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Article

The essence of soil and soil formation in accordance with soil water regime

Tatyana Romanova[1], Aliaksandr Chervan[2,*], Nadezhda Ivakhnenko[1]

[1] Institute for Soil Science and Agrochemistry of National Academy of Sciences of Belarus, Minsk 220108, Belarus

[2] Belarussian State University, Minsk 220030, Belarus

*** Corresponding author:** Aliaksandr Chervan, ChervanAlex@gmail.com

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Abstract: The obtaining of new data on the transformation of parent materials into soil and on soil as a set of essential properties is provided on the basis of previously conducted fundamental studies of soils formed on loess-like loams in Belarus (15,000 numerical indicators). The study objects are autochthonous soils of uniform granulometric texture. The basic properties without which soils cannot exist are comprehensively considered. Interpolation of factual materials is given, highlighting the essential properties of soils. Soil formation is analyzed as a natural phenomenon depending on the life activity of biota and the water regime. Models for differentiation of the chemical profile and bioenergy potential of soils are presented. The results of the represented study interpret the available materials taking into account publications on the biology and water regime of soils over the past 50 years into three issues: the difference between soil and soil-like bodies; the soil formation as a natural phenomenon of the mobilization of soil biota from the energy of the sun, the atmosphere, and the destruction of minerals in the parent materials; and the essence of soil as a solid phase and as an ecosystem. The novelty of the article study is determined by the consideration of the priority of microorganisms and water regime in soil formation, chemical-analytical identification of types of water regime, and determination of the water regime as a marker of soil genesis.

Keywords: soil formation; essential properties; biota (microbiota); water regime; bioenergy potential

1. Introduction

By the beginning of the 21st century, an opinion about the danger of modern environmental management in general for the life of the Earth's population along with the need to protect nature had been formed in the circles of the scientific community. In the last decades, the issue of nature-like technologies for using biosphere resources, including soils, has been actively discussed [1,2]. The design of such technologies requires an adequate understanding of the nature of soils and prediction of changes in their properties under anthropogenic influence [3,4]. This is evidenced by the attention to soil science problems in the scientific literature [5–8] and journalism [9].

The International Society for Soil Science approved World Soil Day (December 5) under the slogan "Soil is the basis of life," but the definition of "soil" remained in a descriptive version according to Dokuchaev's [10] paradigm. The opinion that there is no single definition of the concept "soil" was expressed by Sokolov [11], and the conclusion that "...the essence of the soil-forming process remains completely unclear" has been made [7]. Chukov and Yakovlev [12] describe the lack of consideration of soil characteristics in Russian land legislation.

The results of soil research obtained in recent years are accumulated but are not combined into general theories [13]. This was noted at International Congresses in Montpellier [14], in Philadelphia (2006), at the congresses of Society soil scientists (2008, 2016, 2020).

Dokuchaev [10] defined soil in 1886 as a special natural-historical body. Gerasimov [15] introduced the concept of elementary soil processes (ESP) into the theory of soil science [15]. About 60 ESP have been described, although there is an opinion that the very concept of ESP is ambiguous and often does not correspond to the definition of "elementary" [13]. Nevertheless, the paradigm "factors-processes-properties" remains the recognized level of scientific achievements of modern soil science.

Soil research in Belarus has intensified in connection with the development of hydro-reclamation since the 1960s of the last century. In its first stages, already in the 1970s, negative consequences along with successes were also discovered, including a decrease in soil fertility in areas adjacent to drainage structures. These changes required special attention to the study of soils of varying degrees and natures of moisture in different parent materials. From 1975 to 1995, a large amount of actual field data was collected. Subsequently, soil science in Belarus developed in the direction of soil geography as detailed (scale 1:2000) mapping, development of research methods, and description of the soil cover structure. From 1995 to 2020, generalizations were compiled and published [16–18]. A fairly complete understanding was obtained not only of the needs of the republic's soils for hydro-reclamation and their changes under the influence of drainage [19,20] but also of the water regime as the most important property of the soil [21].

Numerous characteristics of soil profiles revealed features inherent in the soil as a whole, in itself, and in specific soils, which can be considered, on the one hand, as natural systems (part of the biosphere), on the other—as a solid body phase (part of the soil) with a set of knowable properties. It makes possible to display the soil through an ensemble of essential properties and formulate a detailed general idea of the soil as a system of interconnected nonlinear processes. The synergetic approach most likely clarifies the concept of soil origin [16,17].

In this article, the declarative nature of these first formulations is replaced by reasoning based on the interpretation of previously collected materials [22] concerning the essence of soils. However, the essence of something is not observable in itself and is established on the basis of phenomena (basic properties) without which the object (soil, in this case) can't exist. The totality of such properties constitutes the essence of each soil (soil taxon), determines its genesis, which distinguishes it from a number of its own kind and allows to form a general idea of soil formation. A review of the collected information determined the purpose of this study—to clarify existing ideas about soil and soils as nature components and the basis for the development of technologies for their sustainable use. The original actual field data were used by the authors to obtain new data; the object of study is the pedoecological series—catena, and the subject of study is the properties that determine the essence of soils.

