AGROECOLOGICAL SIGNIFICANCE OF CHERNOZEM SOIL PASPORTS FOR EVALUATION OF SOIL DEGRADATION

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Introduction. The price for sustainability of an agricultural landscape includes expenses on sustaining its production and ecological functions, such as nature protection. [2,3]. Natural landscape sustainability often does not hold any significance for agriculture, in particular, when an agricultural scientist is not interested in sustainability, but is interested in the landscape adaptability for melioration and reclamation. [1, 4-6]. In contrast to self-regulating functioning of a natural landscape, an agricultural landscape functions in a human-preset mode. Its sustainability is related to maintaining of the pre-planned functioning parameters (physical and chemical soil conditions, hydrolysis, etc.) by means of certain efforts. In this regard, a special significance is assigned to those indicators that describe soil production capacity and its environmental sustainability. According to the current requirements for soil evaluation, such indicators are included into the document known as “Soil Passport”.

Methodology. Both field and laboratory research was carried out while drafting a soil passport for OOO “Selskie Zori” (located in Timsky District of Kursk Region).

The object of our research is typical medium-loamy chernozem of the Western ecozone in the central part of the Central Russian forest-steppe subprovince. The terrain is marked by different altitude horizons, ancient and recent forms of linear erosion, i.e. a vast network of complexly branched river valleys, ravines and gullies that penetrate the watershed. Furthermore, the terrain is gently undulating, slightly hilly and flat; the density of the valley-ravine network ranges from 0.7 to 1.3 km/km^2, while the density of the gully network varies from 0.1 to 0.4 km/km^2. The area elevation reaches 175-225 m above sea level. According to the botanical and geographical division of the territory, it constitutes a part of the subzone of the central forest-steppe. The land use type of the researched object is agricultural land (arable land, hayfields, pastures, perennial vegetation).

Results. Under current land-use conditions the following soil parameters are elicited: low erosion levels, decrease in humus levels by 5-15% compared to humus levels in non-eroded soils (5.89%), increase in soil density to 1.27-1.29 g/cm^{2}, increase in soil porosity by 95-98%, decrease in depth of the humus horizon. In order to minimize erosion-caused soil degradation, it is recommended to carry out a range of agricultural anti-erosion measures, such as optimization of the cultivated areas structure, soil-protective crop rotation and tillage improvement.

Soil profile of a typical chernozem soil in the national soil classification system is the following: An – A – AB – Bk – BCk – Ck; while the horizons are labeled as PU – AU – AU (Ca) – BCA – C (Ca) in the FAO-UNESCO classification; upper and lower horizon boundary: An^{o}22=A^{22}46=AB^{46}75=Вл^{75}93=BCK^{93} 135=Ск^{135}↓; horizon transition: An-A – clear in structure in density; the boundary is uneven and indistinct, A=ABk – gradual transition in color and calcium carbonate presence, calcium carbonate compounds, the boundary is uneven, distinct, tongued; Bk=BCk – gradual transition in color, the boundary is uneven; BCk=Ck – wave-like color transition.

Soil horizons morphology:

An – arable horizon – dark gray in a dry state, black when moist, moist, weakly cloddy, medium loamy, permeated with roots; soil density is 1.18g/cm 2; total porosity 53.8%, humus content 5.89%, total nitrogen content 0.30%, ratio (C: N) 11.4; The pH of the salt extract is 5.22; The pH of the aqueous solution is 6.39; CEC in accordance with GOST 17.4.4.01. – 33.7 meq/100 g; base saturation – 88.9%, calcium carbonate content (CaCO3) – not detected; the content of mobile phosphorus is 145.6 mg/kg; mobile potassium – 140 mg/kg, the content of exchangeable calcium cations – 31.4 meq/100 g, magnesium – 3.3 meq/100 g; the content of salts in the aqueous extract is K^{+} 0.01 meq/100 g, Na+ – 0.14 meq/100 g, Ca^{2+} 0 0.55 meq/100 g, HCO3 0.86 mol-100 g, 0.43 mmol/100 g.

A – humus-accumulative horizon – dark gray in a dry state, black when moist, moist, lumpy, medium loamy, plant roots, density – 1.22 g/cm^{3}, total porosity – 52.9%, humus content – 5.90%, the content of total nitrogen – 0.28%, the ratio (C:N) – 12.2; pH of the salt extract – 5.58; pH of the aqueous extract – 6.50; CEC – 34.5 meq/100 g, base saturation 90.5%, mobile phosphorus is present.

ABk – a transitional humus horizon, dark gray with a brownish tinge in a dry state, dark gray in a wet state, a lumpy structure, weakly compacted, medium loamy, calcium carbonates are in the form of mold, inclusions of plant roots, effervesces from a depth of 62 cm, wormholes, Dark yellow fine-grained, moist.

