UDC 631.81.0.36

SELF-REGULATION AND MANAGEMENT OF FERTILITY RESTORATION OF TYPICAL CHERNOZEM IN AGROECOSYSTEMS

O. V. Demydenko [1], V. A. Velichko [2]

[1] *Cherkasy State Agricultural Experimental Station, NSC "Institute of Agriculture", NAAS of Ukraine*
13, Dokuchaieva Str., Kholodnianske village, Smila District, Cherkasy Region, Ukraine, 20731
[2] *NSC "Institute for Soil Science and Agricultural Chemistry*
named after O. N. Sokolovsky" NAAS of Ukraine
4, Chaikovsky Str., Kharkiv, Ukraine 61024

e-mail: dem006@yandex.ua; agrovisnyk@ukr.net

Received on February 15, 2016

Aim. To investigate the process of enhancing the self-organization and self-regulation of chernozem towards natural organization under the impact of long-term soil-protective surface tillage and to determine its impact on enhancing the ability of chernozem to adapt to environmental changes, preserving agroecological stability of the agroecosystem of the Left-Bank Forest-Steppe of Ukraine. **Methods.** Field, laboratory, computational, mathematical and statistical. **Results.** The complex years-long studies (1992–2015) demonstrated that the combination of soil-protective technologies of cultivating crops in the agroecosystems is a factor of affecting the character, orientation and self-regulation of energy- and mass exchange in a complicated network of interactions and interrelations of chernozems in agroecosystems. The determinant and governing impact in restoring the fertility of typical chernozem in the Left-Bank Forest-Steppe of Ukraine is soil-protective technologies of cultivating agricultural crops, based on surface tillage. The energy-wise appropriateness of creating the porous space of chernozem in conditions of soil-protective treatment should be deemed as thermodynamic code of soil formation or the process of implementing the "memory" about the morphogenicity of spatial soil form of chernozem of a high self-organization degree, which is in direct correlation with the process of enhancing the residual features of natural soil formation and accumulative orientation of fertility indices. **Conclusions.** The soil-protective system of agriculture should be viewed as a complex of methods and technologies of systemic or ecologically reasonable use of anthropogenic and natural energy resources. It creates the background to solve the main problem of agriculture – rational use of chernozem fertility with simultaneous extensive restoration, which ensures more complete use of the bioclimatic potential with optimal exploitation of natural and anthropogenic resources of the Left-Bank Forest-Steppe territory.

Keywords: soil-protective tillage, tillage system, agroecosystem, natural fertility, self-regulation, self-organization, cultural soil-formation.

DOI: 10.15407/agrisp3.02.063

INTRODUCTION

Modern agriculture is organized with the violation of the systemic principles, due to which the ecological crisis is in the very conceptual essence of its classic paradigm. Soil-protective agriculture (SA), based on soil-protective technologies of cultivating agricultural crops using surface tillage, should be organized in accordance with the laws of systemic integrity of the functioning of non-living systems, where the appropriateness and reasonability of the internal structural composition should be viewed as a reason of ecological stability of agroecosystems [1–8].

Modern agricultural soil science is based on the principles of the general theory of soil fertility, and the determinant notion here is the self-organization of processes and regimes in soil. From the standpoint of achievements of natural and exact sciences, this approach should be viewed as a synergic one [6], and soil should be perceived as an open non-linear system in the state of thermodynamic non-equilibrium with environment, developing as a self-organized system, remarkable for "remembering" certain rules of development.

The aim of this work was to investigate long-term impact of surface tillage on the restoration of typical chernozem fertility in the agroecosystems (Left-Bank Forest-Steppe of Ukraine).

MATERIALS AND METHODS

Field experiments were conducted in Vorskla-Sula and Middle Dnieper-Seym districts. In 1990–1996 the studies were carried out in the southern part of Vorskla-Sula district. The soil surface in the range of southern part of Poltava region is presented with typical medium-humic (5.55–5.65 %) chernozem (> 50 %). By the content of physical clay (PC) and physical sand (PS) chernozem may be referred to light clay: PC = 62.9–– 64 % and PS = 35–37.1 %. These technological indices of granulometric condition are remarkable for typical chernozem of the southern-eastern part of Poltava region and practically the whole territory of Kharkiv region.

From 2001 till 2014 the work was performed in the Middle Dnieper-Seym agrosoil region, which covers the lands of Kyiv, Poltava, Sumy, Chernihiv and Cherkasy regions. The experiment was performed in Drabiv agrosoil district of the Forest-Steppe zone of the Left-Bank lowland province, northern subprovince, on typical low-humus light loamy clay silt chernozem. The structuredness index (SI) is: SI = 25–38 %. The PC:PS ratio equals 1.76:2.52 which is 3.2 times higher compared to typical medium-humic light loamy chernozem. The factor of potential aggregation (FPA): FPA = 0.25–0.27 which is 2.78–2.96 times lower compared to typical medium-humic light loamy chernozem.

