

The concept “soil biophysical fertility: theoretical and applied support”

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Abstract: In terms of the theory of elementary pedogenetic processes, the pedogenetic process represents the totality of the integration processes of abiotic and biotic matter in the composition of the basic soil matter, which represents the first level of integration of matter in the soil, specific to it. Its further evolution is determined by the unidirectional action of humic substances resulting from the operation of the system "living organic matter ↔ dead organic matter". The driving force behind the continuous processes of structural-functional organization of the soil ecosystem are the processes of humus formation and those of accumulation-sequestration and stabilization of organic carbon in the structural aggregates responsible for the functioning of the soil ecosystem materialized in ecosystemic functions, including soil fertility.

1. Introduction

In Soil Science since the '90s of last century the descriptive-quantitative paradigm in the study of soil resources has been replaced by qualitative-structural-functional paradigm aimed at evaluating the natural mechanisms of soil organization, as a complex system, for the purpose of a scientifically based management of the ecosystem functions, including the bioproductive one (Dobrovoliskii and Nikitin, 2006).

In this context, in contemporary pedology, thanks to the development of its branches in part (genesis, physics, chemistry, soil biology, etc.), agricultural technologies have been developed for sustainable management of soil regimes, processes and ecosystem functions, with emphasis on zonal aspects and landscape adaptation (Kiryushin, 2010).

Despite this, in the current agricultural systems the fertility of the soil is reduced only to its ability to provide the plants with the necessary nutrition, and the soil is perceived only in terms of the supplier of those needed to produce crops. The procedural-functional aspect is neglected, practically, in totality, the accents being placed on the technogenic component.

In such an approach, soil fertility is simply perceived as the feature of the soil to provide plants with nutrition and is assessed on the basis of a limited set of physico-chemical and agrochemical parameters (pH, content of: humus, N-NH₄, N-NO₃, P₂O₅, K₂O and mobile forms of Mn, Zn, Cu) in the arable layer (0-30 cm) the emphasis being on mineral fertilization. This has led to accelerated degradation of soil resources and their bioproductive function.

According to our research, arable chernozems in the Prut-Dniester area are affected by 4-5 degradation processes, including physical and bioenergetic degradation, which are the main factors limiting the processes of extended reproduction of the chernozemic process in arable chernozems and their fertility (Jigau & Lesanu, 2021; Jigau, 2019). As a result, arable chernozems have now entered a new phase of evolution caused by the

worsening of water, aeration, aero-hydric, hydrothermal regimes due to degradation of aggregate structure, reduction of aggregate stability, overcompaction, increased penetration resistance of arable and underlying horizons (Trofimova et al., 2017). At the same time, it has been established that the vulnerability of chernozems to climate change manifested in the intensification of arid processes and incipient forms of functional desertification has significantly increased (Jigau & Leşanu, 2021; Lal, 1999).

In the context of the above, the need for the management of physical and bioenergetic factors of fertility in adaptive-landscape-biophysical-remedial technologies based on an integrated concept on the place of biophysical processes in the evolution of arable chernozems, fertility, methods of diagnosis and evaluation of biophysical factors fertility increases.

2. Materials and Methods

The aim of this research is to substantiate the biophysical concept of soil pedogenesis and fertility, to develop the criteria and parameters for the evolution of biophysical fertility factors and to develop the methodological framework for their management within adaptive-landscape-biophysical-remedial technologies.

This study is based on the systematization of a large volume of measurements and laboratory analyzes performed within the MACP Project "Competitive Agriculture in Moldova" in the period 2015-2018 (the study comprised 440 soil profiles located in 12 pedological districts in the area between Prut and Dniester as well as in some experimental plots in the period 2015-2020 within the Research Project 15.817.02.360A and the period 2021-2022 within the Technology Transfer Project 21.80015.581.253T.

Within the MACP Project, the research included the evaluation of the main physical and bioenergetic fertility factors (bulk density, total and differential porosity, aggregate composition and stability, humus content dynamics, nitrification capacity, mesofauna activity, etc.) at the beginning and end of the vegetation period.

Research under Projects 15.817.02.360A and 21.80015.581.253T included monitoring the main physical and bioenergetic factors of fertility in various periods of field crop development under crop rotation conditions with 5 crops.