2. Objects and methods

2.1. The study area

The study area is characterized by a high-altitude soil-geobotanical profile (**Figures 1** and **2**), which is representative of the conditions of mixed forests and southern taiga in the humid zone of Eurasia. The site has the form of a transect with length 2.1 km and radius 0.4 km elongated in the latitudinal direction on the southern slope of the Minsk Upland (the central part of the East European border) on cohesive soil-forming parent materials—Valdai moraine with a cover of silty (loess-like) loams. Tectonically, the territory is an element of the Belarusian crystalline massif with Devonian deposits in the form of dolomites and dolomitized limestones. It is overlain by sedimentary deposits of the Quaternary period of the anthropogenic system. They consist of rocks of the Valdai (Sozh) glaciation with a thickness of 60–135 mm covered with loess-like loams. The thickness of the loams at the site decreases from 5 m at higher elevations to 0.8 m in the lower parts of the slopes where the loams are underlain by moraine sands. The relief of the territory is a gently undulating glacial-accumulative plain rising 150–200 m above sea level. The geomorphological appearance is dominated by long, gentle slopes with shallow valley depressions. In some areas, there are short, gentle slopes adjacent to closed depressions with a diameter of 10–20 m and a depth of 0.5–1.0 m. The soil-forming rocks are light silty (loess-like) loams, in places underlain from a depth of 0.5–0.8 m by moraine sands. The climate is mild temperate continental: radial balance 1500–1800 MJ/m^2, precipitation 560–700 mm per year [21].

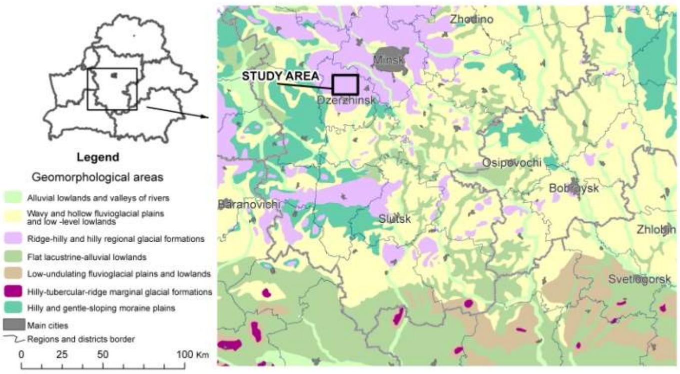


Figure 1. Study area.

According to observations of a weather station 20 km from the test site, the average air temperature for the year is 5.5 degrees, in July 17.6, in January 6.7; sum of temperatures more than 10 degrees 2000–2500, duration of the growing season 190 days. The average annual precipitation is 625 mm, for the warm period 400 mm; moisture coefficient: 1.0–1.1 annual, 1.1–1.2 in spring, 0.7–08 (up to 0.5) in summer. The climate is representative of coniferous-deciduous forests and the southern taiga of the humid zone of Eurasia [22]. Natural vegetation at the test site is represented by oak-spruce and aspen-spruce forests (**Figure 2**).

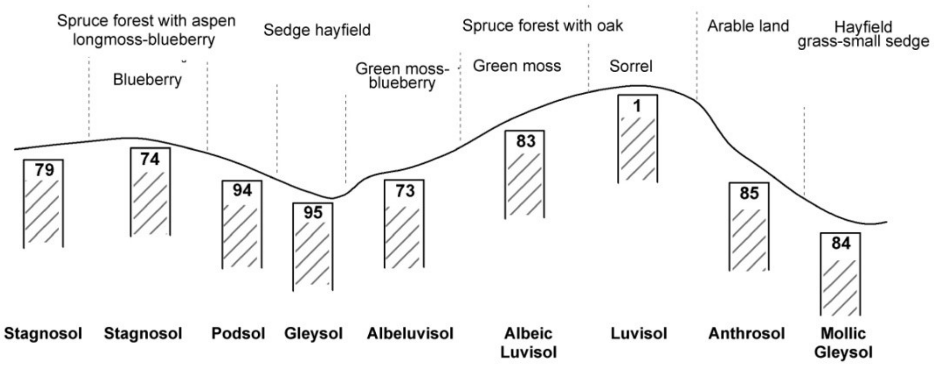
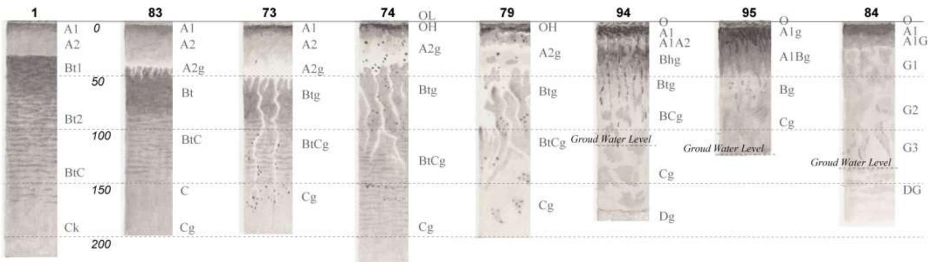


Figure 2. Soil transect.