Climatic conditions of the studies. Period of 1990–1996. The climate of the southern part of the Left-Bank Forest-Steppe is moderate continental (C_c = 168); by warmth the eastern part of the Forest-Steppe agroclimatic province belongs to the stripe of medium-late crops, the sum of active temperatures is +2810 °C; the vegetation period – 163–165 days; the coefficient of atmospheric moistening (MC): MC = 0.62; the probability of dry and drought years (MC < 0.55) is 33 %. The biological efficiency according to Shashko by the climatic index (B_c = 124) is increased. The sum of precipitations in April-October is in the normal range at the optimum of 518 mm.

Period of 2000–2014. The average daily air temperature increased by 0.9 °C in the central part of the Left-Bank Forest-Steppe in spring, and years-long average values – by 1.7 °C. Summer period became +1.8 °C warmer, and the average daily temperature reached 20.4 °C at the norm of 18.8 °C. Autumn was found to be 0.5 °C warmer, and the whole warm period of the year – 0.8 °C warmer. The sum of active temperatures during the warm period of the year increased considerably (by 987 °C): spring was found to be warmer by 85 °C; summer – by 802 °C, autumn – by 101 °C. The sum of effective temperatures in summer increased by 256 °C. The sum of precipitations in spring and summer was at the level of 89–93 % from the norm, and in autumn this amount decreased by 13–18 mm.

Permanent experiment No. 1. The study was conducted in 1990–1996 in a permanent multifactor experiment of the Department of soil science and soil protection of the National University of Life and Environmental Sciences of Ukraine in the following chain (sugar beet–green peas–winter wheat–corn for grain–corn for silage) of 10-course grain-beet crop rotation for the southern part of the Left-Bank Forest-Steppe (cereals – up to 40 %, technical crops – up to 30 %, grain legumes – up to 10 %, forage crops – up to 20 %), where four ways of tillage were investigated: tillage of different depth (22–32 cm); subsurface tillage (22–32 cm); shallow surface tillage (10–12 cm) and minimal surface tillage (5–6 cm) on the background of four fertilization systems – without organic and mineral fertilizers; 15 t/ha humus + $N_{55}P_{55}K_{45}$ (low dose); 15 t/ha humus + $N_{85}P_{75}K_{65}$ (medium dose); 15 t/ha humus + $N_{110}P_{100}K_{85}$ (high dose). The variants were located by the method of split blocks with three repeats. The size of first order plots was 928 m^2, the second one – 232 m^2, the area under registration – 100 m^2.

Permanent experiment No. 2 (The registry of certificates of NAAS No. 040 "The scientific foundations of establishing crop rotations, tillage and fertilization systems in conditions of the Left-Bank Forest-Steppe of Ukraine"). The experiments were conducted in 2001–2014 during the permanent multifactor experiment of the Cherkasy State Experimental station of NSC "Institute of Agriculture of NAAS". Two types of five-course crop rotations were investigated: A: perennial grass–winter wheat–sugar beet–corn–barley + perennial grass (cereals – up to 60 %, technical crops – up to 20 %; perennial grass – up to 20 %); B: green peas–winter wheat–sugar beet–corn for grain–corn for grain (cereals – up to 60 %, technical crops – up to 20 %; grain legumes – up to 20 %).

Fertilization system: 2001–2014 – 6.0 t/ha of by-products; $N_{31}P_{33}K_{41}$ (average dose); $N_{62}P_{66}K_{82}$ (double dose).

The ways of the main tillage: tillage of different depth (22–25 cm) for all the crops; subsurface tillage (22–25 cm) for all the crops; surface tillage (8–12 cm) for all the crops. There were three repeats in both experiments. The area of the experimental plot was 250 sq.m. The area under registration was 100 sq.m.

The methods of determining the indices of study objects. To determine the changes in agrochemical, physical and chemical, and agrophysical indices while studying the nutrition regime, humus and agrophysical conditions, mixed samples were selected from one meter deep soil layers in 10 cm distance on different land plots following the schemes of experiments according to DSTU 7030:2009 (GSTU 46.001-96). The analyses of the samples of soil and vegetative material, the registration and calculations were conducted according to special methods: humidity – by the thermogravimetric method in terms of the main periods of crop growth (DSTU ISO 11465:2001); granulometric composition – according to Kachynsky N. A. (DSTU 4730:2007), the density of composition (structure) – by the method of cuter rings in the modification of Kachynsky N. A. during the periods of intense growth of crops and the periods of harvest formation (DSTU ISO 11272:2001); the structural-aggregate composition – by the sieve method in the modification of Savinov M. I. (DSTU 4744:2007) and by the method of Baksheev I. M.; moisture reserves – by theoretical calculations up to the depth of 150–180 cm.