Based on the systematization of research results were developed gradations for assessing the physical and bioenergetic factors of fertility, physical, hydrophysical and bio-energetic models for three levels (low, moderate and high) fertility of arable chernozems between Prut and Dniester and formulated the principles of technologies adaptive-landscape-biophysical-remedial and the methodological framework for their implementation.

The field research was conducted in accordance with the Practical Guide "Sustainable Land Management" (Cainarean et al., 2015) and the "Self-Assessment Guide to Sustainable Land Management Practices" (Jigau et al., 2018).

The laboratory analyzes and the evaluation of the obtained results were carried out in accordance with the "Guide to the discipline of Soil Physics" (Jigau and Nagacevschi, 2006). The Soil Classification System of the Republic of Moldova is used in the research (Ursu, 2011).

3. Results

In terms of the theory of pedogenesis, soil fertility is a prerequisite for pedogenesis and is a complex multidimensional system determined by a series of pedofunctional processes quantitatively and qualitatively variable in time and space due to self-development and self-evolution of the geosystem. This approach implies the conclusion that soil formation, constitution and evolution of its fertility are the product of the same complex of interdeterminate processes of various kinds, interacting and interdependent, whose meaning and intensity are determined by the concrete conditions of the landscape.

This principle is already outlined in the research of the founders of naturalistic pedology and has provided the scientific framework for zonal agricultural systems for soil fertility management (Dokuceaev, 1899). Later it was developed in the works of Chiriuşin V.I. and forms the core of the theory of landscape adaptation of agricultural systems (Kiryushin, 2010; Kiryushin, 2019).

Such an approach to soil pedogenesis and fertility has implied the need to diversify and deepen research in the field of Soil Science and the intercalated development of the theory of pedogenesis and soil fertility theory.

The number of these researches also includes the principles of soil biogeophysics developed in the works of Smaghin, 2004.

In this analysis we start from the approach of the interacting and indefinite evolution of the physical and biological processes of constitution of the pedostructural matter and the basic matter of the soil which represent the first levels of integration of the matter in the soil specific to it.

3.1. The biophysical concept of the pedogenetic process

In terms of the concept "Elementary pedogenetic processes" pedogenesis in its essence is a bio-physico-chemical phenomenon, and the main factors that determine it are living organisms and the processes of their vital activity.

The theoretical and methodological framework of the biophysical concept of the pedogenetic process is provided by the law of soil unity and biogeocenosis materialized in the ability of living organisms to shape the living environment according to their own needs and involves two basic categories: adaptability and adaptation potential.

Adaptability involves the biocenosis trait of shaping the soil according to its own needs.

The potential for adaptation is the characteristic of the soil to be modeled.

In this context, the basic components of the pedogenetic process are:

a) Biologization and biochemical transformation of the mineral substrate from which the soil is formed.

b) The accumulation of organic matter, its decomposition-transformation - humification.

c) The interaction and integration of mineral and organic substances with the formation of a complex system of specific bio-organo-mineral compounds only of pedogenesis which makes up the genetic code of the type of pedogenesis. Bio-organo-mineral compounds have a decisive role in defining the meaning and intensity of the pedogenetic process. The modification of the pedogenetic framework leads to the transformation of the bio-organomineral integration processes and, respectively, to the modification of the meaning and intensity of the pedogenetic process.

d) Integration of bio-organo-mineral compounds in the process of aggregation-structuring of soil matter, sequestration of carbon and nitrogen and their stabilization in structural aggregates.

e) Migration and differentiation of newly formed products in the soil profile and, respectively, of the elementary pedogenetic processes that take place within it.

f) In this sense, each horizon represents a functional system that provides "pedogenetic information": the overlying horizon determines the processes that take place in the underlying horizon and vice versa.

In view of the biophysical concept of pedogenesis, this is a historical-natural process of integrating biotic and abiotic matter with the formation of a system with features of bio-tic and abiotic body, and much more complicated organization than the initial forms (bio-tic systems and abiotic systems).

In ordinary pedogenetic systems with features of biotic and abiotic body, along with the interactions characteristic to the initial systems, a new group of "biotic-abiotic" interactions are established and evolves. The group determines stability of pedogenetic systems, their productivity, functionality and dynamics and materializes in the

structural-functional organization through which the soil differs from several other consecutive indefinite phases and stages (Table 1).