2.2. The object of the study

The study object is typical soils of Belarus (**Figure 3**) developing on cohesive rocks (loess-like loams)—8 profiles of postlithogenic soils characterized by varying features and degree of moisture (**Figure 2**). The same soils in the World Reference Base for Soil Resources [6] are classified as ones with illuvial-clayey horizons (Bt) and reference soil groups: Albeic Luvisols, Albeluvisols, Anthrosols, Luvisols, Mollic Gleysols, Podsols, and Stagnosols (**Figure 2**). This article further uses the Belarusian nomenclature of soil taxa based on the 1977 USSR Soil Classification. The issues of classification and nomenclature of soils Zonn [8] remain relevant Rozhkov [23]. The experience of constructing a natural classification with determination of soil sites by their properties is presented in [16].



Soil horizons: O - moss; OL - mat fermented; OH - mat humused; A1 - humus-accumulative; A2 - subhumic; A1A2 - transition from humus-accumulative to podzolic; A1Bg - transition from humus-accumulative to illuvial gleyic; A1G - humus-accumulative gley; A2g - subhumic with gleyic at the contact; Bt1 - illuvial-clayic homogeneous; Bt2 - illuvial clayic layered; BtC - soil-forming rock with signs of illuviation; Btg - illuvial-clayic gleyic; Ck - soil-forming rock carbonate; Cg - soil-forming rock gleyic; G1,2,3 - gleyic with different morphology

Figure 3. Pedoecological series and morphology of soil profiles of loamy granulometric texture.

2.3. Research methods

The description of all soil characteristics corresponds to national standards and fundamental research in the field of soil science. The methodology is based on the use of the inductive method (representation of the whole through its parts) and the commensurability of the soil taxon with the ecosystem.

Field (natural) studies included descriptions of the location of soil profiles, the botanical structure of ground cover plants, the morphological characteristics of soils with profile sketching, carbonates and gley testing, sampling for general chemical analyses, and determination of physical parameters of water. Samples for all types of analyses were taken from one common sample.

Observations for the dynamics of soil formation were carried out monthly (30 times in total) along the genetic horizons of profiles 83, 73, 74, 94, and 95 (**Figure 2**).

Field humidity was determined by the thermostat-weight method, and the soil temperature and redox potential (Eh) were estimated. The soil samples were taken for content analysis of eight mobile chemical compounds.

In laboratory conditions were determined: granulometric texture (according to the Kachinsky method), gross chemical structure of the total mass of soil and fine-grained soil material, clay minerals in fine soil particles, content of crystalline and amorphous forms of iron, aluminum, and silicon, content of total nitrogen and organic carbon (humus), groups, and fractional structure of humus. Monitoring of monthly changes in field humidity, pH, and Eh content of P_2O_5, Al_2O_3, K_2O, CaO, MgO, FeO, Fe_2O_3, and MnO was carried out with statistical processing and graphical presentation of the results.

The total number of numerical indicators at the research site is about 15000 [22]. Micromorphological descriptions with microelectron photography [18] were carried out for individual soils.

3. Research results

The soil studies results traditionally include descriptions of the environmental conditions of their formation, the profile morphology, and the determined properties. High-altitude soil-geobotanical profile (**Figure 2**) represents the position of each profile in landscape. Field sketches of soil profiles (**Figure 3**) are ranked by moisture degree according to the gradation accepted in Belarus—each subsequent element differs from the previous one by one degree of moisture (catena approach). The catena approach to soil research was used in Belarus in the last century [24] and is currently used abroad [17,25,26].

Soil morphology reveals a certain organization of vertical profiles persisting over time and indicating resistance to entropy accumulation. According to the second law of thermodynamics, this is only possible in an open system with the supply of additional energy from the outside, which confirms the first feature of the soil itself—its systemic energy-dependent nature. **Figure 3** gives an idea of soil diversity replacing detailed descriptions of soil morphology. It allows noting in the profiles of semi-hydromorphic soils (profiles 73, 74, 79) a general lighter color and the presence of vertical "veins" (possibly a trace of permafrost processes of the Valdai period), dark illuvial-humus horizon Bh (profile 94), and thick humus horizon (A1) of hydromorphic soil (profile 95).

3.1. Soil properties

3.1.1. Water-physical

Water-physical (moisture of soils) is usually represented based on information about field humidity. Soil graphs (average values) display the amount of incoming surface water and its movement (distribution) in soil profiles of varying degrees of moisture (**Figure 4**). This is the basis for the identification of types of water regimes, which will be discussed separately below.