Bk – a transitional horizon, brownish-pale yellow, humus deposits, moist, cloddy structure, compacted, single roots, heavy loam, molehills filled with dark brown fine earth, effervescence throughout the horizon, carbonates in the form of pseudomycelium, boundary is uneven, clear, ligature, color transition.

BCk - lower transition horizon, light-colored, prismatic structure, dense, medium loamy, carbonates in the form of loose pseudomycelium, mold, heavy effervescence, in the lower part the horizon transitions to the parent rock.

Ck - soil-forming rock, brown-pale yellow, KCl pale loess-like loam. The depth of effervescence from hydrochloric acid: low from 62 cm, high from 80 cm. The type of the soil is a typical chernozem soil with average depth and average loam and humus levels.

Chemical and physical-chemical soil indicators:

According to our research, humus levels in the examined soils vary from average (4-6%) on 64% of soil area to above average (6-8%) on 36% of soil area. The main reasons for humus level decrease are erosion and low amount of organic fertilizers.

CEC of a typical chernozem varies within 31.7-51.1 meq/100 g, which determines high buffering capacity as well as resistance to anthropogenic impacts and various chemical contaminations. Among exchange cations, the most important is the number of Ca^{2+} and Mg^{2+} ions, and to a lesser extent the number of exchange H^{+} ions. These cation rates lead to favorable physical properties and structural condition for soil and base saturation. The acid-base conditions of a typical chernozem soil are characterized as subacidic on a pH water extract. This soil condition determines high biological activity, a good accessibility of phosphorus, potassium, favorable nitrogen mode, activation of ammonification, nitrification, nitrogen bonding and accessibility of microelements. Analysis of soil acidity revealed that 65% of arable soil has subacidic and close-to-neutral pH levels, which is favorable both for humus genesis and for activation of microbiological activity, growth and development of plants.

Water extracts contain insignificant amount of cations Na^{+} – 0,002 - 0,007, Sa^{2+} within the limits of 0,002 - 0,016%, and anions HCO3 – 0,006 - 0,052% ; Cl – 0,002 - 0,01%. This data reveals low concentration of soil solution, and the absence of antagonism between cations and accessibility of nutrient element. Thus, deficiency of these elements for plants is non-existent.

Labile forms of phosphorus and potassium are average, increased and high; at the same time, there is a slight variation in nutrient accessibility in subarable horizons of a typical chernozem soil compared to arable horizons (Tables 1, 2).

Table 1-Soil grouping (exchange phosphorus)

№ of group	P2O5 mg/100g	Phosphorus level	Phosphoric fertilizers requirement	Arable land 2014	
				Ha	%
1	Less than 2,0	Very low	Very high	40,60	3,7
2	2,1-5,0	Low	High	0	0,00
3	5,1-10,0	Average	Average	484,00	44,6*
4	10,1-15,0	Increased	Low	559,70	51,6*
5	15,1-20,0	High	Not required	0	0,00
6	over 20	Very High	Not required	0	0,00
	Total:			1084,59	100

№ of group	K2O mg/100g	Potassium level	Fertilizers requirement	Arable land 2014	
				ha	%
1	Less then 2,0	Very low	Very high	0	0,00
2	2,1-4,0	Low	high	0	0,00
3	4,1-8,0	Average	Average	0	0,00
4	8,1-12,0	Increased	Low	252,30	23,3
5	12,1-18,0	High	Not required	739,20	68,2
6	Более 18	Very high	Not required	92,80	8,6
7	Total:		1084,5999		100

Table 2-Soil grouping (exchange potassium)

In order to evaluate soil degradation processes, it is necessary to take into account natural and anthropogenic soil evolution.

Our research attempted to reveal the levels of degradation of soil fertility in typical chernozems under intensive agricultural land use.

There is a strong interconnection between various types of degradation in soil, vegetation, terrain and other components of ecosystems, that is, degradation of one of the components leads to degradation of other components [5].

Table 3 – Degradation indicators of a typical chernozem soil

Indicators	Values of degradation indicators				
	0	I	II	III	IV
Humus, %	6.75	6.19	5.77	5.28	4.85
% of decrease	-	8.3	14.5	21.8	28.1
<0,01 mm, %	34.62	32.51	32.39	32.37	32.23
% of decrease	-	6.1	6.4	6.5	6.9
pH kcl	5.61	5.65	5.67	6.03	6.60
% of indicators increase	-	0.7	1.1	7.5	17.7
CEC, meq/100g of soil	42.38	41.6	41.08	40.65	38.8
% of decrease	-	1.8	3.1	4.1	8.4

Based on the experimental data, we have evaluated chernozems soil degradation with the following parameters: humus levels, clay levels, величина обменной кислотности, CEC for cultivated horizons. According to the research results, various degrees of chernozem degradation are suggested: «no degradation»-0, «low degradation»-I, «medium degradation»-II, «increased degradation»-III, «high degradation»-IV.