Table 1. Phases and stages of soil evolution in biophysical pedogenesis

Phase	Stage	Content	Duration, years
Abiotic	Geophysical-chemical	Physical, chemical and geochemical processes (mineral transformation-synthesis) for modeling the abiotic environment (thermal, hydric, physical, chemical properties; regimes: hydrothermal, aerohydric, redox, hydric, thermal, aeration, nutritive) abiotic factors (climate, relict) that occur in the mineral substrate, over time, with the formation of an abiotic entity - the parent rock - which favors the start in it of biological and biochemical processes.	Thousand, tens of thousands
	Primary	Early processes of biological circuit of substances. Abiotic processes uncharacteristic of soils predominate. Absence of soil characteristic features (beginnings of aggregation-structuring) in the composition of the solid phase. Organo-mineral processes with the formation of clay-humic complexes (solid pedogenetic products). Poor interactions between the biotic and the abiotic component. Incipient processes of soil biota formation and biological modeling of the pedogenetic environment. Biology of the mineral substrate: synthesis of new biological molecules and biosynthesis of humic substances of origin, mainly microbial-algae.	Hundreds, thousands
Biotics (pedogenetics)		a) Accelerated development. Intensification of biochemical mesoprocesses and the biological circuit of substances. Intensive processes of formation, accumulation of humus, sequestration and accumulation of organic carbon. Intensive bio-organo-mineral integration processes materialized in the aggregation-structuring of the soil substance. Establishment of biogeochemical circuits of substances. Biogenic accumulation. Vertical differentiation of substances with the formation of pedofunctional profiles (humic, aggregate, carbonate, saline) and pedogenetic horizons. Ordering and differentiating the properties, regimes, features and processes at the hierarchical levels of aggregate, horizon and profile of structural-functional organization of substances. b) The attenuated development phases It reduces the intensity of processes in the biological circuit of substances, Development of micro-, meso- and macroprocesses of integration of substances at the hierarchical levels aggregate, horizon and profile of structural-functional organization of the profile. One-way development of expanded reproduction of soil fertility.	Hundreds, thousands

Phase	Stage	Content	Duration, years
	Balanced operation - dynamic balance is maintained in the "soil-pedogenetic factors" system	All processes are performed in relatively balanced biogeochemical circuits of substances. Relative stability of the main diagnostic features. One-way realization of micro-, meso- and macroprocesses of expanded reproduction of soil fertility in closed circuits of substances.	Indefinite duration

The third stage (of balanced functioning - climate) can be succeeded by the stage of soil evolution as a result of the evolution of the ecosystem. In this context, the evolution can be homologated with the stage of soil development in the newly formed conditions until the establishment of a new balance in the system "soil ↔ pedogenetic factors".

The abiotic and biotic stages follow one another in the mineral substrate in the soil profile and materialize in three substrates:

a) Pedogenetic-functional in which the decisive role in the constitution and reproduction of the pedogenetic process belongs to the biophysical processes of integration and modeling of soil substances. In the soil profile it materializes in the humus-cumulative horizon (Am + AmB).

b) Biogeochemically and pedogenetically active, the evolution of which is determined by the intercalated realization of biogeochemical and biophysical processes and is materialized in the transition horizon B. Depending on the ratio between biogeochemical and biophysical processes it is divided into active biophysical layer (Bm) and active biogeochemical (Bc).

c) Active geo-physico-chemical, the evolution of which is determined by the intercalated development of the processes of physical, chemical and biological alteration. It materializes in the transition horizon to the bedrock (BC).

The succession on profile of the stages of evolution of biophysical pedogenesis indicates the vertical extension of pedogenetic process and its progressive-cumulative character.

3.2. The biophysical concept of soil fertility

Within the biophysical concept of soil fertility, we start from the idea of the decisive role of the unidirectional action of living organisms on abiotic components (solid, liquid, gaseous) in order to model and optimize the living environment according to their own needs. These materialize in the structural-functional organization of the soil.

Starting from the concept of "ecological functions of the soil", several authors consider that for a better understanding and more efficient management of them, including the bioproductive function, it is more appropriate to examine them from the ecosystem positions and functions of modeling the living environment. relationships between pedogenetic factors, ie. the ecological system of the soil (Semenov and Semenova, 2018; Semenov et al., 2019; Sokolov et al., 2020).