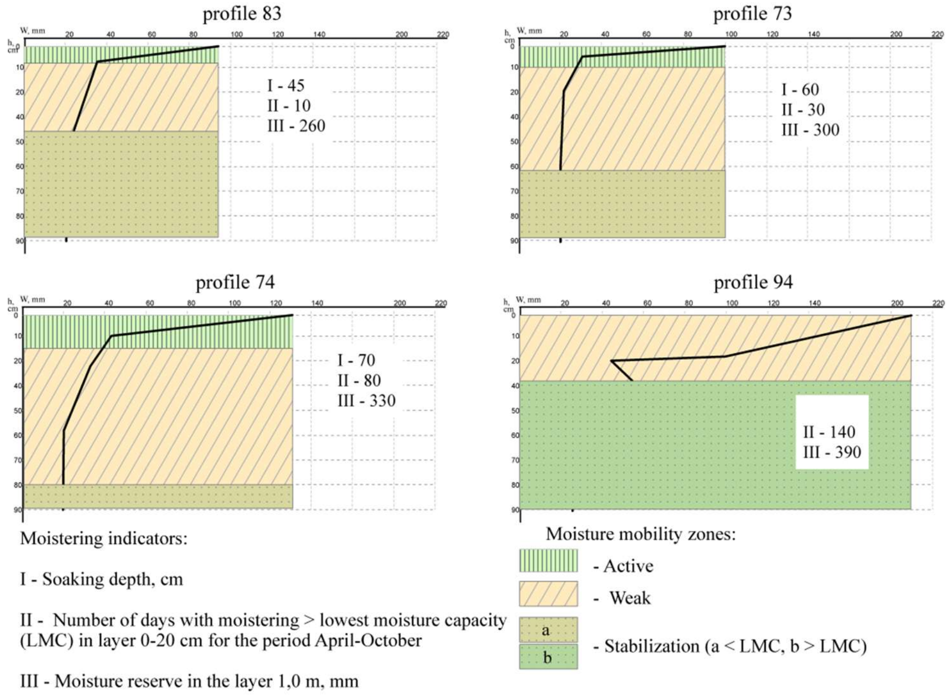


Figure 4. Soil graphs of moistering indicators and mobility zones.

The distribution of moisture over the genetic horizons of three soils with different degrees of moisture (profiles 83, 73, 74) was verified by a statistical (arithmetical mean) method of processing data on the mobility of the previously listed oxides and made it possible to establish reliable depths of wetting (penetration of hydrostatic moisture) into each soil (**Figure 4**).

3.1.2. Soil granulometric texture

Loess-like loams as soil-forming parent materials are widespread in the upland conditions of Belarus. Their originality lies in the predominance (50%–70%) of silt particles (0.05–0.001 mm) with an almost complete absence of large fractions (more than 1.0 mm) and a close to equal (20%–25%) content of fine sand fraction (0.25–0.05 mm) and clay-silt fraction (less than 0.01 mm) as well as coarse silt (0.05–0.01 mm) and clay (less than 0.001 mm)—approximately 10%.

A feature of the granulometric texture of soils developing on loess-like loams is considered to be the textural differentiation of profiles with the accumulation in their middle part of clay (20%–25%) and silt (12%–15%), forming the Bt horizon—illuvial-clayey.

It is known that soil-forming parent materials as a result of physical weathering are crushed to particles with a diameter of about 0.001 mm, but further destruction of these particles to pre-colloidal and colloidal sizes is carried out by microorganisms [2,27–29], revealing the biological origin of the initial part of the soil granulometric texture.

3.1.3. Mineralogical structure

Local loess-like loams have a simple mineralogical structure: quartz 80%–90%, feldspars 10%–15%, accessory minerals—biotite, amphiboles, garnets, etc. ~ 1% [18]. The total mass of soils is dominated by the original ones (quartz, feldspars, micas), and some newly formed minerals are present. The structure of the silty fraction is characterized by the presence of hydromica, kaolinite, chlorite, and fine-grained quartz, as well as newly formed clay (soil) minerals. Moreover, these are clay minerals of the vermiculite group, close to hydromicas in automorphic soils (profiles 1, 83) and montmorillonite group in semi-hydromorphic soils (profiles 73, 74, 79, 94). The connection between the transformation of hydromicas and soil hydromorphism, as well as a progressive increase in transformation up the profile, indicates the soil origin of clay mineral associations. At the same time, it is emphasized that only a small part of clay minerals participates in the biological cycle [30]. According to the majority of researchers starting with Dokuchaev [10], it is recognized the leading role for soil biota and especially for microorganisms in the transformation of minerals due to their ability to selectively absorb elements—biophiles [5]—with the mobilization of solar and atmospheric energy as well as after minerals destruction's energy due to their life activity.