As Table 3 indicates, non-degraded soil contains 6.75% humus levels. Insignificant soil destruction processes decrease humus level by 8.3%, consequently, average humus level is 6.19%. With intensification of degrading processes, humus level in cultivated horizons decreases to 5.77%, or by 14.5% compared to undisturbed soil. With increased manifestations of soil degradation, humus level in arable horizons decreases by 22% and humus level falls to approximately 5.28%. At high degrees of anthropogenic degradation, humus level decreases by 28.1% and reaches 4.85%. Since humus level is a vital condition for ecological sustainability and proper ecological functioning, it is possible to conclude that intensive land use, intensive mechanical soil tillage and insufficient distribution of organic fertilizers cause transformational changes and migration of humus compounds.

Main indicators of soil fertility depend on its granulometric composition, which is a fundamental property of any soil. Distinctive hilly terrain of the forest-steppe areas creates conditions for water erosion and eluviation of the clay particles by downstreaming ground waters. In this connection, we have detected anthropogenic impact on the changes in clay particles in the arable horizon of a typical chernozem soil.

In those typical chernozems that are not subject to any anthropogenic impacts, clay particles constituent 34.62%, while the amount of clay particles decrease by 6.1-6.9% in degraded soils depending on soil degradation intensity. Decrease in clay particles (which are average- and small-sized dust and silt) cause decrease in soil sorption capacity and worsening of water-physical and physical-chemical parameters.

In the conditions of forest-steppe zone, the principal cause of anthropogenic change of soil is the danger of erosion development, which can result in reduction of the humus layer depth, increase in the level of detection of calcium carbonates in soil, changes in soil environment. The research reveals that the values of exchange acidity in arable horizons change in the presence of degrading transformations. It is shown that when the rates of soil wash-off increase, pH levels increase from close to neutral up to neutral, from pH 5.61 to pH 6.6, that is, gradual soil alkalization occurs in soil.

Soil degradation causes decrease in soil sorption capacity, predefined by the presence of organic matter and clay particles. The table shows that the anthropogenic changes in typical chernozems are related to the changes in CEC values. First, CEC is 42.38 meq/100 g in non-degraded soils, afterwards degradation levels result in CEC decrease by 1.8% at a low degradation level and up to 8.4% at a high degradation level.

The obtained results allow us to conclude that when soil is transitioned to a less stable state, soil genesis and transformation take place is in the conditions of development of degradation processes.

The evaluation of heavy metals in soils and their influence on the components of an ecological system has an important practical value. Increased concentrations of particular heavy metals change the composition of microbiota and vegetation communities. Heavy metals can alter the intensity and direction of soil formation processes, furthermore, formation of top layers soil fertility takes place under soil transition to a less stable state.

Table 4 – Labile forms of heavy metals in the arable layer of degraded typical chernozems (mg/kg)

Degradation level	Cu	Cd	Pb	Zn
Not detected 0	0.042	0.053	0.58	0.46
Low I	0.049	0.056	0.64	0.54
Medium II	0.051	0.057	0.68	0.49
Increased III	0.05	0.16	0.67	0.56
High IV	0.06	0.63	0.72	0.48

The development of degradation changes in soil results in a natural change of the concentration of heavy metals. Thus, for copper, cadmium and lead to greater extent influence of pH level to confirming of these metals is displayed, higher base levels and pH values correlate with higher heavy metal concentration in arable soil layers.

Chernozem fertility changes as a result of development of natural and anthropogenic degradation. Assessment of the economical damage reveals that the cadastral cost of the examined area is 13.05 RUR/1m^2. The total cost of a 1084.6 ha territory is 141 540 300 RUR. 1.47% humus loss from the initial 6.75% average humus levels causes depreciation of the area by 30 824 332 RUR or 28.42 thousand RUR per ha.

CONCLUSION:

Changes in chernozem soil fertility as s result of anthropogenic impact lead not only to decrease in ecological sustainability and subsequent harvest losses, but also to a significant economic damage, which requires immense expenditures to reproduce lost fertility and obtain projected harvest.

In cases when soil tillage and soil energy state are transitioned to a higher level, soil stability decreases and can only be maintained by a correspondent anthropogenic influence. Cessation of such influence causes intensive soil degradation. Knowing soil processes and conditions allows to estimate optimal parameters for various conditions of economic use. Development and drafting of a Soil Passport constitutes both effective land use and its legal regulations.

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