The soil ecosystem consists of the inorganic component, living organic matter (biota), and organic matter (biogenic dead mass, metabolites and products from the hydrolysis of biogenic dead mass). Within the soil ecosystem, the basic pedogenetic, biological, bio-chemical, physico-chemical processes of transformation of substances and materialized energy in the biogeochemical circuits of substances take place, but also the processes of integration of biotic and abiotic matter, materialized in the structural-functional organization of the soil ecosystem. at various hierarchical levels of operation: elementary particle, microaggregate, aggregate.

The decisive role in the constitution of the soil ecosystem belongs to the living matter which attributes to it the capacity to model the environment of the vital environment, the productivity, its own diversity and the capacity to buffer in the relations with various

stressors. At the same time, the soil ecosystem provides biophilic elements, biologically and physiologically active substances to heterotrophic plants and organisms, ensures the source and flows of biophilic elements.

From the point of view of the biophysical approach of the pedogenesis process, soil fertility depends exclusively on the meaning and dynamics of the "living organic matter-dead organic matter" system, which has the decisive role in the pedogenesis process, the establishment of the physical, physico-chemical and biogeochemical framework corresponding to the concrete conditions of the landscape, ensuring the ecological system "soil-plant" with water, air, heat, organic and organo-mineral phytonutrients, biologically and physiologically active substances.

The share of abiotic processes in soil fertility is insignificant and incomparable to that provided by the soil ecosystem.

According to the exposed conceptual aspects of interacting, indefinite and interdependent evolution of physical and bioenergetic fertility factors, soil fertility management involves ensuring dynamic quantitative and qualitative balances between the inorganic and the organic component within the soil ecosystem.

In this context, the systematization of the research results highlighted three levels of fertility determined by the concrete land conditions materialized in the structural-functional, hydrophysical and bioenergetic models of soil fertility. In their context, we mention that the biopedoclimatic framework of the space between the Prut and the Dniester ensures favorable conditions for the preponderance of the "increased" and "moderate" levels. In conditions of agrogenesis, however, the realization of this potential is limited by bioenergetic resources.

According to Andrieș et al., 2010, over 100 years in the chernozems between the Prut and the Dniester the average humus content in the Am horizon decreased from 5-6% to 3.0-3.5%, and the humus reserves from 200 to 100 t/ha (Andrieș et al., 2010). At the same time, according to more recent calculations, from 1965 to the present, due to intensive humus loss, the area of low-fertility land has increased from 30.6% to 38.3%, and the area of high-fertility land has decreased from 23.1% to 8.4% (Jigau and Leșanu, 2021).

In the last 50-60 years the reduction of bioenergetic resources is determined by the mineralization of the inert humus fraction and is accompanied by the reduction of the aggregate stability of the arable layer below 45%. As a result, a one-way trend of compaction and over-compaction of the agrogenic layer and degradation of the porous space of the soils has been established in soils (Jigau, 2019). Degradation of the porous space is accompanied by degradation of the environment of the process of formation and accumulation of humus and reduction of the amounts of organic and organo-mineral phytonutrients from the humification of fresh organic matter. As a result, the processes of humus loss and, respectively, those of degradation of the structure and degradation of the functional biophysical framework are intensified, respectively.

According to calculations, within the current biophysical humus formation framework, only 20% of the total mass of organic matter entering the soil is used for humus formation. About 80% of the organic residues is mineralized. The same calculations show that about 60% of the number of chemical elements mobilized during the mineralization process are leached into the deep layers of the soil profile, and another 20% are transformed and released into the atmosphere (Jigau and Leșanu, 2021). The mentioned processes involve, first of all, nitrogen resulted from mineralization. As a result, the humus formation process is also limited by the small reserves of available biological nitrogen.

Based on the above, the chernozems of the Prut-Dniester area are characterized by three levels of fertility (low, moderate, high) determined by biopedoclimatic conditions and parameters of soil fertility factors (Tables 2, 3, 4).

According to the parameters presented in table 2, in the evaluated space the soils with moderate fertility predominate. Their fertility is determined by the composition of

medium fine granulometry: the predominance of the fractions of coarse silt, fine silt and fine clay in its composition and moderate humus reserves.

Depending on the predominant hydrophysical parameters soils have moderate humus content, with values of field capacity for water 25-30% w / w, good total porosity (50-55%) and air capacity 15-20% (Table 3). The relatively moderate values of the wilting coefficient are among the favorable factors.

