	-	-	-	-
Profile 2. Arable gray soil (grayziom)										
Ahp1 0-10	6.6	0	0.09	2.30	0.136	9.8	2.7	22	2.4	0.5
Ahp1 10-20	6.4	0	0.09	2.13	0.130	9.5	2.2	19	2.3	0.4
Ahp2 20-35	6.4	0	0.08	1.77	0.110	9.3	1.6	18	1.9	0.3
Bhtw 35- 50	6.4	0	0.07	1.05	0.071	8.6	0.6	22	1.4	0.2
BCtw 50-80	7.0	0	-	0.64	-	-	-	-	-	-
BCtwk 80-100	7.9	3.6	-	0.58	-	-	-	-	-	-
Ck 100-120	8.1	13.6	-	0.45	-	-	-	-	-	-

CONCLUSIONS

The south-eastern and south-western hills of the Central Codri Plateau from Republic of Moldova are characterized by specific composition of the pedogenesis factors. Soils formed under deciduous forest vegetation in the peripheral part of Codri, recently called gray soils or grayzems, differ analogical from forest steppe soils from the Russia called gray soils by V.V. Dokuceaev: They have evolved in warm and semi humid climates; textural profile differentiation is low or moderate and predominantly caused by the "in situ" alteration of the parental material and only partly by the colloids fraction lessivage but not due the podzolic process characterized with sesquioxides migration, characteristic for gray soil. Taking into account the soil formation conditions, processes that formed the investigated soils, their genetic horizons characteristics and color, it is recommended for them to be called brown soils (brunizems).

As result of soils gray using in agriculture were occurred essential negative changes in their characteristics, among which: the decrease of humus content in the arable layer almost 2 times compared to forestry soils, destructuration and strong compacting of arable layer, and acidification - which is a difficult problem to their recovery.

Remediation of arable gray soil characteristics consist in: increasing organic matter flux in arable layer, restoration of unfavorable structural status of ploughing layer, periodically loosening by subsoiling the upper iluvial - cambic horizon.

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