

Podzolized soils of the river's first-loess terraces in the Forest-Steppe

Solovei V.¹, Lebed V.²

NSC «Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovskiy», 4, Chaikovska str., Kharkiv, 61024, Ukraine; e-mail: ^{1,2}gruntpokrov@ukr.net

The purpose. To determine ecological-genetic status of soils of first-loess terraces. **Methods.** Quantitative diagnosing of soils on morphological-genetic structure of a profile with subsequent refinement with results of analytical probes of the select soil samples. **Results.** Podzolized soils of first-loess terraces, in comparison with typical chernozem, are characterized by decrease of the sum of exchange cations, that diminishes their buffering power a little to react against change of pH, displaces response of soil substrate aside slightly sour. It needs to be considered at development of fertilizing systems and soil reclamation. Podzolized soils are more sensitive to importation of heightened doses of fertilizers, especially physiologically sour. They can aggravate agrophysical state at delayed agrotechnological operations on soil cultivation. The great value has the account of the ecological-genetic status of chernozems of first-loess terraces at realization of monitoring over their state.

Conclusions. Soils of first-loess terraces of Left-bank Forest-steppe according to existing soil-maps and charts are mainly typical chernozems, however differ from them in parameters of morphological-genetic properties. Application of quantitative diagnostics with the use of quotients of COPR, CPHA and CRHA enables uniquely to position genetic features of soils of first-loess terraces. It is fixed that on the significant areas which are adjacent to first over flood plain terrace as a wildlife reserve of forest vegetation the soil covering of first-loess terraces is presented by podzolized chernozems which sporadically were exposed to forest vegetation. Podzolized status of soils of first-loess terraces is necessary for normative-monetary assessment of lands, differentiation of agrotechnologies for their intelligent use, determination of resource opportunities, monitoring state.

Key words: river terraces, soils, podzolization, diagnostic criteria, quotient of regressiveness of organic profile.

<https://doi.org/10.31073/agrovisnyk201812-03>

Introduction. First-loess terraces are specific landscapes component of the river's left-banks in Forest-Steppe which flowing in the submeridional direction, mainly from the north to the south: Desna, Sula, Psel, Vorskla, Seversky Donets, etc. In accordance with the principle of Ber-Babine, terraces were formed mainly on eastern banks of the river are characterized by the presence of a single layer of loess over ancient alluvial sands. Their total area reaches 1 million hectares, the cultivation exceeds 80%. Territorially these formations are bordered by a first overfloodplain terrace, which is characterized by the presence of pine plants and the forest genesis of soils – marked on the map as soddy podzolic, soddy podzolized mainly coherent-sandy and sandy loam on the sands. At the same time, loamy soils of first-loess terraces are predominantly distinguished as typical chernozems, similar to chernozems on the loess terraces of a higher hypsometric level, which contradicts the secventnist of soil formation. In large-scale studies in 1957-1961 some soil scientists drew attention to the specific morphological features of the first-loess terraces soils. Solodic chernozems, residual solonetzic, and sometimes even ordinary chernozems were allocated locally, which is nonsense for the forest-steppe zone. The lack of unity of views on the genesis of chernozem soils of first-loess terraces indicates the unreliability of traditional morphological diagnostics based on the structure of the profile, the necessity of applying quantitative diagnostic criteria for soil properties. This issue is exacerbated specially at the current stage of reforming the agrarian sector of the economy, requiring accurate and reliable information on agricultural production quality of soils for their normative-monetary evaluation, investment attractiveness determination, differentiation of agrotechnologies in accordance with genetic features of soils. To date, a number of diagnostic coefficients of the genetic status of soils have been developed, such as the coefficient of relative humus accumulation (CRHA), the coefficient of profile humus accumulation (CPHA) [1,2], and the coefficient of organic profile regression (COPR) [3,4]. Their application allows to more objectively diagnose soils, especially the discussion genesis.

The purpose – through the use of quantitative diagnosis to determine the ecological and genetic status of first-loess terraces' soils.

Objects and methods. The research was carried out on the first-loess terraces of the Vorskla, Psel and Siversky Donets rivers within the Sumy, Poltava and Kharkiv regions respectively.