3.1.4. Chemical composition

The chemical composition of the studied soils is characterized by the maximum number of analytical indicators. The most informative of them are used in physical models of chemical differentiation profiles (**Figure 5**) in the form of graphs of the total silt content in the soil-forming material, the total content of bases (CaO and MgO) and sesquioxides (Fe_2O_3 and Al_2O_3) in the total mass of soil and in clay material, as well as indicators of clay decomposition (SiO_2:Al_2O_3) and the content of amorphous iron (**Figure 5**). The presented models are visualized by curves; their origin and combination are the distinctive (diagnostic) characteristics of each soil as a taxon.

A comparison of the vertical distribution of total clay in the parent material (taking into account ignition losses) and in fine-grained soils (marker—the total content of sesquioxides) reveals similarities in the chemical composition of the soil and parent material. The gross composition of silt, on the contrary, clearly reflects the difference between soil and parent material. Thus, in profiles 73, 74, and 83, despite the textural heterogeneity of the profiles, the chemical composition of the silt and the SiO_2:Al_2O_3 indicators in the silt almost do not change across the horizons (**Figure 5**). This fact may indicate intrahorizontal transformations of the chemical composition of clay material without decomposition of minerals and without movement of products or the movement of fine-grained soil material in an unchanged state—lessivage [17], or primary (lithogenic) heterogeneity of the substrate. The soil of profile 94 has obvious signs of mineral decomposition (dashed line SiO_2:Al_2O_3). Soil hydromorphism is manifested in the distribution of amorphous iron along the profiles (**Figure 5**).

Comparing chemical differentiation (**Figure 5**) with graphs of changes in moisture content of the same soils (**Figure 4),** it is easy to notice the similarity of profiles 73, 74, and 83 in the distribution of moisture and sesquioxides. The observed differences between the soils of this group and the soil of profile 94 indicate their different nature. This allows us to conclude that the chemical differentiation profile curves make it possible to differentiate soils based on the test results, regardless of the methods used.

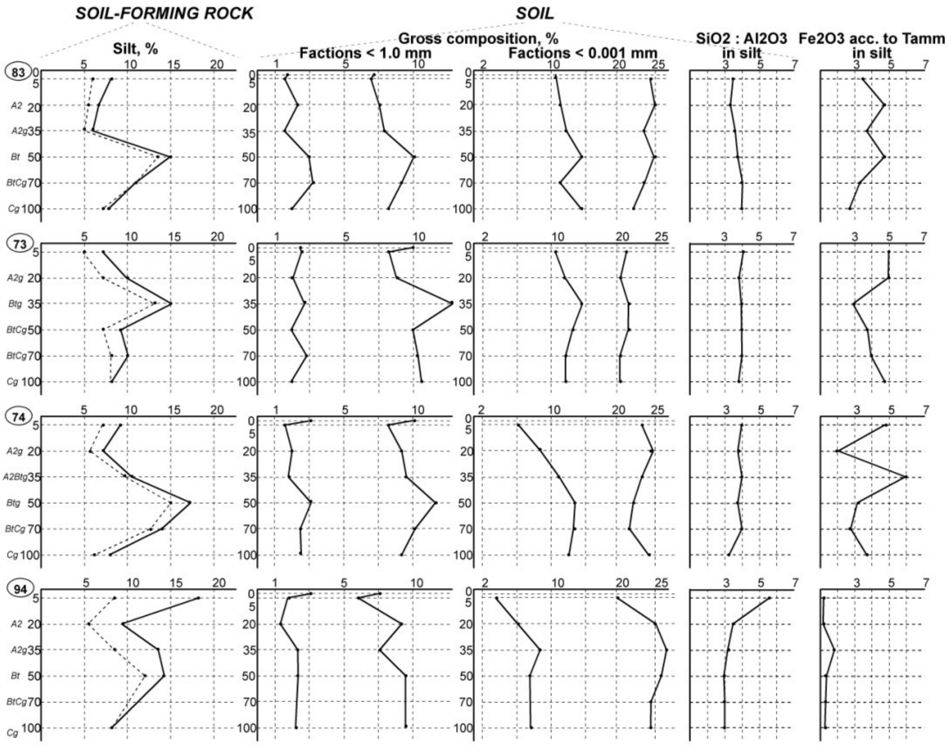


Figure 5. Chemical differentiation of soil profiles.

3.1.5. Organic matter, including humus

Organic matter—including humus—is an integral component of soil as a natural formation. The analytical characteristics of humus in the studied soils are presented in **Table 1**.

Humus content (%) and its reserves in the 0–20 cm layer (t/ha) indicate a correlation with hydromorphism. The relatively high share of humin as the most stable humus component indicates that the humus of the studied soils is characterized by low solubility and a high degree of mineralization. The humus composition ratio (Ch: Cf = 1.0–1.2) is given in **Table 1** and close to the structure of humus in gray forest soils [5]. The share of humic acid carbon in total soil carbon is in the range of 22%–38% (**Table 1**), which corresponds to the natural conditions of the broad-leaved forest zone [31,32]. Both of them indicate a connection between the group structure of humus and zonal climatic conditions [33]. Fractional structure of humic acids (**Table 1**) is determined by the chemistry of the soil-forming materials—fractions associated with sesquioxides (Ch1) predominate, a small proportion of fractions associated with calcium—Ch2, and quite high (with the exception of profiles 94, 95) with soil minerals—Ch3.