Table 2. Parameters of the structural-functional model of agrophysical fertility of the chernozems of the space between the Prut and the Dniester

Fertility factors	Parameters for fertility levels		
	low	moderate	increased
Granulometric composition			
physical clay content (<0.01 mm), %	15-30	30-45	45-60
fine clay content (<0.001 mm), %	12-20	20-30	30-40
Microaggregate composition			
Content of agronomically valuable microaggregates (>0.01 mm), %	65-70	70-82	>82
Content of agronomic microaggregates of little value (<0.01 mm), %	3-4	2-3	<2
Structural-aggregate composition			
Content of agronomically valuable aggregates (0.25-10 mm), %	65-70	70-80	>80
Content of waterstable aggregates >0.25 mm, %	<40	40-60	>60
Dispersion coefficient, %	25-40	15-25	<15
Degree of aggregation, %	50-65	65-80	>80
Structuring coefficient	<0.67	0.67-1.5	>1.5
Bulk density, g/cm ³	<1.0, >1.3	1.0-1.1	1.1-1.3
Penetration resistance, kg/cm ²	>50	50-26	<25

The valuable agronomic structure represents formations: Mezoaggregates (0.25-10 mm) with an increased volume of aggregate capillary pores, hydrostability, increased storage and moisture conservation capacity, favorable aerohydric and hydrothermal conditions for biochemical processes and plant root system development (Voronin, 1986; Sorocikin, 1989; Koroliov, 2005; Shein and Goncharov, 2006).

Table 3. Parameters of the hydrophysical fertility model of the chernozems of the space between the Prut and the Dniester

Fertility factors	Regulations for fertility levels		
	low	moderate	increased
Water permeability, average values for 6 hours, mm/h	<25	25-35	35-40
Field capacity for water, % g/g	<25	25-30	>30
Total porosity, %	<50	50-55	55-65
Moisture conductors, % of the total porosity	<40	40-55	55-65
Air capacity, %	12-15	15-20	20-25
Unacceptable water content, % g/g	>13	13-11	<11
Productive water reserves (layer 0-100 cm), mm	<140	140-180	>180

The data presented in Table 4 highlight a number of factors with low and moderate values of bioenergetic fertility parameters. Depending on the whole complex of predominant factors of production there are soils with low and moderate fertility levels.

At the same time, research conducted over the last 10-12 years has shown that the ecosystem of arable chernozems is receptive to rehabilitation measures in agricultural

technologies that involve the synchronized optimization of the physical-hydro-physical and bioenergetic framework.

Table 4. Parameters of the bioenergetic fertility model of the chernozems of the space between the Prut and the Dniester

Parameters	Fertility levels		
	low	moderate	high
Humiferous layer thickness (humus content >1%), cm	<60	60-80	>80
Thickness of the Am + AmB layer, cm	<40	40-60	>60
Humus reserves in the horizon Am, t/ha	<50	50-100	>100
Humus reserves in the Am + AmB layer, t / ha	50-100	100-150	>150
Humus reserves in the humus layer (A + B), t / ha	100-200	200-400	>400
Degree of humus enrichment with nitrogen (C: N ratio in humus composition)	>14	14-11	<11
Distribution of humus reserves in the layer 0-100 cm	Sudden decrease	Slow decrease	Very slow decrease
Nitrification capacity, mg / kg	<15	15-30	30-60
Mobile humic substances content, %/t/ha	<0.2/3-6	0.2-0.4/6-12	>0.4/>12
Nitrogen content in mobile humic substances (horizon A), kg / ha	<240	240-480	>480
Minimum annual organic matter required in soil (dry mass), t / ha	6-9	4-6	4-2
Mobile phosphorus content (P2O5), mg / 100 g soil	<1.5	1.6-3.0	3.1-4.5
Mobile potassium content (K2O), mg / 100 g soil	<20	20-40	>40

The optimization of the bioenergetic framework involves the complex practice of complex measures to increase the reserves of fresh organic matter in the soil and to restore the composition and biodiversity of the soil biota (Table 5).