The digging of soil pits and soil sampling was carried out in accordance with DSTU 4287: 2004 Quality of soil. Sampling. Description of the morphological and genetic profile of soils was conducted in accordance with DSTU 7535: 2014 Quality of soil. Morphological and genetic profile. Rules and order of description [5]. Each soil pit was tied in a geographic coordinate system with the help of device for satellite geo-positioning (GPS).

Soil diagnostics were carried out according to the morphological and genetic structure of the profile with subsequent refinements based on the results of analytical studies of the selected soil samples.

The content of organic matter in soil samples was determined with DSTU 4289: 2004 Quality of soil. Methods of determination of organic matter, in percent, humus content by calculation method in percentages, exchange cations according to DSTU 7861: 2015 Soil quality. Determination of exchangeable calcium, magnesium, sodium and potassium in the soil by Schollenberger in modifications of the ISSAR, granulometric composition of soil according to DSTU 7842: 2015 Quality of soil. Evaluation of soil quality by granulometric composition [5].

In order to clarify the genetic status of soils and establish their belonging to a certain type of soil formation, the coefficient of organic profile regression (COPR) was calculated. Also, coefficients of humus accumulation were calculated for the establishment of subzonal and zonal peculiarities of soils - CRHA and CPHA.

Research results. On first-loess terraces, which are not always properly reflected in cartographic materials, there are various combinations of soil-forming processes. As a result, a variegated complex of soil differences was formed, which complicates their definition and often has a controversial nature. Often, researchers assume mistakes when using the profile-morphological method of soil determination, which is subjective, which in turn makes it impossible to accurately diagnose.

In analyzing the cartographic material of a large-scale soil survey of 1957-1961, it was discovered that the highlighted soil differences do not always correspond to reality and contradict the law of zonality. So, for example, on terraces of the Severski Donets in the forest-steppe zone, ordinary chernozems are common (Fig. 1,2).



Fig. 1 Deep solonetzic chernozems (cipher 85) and deep leached ordinary chernozems (cipher 48) between podzolized by coherent-sandy and sandy loam soils of the first overfloodplain terrace and medium-humus heavy-loam typical chernozems (cipher 43) (Vovchansky district of the Kharkiv region)



Fig. 2 Deep ordinary chernozem (sipher 46) between soils of first overflowplain terraces and typical chernozems (sipher 43) (Pechenezgky district of Kharkiv region)

The river terraces' soils alternate as move away from the left bank, in accordance with the law of ecological secventnost, which is directed at the consistent change of soils in space through a consistent change in the factors of soil formation [6]. The main factors that determine the direction of the soil formation process on first-loess terraces include are relief, the type of bedrock, the presence of forest vegetation and the depth of subsurface water. At the same time, at relatively short distances there are complex combinations of soils.

For example, at the first variant in the Vovchansky district, the coherent-sandy and sandy loam soils of the first overflowplain terrace are going to the meadow-chernozem and chernozem-meadow, which are within the limits of the nearterraces' lowering. Further, on the territory of a first-loess terrace there are typical chernozems of lightweight sandy-heavy-loam. In this case, the hydromorphic soils between podzolized and typical chernozems have become a kind of barrier for the onset of forest vegetation.

Otherwise, in the absence of a natural hydrological barrier, podzolized soils of the first floodplain terrace are going to the podzolized chernozems of lightweight sandy-heavy-loam. A similar situation is observed in the Pechenezgky district, where the soils are distinguished on maps as ordinary chernozems, are between the podzolic soils of the first floodplain terraces and typical chernozem. As already noted, ordinary chernozems are not typical for the forest-steppe zone, so it was decided to determine, with the help of quantitative criteria, which soils are located in these areas.

We have established that the soil of one row of soil formation has a similar character of the profile humus distribution associated with the downward movement of the roots of grassy vegetation [3]. In connection with this, there was the idea of the presence of a certain constant - a constant value, which parametrically characterizes the rate of decline of humus with depth - coefficient of organic profile regression. The most informative, in our opinion, is the ratio of humus content in layers of 0-30 cm and 30-100 cm.