The source of humus is biomass (plants, fungi, animals, and microorganisms) accumulated and decomposed by microorganisms with the participation of enzymes [34], which have the ability to deeply transform the "raw material resource". Humus accumulates the energy from the Sun and the Earth initially assimilated by plants and animals, the energy of the atmosphere in the form of moisture entering the soil, and the energy of the destruction of minerals [35]. This fact allows us to consider humus as an indicator of the overall energy supply of the soil. "Green plants together with microorganisms involve solar radiation energy in the process of soil formation", as

D.G. Zvyagintsev writes [29].

Table 1. Analytical characteristics of humus in the studied soils.

Indicators		Soils (№ profile)							
		1	**83**	**73**	**74**	**79**	**94**	**95**	**84**
General humus	Depth A1, cm	4	4	4	5	6	10	21	17
	OSM content, %	5.9	5.5	7.0	13.5	16.2	19.3	19.0	29.2
	Reserves in the layer 0–20 cm, t/ha	31.2	43.0	75.0	105.4		152.3	144.0	239.8
Group humus	Group structure	1.4	1.0	1.0	1.2	n/m	1.0	1.1	1.4
	Humin, %	55.4	44.8	43.6	27.5	32.3	34.7	26.3	33.3
	Ch/Ctotal, %	n/m	22.5	22.4	28.4	n/m	33.0	37.0	38.0
Fractional humus	Ch1 from the sum Ch, %	n/m	52	67	54	n/m	71	59	24
	Ch2 from the sum Ch, %	n/m	2	0	6	n/m	12	12	41
	Ch3 from the sum Ch, %	n/m	46	33	40	n/m	17	29	3

3.1.6. Redox potential

Redox potential characterizes the biological activity of soils through an indicator of the intensity of their chemical and biological state—redox potential—Eh with a range of fluctuations from 180 to 700 mV [21]. Romanova notes [21] that the most important factors influencing redox conditions are temperature, humidity, and biological processes. At the same time, some authors give preference to hydrothermal conditions [36], others—to biological processes [5,37]. Our observations of Eh and biological activity of soils showed that the most noticeable correlation between soil Eh is with the autumn supply of litter and plant residues. In autumn, Eh was determined to be equal to 200 mV, and during spring waterlogging (maximum precipitation)—500 mV [22].

3.1.7. Soil water regime

In our study, special attention is paid to the soil water regime. The foundations of the doctrine of the water regime of soils laid by G.N. Vysotsky developed by Rode [38], who represents the water regime of soils in two aspects: 1) movement or stagnation of moisture in the profile—the type of soil water regime; 2) moisture content in the profile—soil moisture. Types of water regime of soils in the humid zone of the Northern Hemisphere within b. USSR proposed by Rode [29] still serve as a guide used for scientific and practical purposes. The materials collected in Belarus (including those described) made it possible to compile a new (complete) list of types of soil water regime based on monitoring the average long-term moisture supply of arable soils in the country. **Figure 2** demonstrates the role of terrain as a factor in the formation of water regime types, which, in turn, determines the entire diversity of genetic soil types (**Figure 3**). The cause-and-effect relationship between the genesis of soils and the geomorphology of the territory is considered by Dixon [1].

The data in **Table 2** provide generalized information about the water regime of natural soil types in Belarus and illustrate the research results. The following data are presented: 1) a list of types of soil water regime in a new edition (preserving the principle used in the names of A.A. Rode); 2) movement of moisture in the soil profile; 3) soil moisture.

The movement of moisture can be estimated by the severity of chemical differentiation of profiles compatible with the presence or absence of signs of decomposition of soil minerals (**Figure 5**). The direction of movement and the nature of moisture entering the soil can be traced in **Figures 2** and **4**.

Table 2. Types of soil water regime (based on research materials).

Type of water regime	**Movement of moisture in the soil profile**			**Soil moisture**			
	Chemical profile differentiation (Figure 5)	**Direction**	**Admission (source)**	**Soaking depth (m)**	**Waterlogging period (days), (Figure 4)**	**Moisture reserve (t/ha)**	**Hydromorphism (№ profiles) (Figure 2)**
Non-flush	Not evident	Vertical	Peliculation (dampening)	0.5	10	260	Automorphic (83)
Stagnant-flush	Not evident (weak)	Lateral	Infiltration and accumulation	0.6–0.8	30–80	300–350	Semi-hydromorphic (73;74)
Flush	Clearly expressed	Vertical	Infiltration and influx	1.3	140	380	Semi-hydromorphic (94)
Effusion	Accumulation at the border of the capillary fringe	Ascending	Evaporation (deduction)	Not determined	Not determined	Not determined	Hydromorphic (84)
Stagnant	Not expressed, absent	Stagnant	Accumulation	Groundwater Level	Not determined	Not determined	Hydromorphic (85)