Table 5. Criteria for identifying the minimum amounts of organic matter and mineral fertilizers required for the biologization of agricultural systems according to the level of fertility

Fertility level	Mobile humic substances content, %/t	Required amount of organic residues/organic fertilizer	The amount of nitrogen fertilizers, etc. needed	Biological procedures
Low	<0.1/<3	9-12	65-75	Cultivation of perennial herbs. Short crop rotations (share of grains and legumes >60%). Systematic incorporation of organic residues with modification of the incorporation depth.
	0.1-0.2/3-6	6-9	50-65	Administration of biohumic preparations. Intermediate crops.

Fertility level	Mobile humic substances content, %/t	Required amount of organic residues/organic fertilizer	The amount of nitrogen fertilizers, etc. needed	Biological procedures
Moderate	0.2-0.4/6-12	5-6	40-50	Green fallow. Average crop rotations (share of grains and legumes >50%). Systematic incorporation of plant residues with modification of the incorporation depth. Administration of biohumic preparations. Intermediate crops.
	0.4-0.6/12-18	3-5	25-40	
High	>0.6/18	2.5-3	20-25	Crops (7-9 crops) biologically and landscaped adapted. Mandatory inclusion of legume crops in the crop structure. Cultivation of intermediate crops. Systematic incorporation of organic residues into the soil with the formation of the organo-terros mulch layer. Administration of biohumic preparations.

The optimization of the physical-hydrophysical environment implies the differentiated practice of agrotechnical measures depending on the physical condition of the soils (Table 6).

Table 6. Criteria for identifying the agrotechnical measures for the management of the physical and hydrophysical framework of the chernozems of the space between the Prut and the Dniester

Physical parameters			More suitable work systems
Bulk density, g/cm ³	Penetration resistance, kg/cm ²	Aggregate content >10 mm, %	
1.0-1.1	10.25	<10	Loosening with the return of the furrow Loosening without furrow turning Combined at different depths
1.1-1.2	25-30	10-20	Superficial with mulch No-till.
1.2-1.3	30-40	20-30	No-till Superficial with surface mulching Combined with alternating working depth Deep loosening without turning the furrow
1.3-1.4	40-60	30-40	Loosening with the return of the furrow. Loosening without turning the furrow. Combined at different depths alternating with the superficial one

Physical parameters			More suitable work systems
Bulk density, g/cm ³	Penetration resistance, kg/cm ²	Aggregate content >10 mm, %	
>1.4 The underlying layer is clearly outlined	60-100	>40	Loosening 20-22 and 27-30 cm with the turn of the furrow. Deep loosening without turning the furrow and preserving the remains of the vegetal surface Combined with shallow loosening and alternating working depth

According to the biophysical concept of pedogenesis, the achievement of these objectives involves several consecutive technological steps:

I. Synchronized restoration-optimization of the biophysical-functional framework within biophysical-remedial technologies adapted to the concrete conditions of the country. Within them, the emphasis will be on the rational / adapted use of agrotechnical, phytotechnical, bioremediative measures.

II. Aiming to one direction of synchronized optimization processes of biophysical processes (humification ↔ aggregation-structuring). Support of the bioproductive function by intensifying the production processes.

III. Ensuring the stability of the soil system ↔ agrophytocenosis in agroland and biophysical-remedial conditions.

4. Conclusions

In terms of the theory of elementary pedological processes, pedogenesis is essentially a bio-physico-chemical phenomenon, and the main factors that determine it are living organisms and the products of their vital activity and represent the totality of integration of biotic and abiotic matter with the formation of soil biopedoplasm which represents the first level of integration of the basic matter of the soil. The unidirectional action of biological and biochemical processes on abiotic components (solid, liquid, gaseous) leads to the modeling of the basic matter of the soil according to the vital needs of the biogeocenosis and materializes in the ecosystem and soil fertility. In this sense, soil fertility is a prerequisite for pedogenesis and is a multidimensional system determined by a complex of pedo-functional processes quantitatively and qualitatively dependent on concrete land conditions, variable in time and space due to self-development and evolution of the geosystem is the soil. In the biophysical approach, soil fertility depends on the dynamics of the system "living organic matter - dead organic matter" which has the decisive role in establishing the pedogenetic and pedofunctional environment, ensuring the ecological soil-plant system with water, air, heat, organic and organo-mineral phytonutrients and biological substances. and physiologically active. The biophysical concept of pedogenesis and soil fertility provides conceptual support for the theory and methodological management of sustainable bioproductive function and the extended reproduction of the pedogenetic process within adaptive biophysical-remedial technologies.

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