This coefficient quantitatively characterizes the organic profile regression of soils depending on the peculiarities of the distribution of the roots of herbaceous plants - the main source of humus in the soils. It is established that in soils of accumulation rows of soil formation, in particular typical chernozems, its value is 1.5-1.6 (Table 1). For soils of the podzolized series (podzolized chernozems, dark gray podzolized, gray forest soils), its value is increased to 1.8-3.6.

Table 1. Parameters of quantitative diagnostic coefficients in soils of different rows of soil formation in Forest-Steppe [1,2]

HTC _{v-ix}	Soil	Coefficients of humus accumulation		
		CPHA	CRHA	COPR
Accumulation row				
0.90-1.40	Typical chernozem	0.075-0.100	0.98-1.35	1.5-1.6
Podzolized row				
1.00-1.80	Podzolized chernozem	0.051-0.070	0.74-1.15	1.8-2.3
1.05-1.80	Dark gray podzolized	0.040-0.050	0.63-0.95	2.1-3.1
1.17-1.80	Gray forest soil	0.031- 0.040	0.40-0.70	2.1-3.6

As we can see from the table, the COPR index is stable and clearly characterizes belonging to one or another row of soil formation, with a wide range of values of CRHA and CPHA within the limits of the natural zone in soils of varying humidity and granulometric composition.

On the first-loess terrace of the Seversky Donets river the in forest-steppe near township Primorsk, where the ordinary chernozems are common, was digging pit № 1 (Fig. 3). The absence of a white soft spot as an attribute of ordinary chernozem at first glance suggests that this is typical chernozem.

This pit was laid on an aligned watershed between lowering, with the following structure of the profile:



H 0-43(45) cm
Hp 43-57 cm
HP/k 57-75
cm
Phk 75-100
cm
P(h)k 100-125
cm
Pk > 125 cm

Fig. 3 General view of the profile of the soil, which is marked on the maps as an ordinary chernozem

At the same time, certain differences were found between the typical chernozems common in the region on the higher terraces and plateau:

- reduction the thickness of soil profile by 15-20 cm;
- less the mole tunnels in soil profile;
- weak but noticeable luster on the structure aggregate in the transition horizons;
- a tendency to a nutty structure;
- deeply effervescence from 10% HCl.

This soil, predefined as chernozem typical, according to the calculated value of COPR, which is 1.9, refers to the podzolized row of soil formation. This, above all, is connected with the periodic settlement of forest vegetation on the territory of a first-loess terrace in the past, the more that there is a first overfloodplain terrace - a kind reserve dendroflora.

For the comparison of background soils on terraces which is located on different levels, data on the profile of typical chernozem near the village Chkalovskoye, Grakivsky district of the Kharkiv region, which is located on an ancient terrace of the Siversky Donets river.

On this territory, the typical chernozems medium-humus light clayly dominate and are characterized by a profile with a total capacity of 100-110 cm. The pit №2 is laid on the flat part of the terrace with deep level of groundwater.

The profile structure of these chernozems has the following form: H - 0-43(45) cm; Hpk - up to 65-75 cm; HPk - up to 85-90 cm; Phk - up to 100-110 cm; Pk - from the depths > 100-110 cm

The absence of secondary signs of podzolization in the profile, which is characteristic of the previous soil and the value of COPR in the range of 1.5, clearly indicates that it belongs to the accumulation row of soil formation. This is facilitated by the remoteness of the territory from the first overfloodplain terraces, which it makes impossible the influence of forest vegetation and the development of the podzolization process.

Another example of the discrepancy between the marked on the map and to the real state is the territory of the first-loess terrace of the Psel river in the Kozelshchynsky and Shishakivsky districts of the Poltava region.

The pit №3 is laid at an elevation near the pine forest terrain. Soil is podzolized chernozem light loamy over sandy loam.

Similarly to the podzolized soils of the first-loess terrace of the Seversky Donets river, the soils are characterized by reduced thickness of soil profile, reduced humus accumulation intensity, deeper effervescence of carbonates, and less the mole tunnels in profile than the typical chernozems on terraces of the higher level. Despite the lack of pronounced texture differentiation of the profile inherent in podzolized soils, the presence of silica spray in the upper horizon indicates the involvement of forest vegetation in their formation (Fig. 4).