Soil moisture in Belarus (quantitative assessment) was developed and published in the journal "Soil Science" at the end of the twentieth century. Today it is taken to be the number of days with humidity above the minimum moisture capacity in the 0–20 cm layer for the period April–October. In **Table 2,** soil moisture, moisture depth, and moisture reserves in the meter layer are the result of specific measurements of field moisture (**Figure 4**). The movement of moisture (chemical differentiation of profiles) and moisture content together reflect both general features (the level of hydromorphism and the characteristics of each type of water regime). The list and completeness of the given characteristics of the types of water regime of soils in Belarus suggest their relevance for the entire southern part of the humid zone of Eastern Europe.

Types of soil water regime:

- non-flushing—an attribute of automorphic soils with frontal vertical penetration of gravitational water (wetting) to a depth of half a meter from the day surface without chemical differentiation of profiles and signs of mineral decomposition;
- Stagnant-flushing—characterizes semi-hydromorphic soils with a predominant wetting depth of about one meter with lateral movement and episodic stagnation of intrasoil moisture above the stabilization zone (**Figure 4**) with weak signs of chemical differentiation of profiles and without signs of mineral decomposition;
- flushing—belonging to semi-hydromorphic soils in which capillary suspended

surface moisture occasionally, periodically, or constantly (depending on the degree of moisture) closes with capillary suspended moisture, reaching the level of soil-groundwater. Chemical differentiation of profiles and signs of mineral decomposition are clearly expressed (**Figure 5**);

- effusion (deductive-effusion)—the water regime of semi-hydromorphic soils, diagnosed by the accumulation of sesquioxides and bases at the boundaries of the capillary fringe above the seasonal levels of soil-ground or allochthonous intrasoil waters.
- Stagnant—is formed in hydromorphic soils (silt-gley, peat-bog), which are saturated to full moisture capacity due to the influx of groundwater or the accumulation of surface water.

3.2. Signs of soil formation

The biological component of soil formation except the enzymatic activity and observations of redox potential were not the subject of our research. However, the logic of things in the given descriptions and scientific literature over the past 50 years indicates the dominant role of biota, especially microorganisms, in the transformation of parent materials into soils ([34].

Zvyagintsev et al. [2] believe that "... the transformation of matter and energy by soil in biogeoceonoses is one of the most important functions of soils, determined mainly by the activity of microorganisms and soil invertebrate animals living in the soil". Studies of microflora, enzymes, and nucleic acids in the forests of Belarus [39] indicate a close connection between biological components and soils.

Energy of soil formation. The participation of solar and atmospheric energy—the energy of mineral destruction—in the formation of soils is known [40,41]. In Belarus, the experience of energy characterization of soils formed on loess-like loams was undertaken for four varieties under natural vegetation, also for ten highly cultivated arable varieties [18] and for soils with varying degrees of erosion and salinisation [19,42]. The reserves of total internal energy for all these soils were calculated according to the method developed by Volobuev et al. [35]. Also, it was estimated the energy associated with humus, with the mineral part of the soil, and the energy contained in 1 g and 1 g cm^3 of matter in the 0–50 cm layer.

The energy of soils, according to Fersman [43], is taken into account through the energy of the crystal lattice of chemical elements that make up the soil minerals. It is estimated by the amount of energy required for their complete destruction so that the energy accumulated in soils and taken into account according to Fersman should be estimated quantities inversely proportional.

4. The discussion of the results

4.1. General issues

The original factual material was used by the authors to obtain new data; the object of study is the pedoecological series—catena, and the subject of study is the properties that determine the essence of soils. However, before considering the essence of soil, it is necessary to answer the question of how "soil" differs from a “soil-like body" or “non-soil” [44]. There is an opinion from E.D. Dmitriev [45] that “...the boundaries between “soils” and “non-soils” will always be of a negotiated nature” [44]. Our research has led to the conclusion that the boundary between “soil” and “non-soil” can be the moisture supply. It is the main condition for the existence of a bio-inert system. According to the results of Romanova [17], “soil” according to our data, contains moisture available to plants in a layer of 0–20 cm for at least 5 days during the growing season of an average year in terms of moisture content.

From a philosophical position, “non-soil” (“soil body”) is a phenomenon about which only the fact of its existence is known; “soil” is an object that has a set of observable properties—a specific “natural-historical body”. At the same time, we note that the view of soil as a “natural-historical body of nature” is currently being revised since soil is not a “body” in the full sense of the word—its boundaries except the upper one are not clearly defined. Thus, we suppose “soil” can be defined rather as a fragment of terrain transformed by the action of external factors into a synergistic system with fertility (productive capacity).