H (e) – 0-42
cm

Hp (i) – 42-68
cm

Ph (i) – 68-100
cm

P(h) > 100 cm

Fig. 4 Presence of noticeable silica spray in the soil profile on a first-loess terrace (pit №3)
Parameters of COPR values for this soil, as well as for the previous one, are similar to podzolized soils (Table 2).

Table 2
Comparison of the content of humus in podzolized soils of first-loess terraces of the forest-steppe with typical chernozems

№ pit	District	Depth, cm	Humus, %	CPHA	CRHA	COPR
Podzolized chernozem medium loamy on the loess (fallow)						
1	Kharkiv region Pechenizky district	0-10	3.7	1.9	0.07	1.0
		15-25	3.8			
		30-40	3.0			
		50-60	1.9			
		70-80	1.0			
Podzolized chernozem light loamy over sandy loam (virgin)						
3	Poltava region Kozelshchynskyi district	0-10	3.5	2.1	0.1	1.4
		15-25	2.0			
		30-40	1.7			
		50-60	1.5			
		70-80	0.7			
Typical chernozem medium loamy on the loess (arable)						
4	Poltava region Shishakivskyi district	0-10	4.1	1.6	0.08	1.0
		15-25	3.9			
		30-40	3.4			
		50-60	2.7			
		70-80	2.3			
Typical chernozem light clayly on the loess (arable)						
2	Kharkiv region Chuguevsky district	0-10	5.5	1.5	0.08	1.0
		15-25	5.5			
		30-40	4.7			
		50-60	4.1			
		70-80	3.4			

Based on the results of the humus content and the nature of its distribution in the genetic horizons we can note the more sharp difference between the layers 0-30 cm and 30-100 cm in podzolic soils compared with typical chernozems.

Particularly noticeable is the decrease in humus content from 50 cm there are the depth of distribution in the past tier of skeletal roots of woody vegetation (Fig. 5). In this regard, the use of COPR as a diagnostic factor has advantages over CPHA and CRHA. The parameters of the values of the latter are significantly influenced by the presence of virgin and fallow variants, while the diagnostic gradations were calculated for arable land.

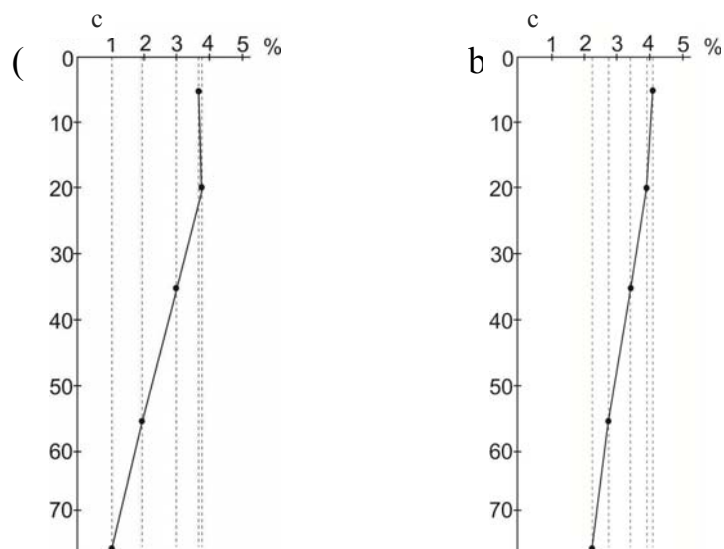


Fig. 5 Distribution of humus by profile (a) podzolized chernozem and (b) typical chernozem

The coefficient of organic profile regression almost does not change from the different degree of moisture and granulometric composition of soils within one natural zone, as opposed to subzonal CRHA and zonal CPHA. In calculating the mean values of these coefficients, for each soil, the data on arable lands were taken into account, therefore, in virgin and fallow variants of podzolized chernozem (pits 1,3), the indices go beyond the range of podzolic soils and are similar to typical chernozems. Based on this, the COPR most accurately reflects the genetic features of soil formation.

The synchronously with humus also changes such an indicator as the sum of exchange cations of the soil (Table 3). Thus, an increase in the content of humus leads to an increase in the content of exchange cations of calcium and magnesium in typical chernozems. In this case, the percentage of sodium from the amount of absorbed cations is insignificant, which positively affects the agrophysical properties of soils.