4.2. Main (essential) properties of soils

Such properties in the study are properties without which the soil cannot exist. At the same time, the soil profile morphology is the most imagined property determined by the energy of soil formation. The granulometric texture of the soil as a whole is not an essential property since it differs little from the parent material, but in the presence of ultrafine fractions, it has signs of a transition of the substance from inert to bioinert—from parent material to soil.

The mineralogical structure of soil silt is characterized by the new formation of clay (soil) minerals and is the main property that distinguishes soil from parent material. Organic matter (humus) by definition is the essence of soil. In humus, the connection between the exchange of biota and minerals is the dominant feature of soil formation. The chemical composition of the substance of genetic horizons in itself in the form of specific indicators like the granulometric texture is not the main property of the soil, but the chemical differentiation of profiles serves as the basis for models that distinguish soils based on the totality of their properties.

The water regime, which determines the existence and circulation of biota, chemical differentiation of profiles, and genetic diversity of soils, is one of the main, if not the most important, properties—a marker of the genesis, nature, and degree of moisture. The redox potential is a reliable indicator of the role of biota in soil formation.

From the above review, it follows that the essential properties of soils include mineralogical structure, humus content, and water regime. The main agent of soil formation is the living population of the soil, primarily microorganisms, which mobilize biophilic elements contained in minerals using the energy of the sun, the atmosphere, and the energy of the destruction of minerals. The participation of microorganisms in the formation of ultrafine particles and clay minerals allows us to consider these phenomena as one common essential property called the transformation of minerals.

Characterization of the observed properties and identification of the main ones lead to the idea that soil formation is in fact not a process but a natural phenomenon consisting of many individual processes that transform parent materials into soils.

The idea of the essence of the pedosphere was formed on the basis of a generalization of information from a variety of monographs [13,37,45,46] to our own conclusions. As a result, it was concluded that the pedosphere is essentially part of the biosphere with a concentration of microbiota in subaerial conditions.

To the above, it is necessary to add research on soil energy. The information encoded in the energy characteristics of the soil may in the future become the basis of theoretical soil science and the basis for the development of nature-like land use technologies.

Exploring soil, one cannot help but note the duality of the very concept of soil. On the one hand, the soil itself, with its essential properties, acts as an idealized abstraction. On the other hand, it is a specific object with the same essential properties but in different combinations that determine genesis—the only reliable criterion that distinguishes soil from a number of its own kind.

5. Conclusion

The presence of extensive literature and "scientific capital" collected in Belarus, including on the territory of the research area, allows us to expand our understanding of soil as well as soil formation and the pedosphere by identifying their essential properties. This can contribute to the reduction of separately studied soil subsystems into a single soil system [23] that is relevant at least for the wet zone in the form of the following formulations.

The results of this study are an interpretation of the available materials, taking into account publications on the biology and water regime of soils over the past 50 years: 1) the difference between soil and soil-like bodies; 2) soil formation as a natural phenomenon—the mobilization of soil biota from the energy from the sun, the atmosphere, and the destruction of minerals in the original rocks; 3) the essence of the soil a) as a solid phase—a substrate transformed by the transformation of minerals, humus formation, and the water regime; b) as an ecosystem—a fragment of the area, transformed by the action of extraterrestrial and terrestrial factors into a synergistic system with fertility; 4) the essence of the pedosphere is a part of the biosphere with the concentration of microbiota in subaerial conditions.

The essence of soil formation (the transformation of parent material into soil) lies in a natural phenomenon—the mobilization by biota of the energy of the sun, the atmosphere, and the destruction of minerals of the original parent materials. The essence of the soil as a natural system (ecosystem) is the fragment of the territory transformed under the influence of extraterrestrial and terrestrial factors into a synergistic system with fertility (productive ability). The essence of the soil solid phase is that the substrate changed as a result of the transformation of minerals, humus formation, and water regime. The essence of the pedosphere is a part of the biosphere with a concentration of microbiota in subaerial conditions.

The significance of the results obtained in scientific terms lies in the confirmation using specific examples of general ideas about the surrounding world and about soil as a natural system with the decisive role of biota (microbiota) and water regime as a marker of soil genesis in the southern part of the humid zone of Eurasia. For the first time, based on the modules of chemical differentiation of soil profiles, types of water regimes have been identified. The concept of "soil" is considered in the aspect of representing soil as such (in itself) and as a specific object of a) the geobiosphere (natural system-ecosystem) and b) the biolithosphere (substrate modified by microbiota under different types of water regime).

The soil, due to its genesis, characterizes not only the state of the surface layer of the modified parent material but also represents a "solid basis for life" as a complex natural ("bio-inert") system of interaction between alien and terrestrial factors. From the point of view of treating soils as natural resources, an important guideline is the objective diagnosis of the genesis and especially the hydromorphism of soils with the prospect of assessing the bioenergy potential as comprehensive digital information about the diversity, properties, and natural fertility (productive capacity) of soils. Scientific knowledge about the essence of soils is the basis for the development of nature-like technologies for sustainable land use.

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