Thus, podzolized soils of first-loess terraces compared with typical chernozems are characterized by a decrease in the sum of exchange cations, which somewhat reduces their buffering ability to counteract the change in pH, displaces the reaction of the soil medium towards slightly acid. This should be taken into account developing systems of fertilizer and reclamation of soil.

Table 3 Comparison of physical and chemical indices of podzolized soils of first-loess terraces with typical chernozems

№ pit	Depth, cm	pH water	Exchange cations, mmoles /100g					Physical clay, %
			Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	Σ	
Podzolized chernozem medium loamy on the loess (fallow)								
1	0-10	6,9	20,1	3,1	0,07	0,2	23,5	40
	15-25	7,0	19,3	2,6	0,07	0,3	22,3	38
	30-40	6,5	15,5	2,1	0,06	0,3	17,9	42
	50-60	7,2	16,4	2,1	0,07	0,2	18,8	38
Podzolized chernozem light loamy over sandy loam (virgin)								
3	0-10	6,5	10,1	1,5	0,04	0,3	11,93	21
	15-25	6,7	8,2	1,3	0,04	0,1	9,68	19

	30-40	6,7	8,3	1,4	0,02	0,1	9,81	22
	50-60	6,9	9,4	1,2	0,04	0,1	10,77	18
	100-110	7,0	7,1	1,0	0,04	0,1	8,22	19
Typical chernozem medium loamy on the loess (arable)								
4	0-10	7,1	23,8	3,7	0,08	0,4	28,1	43
	15-25	6,9	24,2	4,1	0,1	0,6	29,0	39
	30-40	7,2	22,7	3,5	0,06	0,3	26,6	40
Typical chernozem light clayly on the loess (arable)								
2	0-10	7,0	37,2	4,1	0,31	1,1	42,7	58
	15-25	6,9	37,8	4,0	0,3	0,9	43,0	59
	30-40	6,9	36,0	3,0	0,27	0,6	39,8	58

Clarification of the ecological and genetic status of soils of first-loess terraces in addition to scientific has a practical significance. Firstly, the normative-monetary valuation of land will change, which will bring appropriate adjustments to their agro-investment attractiveness. Second, the podzolized status of these soils causes their greater vulnerability to the effects of anthropogenic factors. They are more sensitive to the introduction of higher doses of mineral fertilizers, especially physiologically acidic, may aggravate their agro-physical state when untimely execution of agro-technology operations on soil cultivation. Implementing the latter directly in front of the rain or in the over moistened state may lead to the soil overcrust, followed by the incrustation, the presence of a silica spray of SiO₂ on the surface, etc. The possibility of sporadic deterioration of the agrophysical properties of chernozem soils of loess terraces has been known for quite a long time, sometimes they have been described as "weakly structured" or even specific "terraced" chernozems. However, this phenomenon today has a logical explanation relatively for the corresponding ecological and genetic features of soil formation.

Is important to take into account the ecological and genetic status of chernozem on the first-loess terraces at their monitoring. False union of them with typical chernozems on the terraces of a higher level or plateau can lead to incorrect conclusions of their evolution, such as "dehumification", "decalcification", "agro-physical degradation", etc. According to the productive qualities of podzolized chernozems on the first-loess terraces are not inferior to typical chernozems, but only if their genetic features are taken into account for rational use.

Conclusions

1. The soils of first-loess terraces of the Left Bank Forest-steppe, according to existing soil-mapping materials, are mainly described as typical chernozems, but differ from their morphological and genetic properties.
2. Morphological diagnostics of these soils is subjective and does not allow to uniquely identify their ecological and genetic status.
3. The use of quantitative diagnostics using coefficients COPR, CPHA and CRHA allows to uniquely establish the genetic features of soils of first-loess terraces. It was established that on the large areas directly adjacent to the first overfloodplain terrace as to a reserve of forest vegetation, the soil cover of first-loess terraces is represented by podzolized chernozems, which are sporadically influenced by forest vegetation.
4. Podzolized soils on first-loess terraces are absent in the presence of a hydrological barrier with a first overfloodplain terrace.
5. The podzolized status of soils of first-loess terraces must be taken into account in the normative-monetary assessment of land, differentiation of agrotechnologies for their rational use, definition of resource capabilities, monitoring of the state.

References:

1. Polupan M.I., Solovei V.B., Velychko V.A. (Polupan M.I. Ed.) (2005). *Klasyfikatsiia gruntiv Ukrainy* [Classification of soils of Ukraine]. Kyiv: Ahrarna nauka. 300 p. [In Ukrainian].
2. Polupan M.I., Solovei V.B., Kysil V.I., Velychko V.A. (2005). *Vyznachnyk ekoloho-henetychnoho statusu ta rodiuchosti hruntiv Ukrainy*. [Identifier of the ecological and genetic status and soil fertility of Ukraine]. Kyiv: Koloobih. 304 p. [In Ukrainian].

3. *Pat. 101351* Ukraina, MPKG 01 N 33/24. Sposib kilkisnoho vyznachennia nadtypovoho rivnia gruntoutvorennia. [Method of quantitative determination of a supertype level of soil formation]. V.B. Solovei; zaiavnyk ta patentovlasnyk Natsionalnyi naukovyi tsentr «Instytut gruntoznavstva ta ahrokhimii imeni O.N. Sokolovskoho». № u201501869; zaiavl. 03.03.2015; opubl. 10.09.2015, Biul. № 17. [In Ukrainian].
4. *Solovei V.B.* (2016). Pidvyshchennia informatyvnosti gruntovo-kartohrafichnykh materialiv — priorytetnyi napriam rozvytku gruntoznavstva. [Increasing the informativity of soil and cartographic materials is a priority trend in the development of soil science]. *Visnyk ahramoi nauky*. Spets. vypusk. Zhovten. P. 11–16. [In Ukrainian].
5. *Baliuk S.A., Lazebna M.Ie.* (2017). Perelik osnovnykh normatyvnykh dokumentiv u haluzi gruntoznavstva, ahrokhimii ta okhorony gruntiv. [List of basic normative documents in the field of soil science, agrochemistry and soil protection]. Kharkiv. 72 p. [In Ukrainian].
6. *Sokolov Y.A.* (2004). Teoretycheskye problemy henetycheskoho pochvovedenyia. [Theoretical problems of genetic soil science]. 2-e yzd. Novosybyrsk: Humanytarnnye tekhnolohyy. 288 p. [In Russian].
7. *Boul S., Khoul F., Mak-Kreken R.* (1977). Henezys y klasyfykatsyia pochv [Genesis and classification of soils]. Moskva: Prohress. 416 p. [In Russian].
8. *Krupskyyi M.K.* (Ed.). Grunty Ukrainy ta yikh ahrovyrobnycha kharakterystyka [Ukrainian soils and their agro-industrial characteristics]. Kyiv: Urozhai, 1964. 164 p. [In Ukrainian].
9. *Laktionov N.I., Tikhonenko D.G., Gorin N.A.* et al. (1988). Genezis, evolyutsiya i tipologiya pochvoobrazuyushchikh porod severo-vostoka Ukrainy [Genesis, evolution and typology parent rocks north-east Ukraine] : ucheb. posobie. Khar'k. s.-kh. in-t im. V.V. Dokuchaeva. Khar'kov. 72 p. [In Russian].
10. *Metodyka* krupnomasshtabnoho doslidzhennia gruntiv kolhospiv i radhospiv Ukrainskoi RSR [The method of large-scale research of soils of kolkhozes and state farms of the Ukrainian SSR]. Kharkiv: Derzhsilhospyvdav. 1958. 487 p. [In Ukrainian].
11. *Ponomareva V.V., Plotnikov T.A.* (1980). Gumus i pochvoobrazovanie [Humus and soil formation]. Leningrad: Nauka. 319 p. [In Russian].
12. *Rode A.A.* (1984). Genezis pochv i sovremennyye protsessy pochvoobrazovaniya. [Soil Genesis and Modern Soil Formation Processes]. Moskva: Nauka. 256 p. [In Russian].
13. *Crocker R.L.* Soil genesis and the pedogenic factors. *Q. Rev. Biol*, 1952. P. 139–168.
14. *Buol S.W., Southard R.J., Graham R.C., McDaniel P.A.* Soil Genesis and Classification, Sixth Edition. *Wiley-Blackwell*, 2011. 560 p.