The content of total humus was found according to Turin I. V. (DSTU 4289:2004); pH_{KCl} – potentiometrically (DSTU ISO 10390:2007); the hydrolytic acidity – according to Kappen in the modification (GOST 26212–91); the sum of absorbed alkali – by the method of Kappen-Hilkovits (GOST 27821–88); the degree of alkali saturation – theoretically; labile phosphorus – photocolometrically; exchange potassium – flame photometry (DSTU 4405:2005 in the modification of NSC “Institute for Soil Science and Agricultural Chemistry” (ISSAC); the content of mineral nitrogen – by the photometric method with Nessler’s reagent; humus substances, occurring in the process of peptization of soil colloids – according to Hodlin; active and passive humus (active humus was determined by chromatography) – by the method of Sokolovsky; the content of peculiar humic substances (PHS) and detritus (D) – according to Springer in the modification of NSC ISSAC; group and fraction composition of humus – according to Ponomariova and Plotnikova.

The calculation method was used to determine: the dispersion factor (DF) according to Kachynsky N. A; the coefficient of structuredness (K_{st}) according to Fageler, the degree of aggregation (Ka) according to Baver and the granulometric index of structuredness – according to Vadiunina; saturation of physical clay (PC) with humus –according to Hodlin, and the indices of erosion resistance – according to Voronin. The content of soil air was determined by the tube method (according to Matskevich) with subsequent analysis of soil air in the gas analyzer GVV-2; the content of carbonates – by the volumetric estimation (DSTU ISO 10693-2001); the respiratory coefficient (Rc) − by calculations (according to Zboryshchuk); the intensity of CO_2 emission – by Shtatnov’s method. The field conditions were used to determine: the least water field capacity (WFC) – by the method of flood filling; the humidity of a break in capillary links (HBC) – according to Abramova, the maximal hygroscopic moisture (MH) and humidity of crop withering point (CWP) – by calculations according to Michurin and Litaev; the total specific surface area –by the method of Kutilik; the volumetric moisture of soil − by the known density per dry mass (DSTU ISO 16586:2005).

The results of field studies were statistically processed by the dispersion analysis method using Statica-6 statistical program.

RESULTS AND DISCUSSION

From the standpoint of cybernetics, the systems, capable of preserving their productivity (in our case – fertility) during unexpected changes in the properties of the natural object, management purposes or environment with the change in the functioning algorithm or search for optimal solutions, may be called self-organized and self-regulated systems. A specific way of revealing self-regulation is the organization and evolution of soil fertility [2]. The process of restoring chernozem self-organization should be related to the occurrence of a coherent relation between the elements of the soil system (SS), which leads to the formation of stable and significant relations between its constituents, i.e. the ones, forming the order and acquiring the quality of structure and composition laws [8]. The notion of ecologic sustainability is considerably dependent on the self-organization processes, which is materialized in enhancing chernozem capability of adapting to environmental changes by minimal changes in its optimized parameters, preserving agroecosystem sustainability [9].

It is common to distinguish between the relations of the first order, which are functionally necessary, *i. e.* the system cannot exist without them, and those of the second order, which stabilize SS activity, improve its quality condition considerably, but are not functionally necessary. Taking this distribution into consideration, the self-organization means ensuring higher efficiency of an integral soil system, compared to the sum of interaction effects of specific subsystems and elements [9, 10].

The relations of the first order may be referred the relation between the humus content and structure density, structure density and field humidity, humus content and field humidity, and the relation of the mentioned parameters and constituents of structural composition of soil. The relations between the elements of structural condition belong to the relations of the second order. The calculation of matrices of even correlation coefficients between the elements of structural condition, humus content (%), structure density (g/cc) and field humidity (%) in 0–100 cm chernozem layer demonstrated that long-term surface tillage affects the percentage of correlation coefficients of the medium and strong relations ($R > \pm 0.45$) of both direct and reverse action. There were 29 % of them at systematic ploughing, and 43–52 %, *i. e.* 1.5–1.8 times more, at surface tillage. There were 1.3–1.9 times more direct correlation coefficients at minimal surface tillage and 1.7–2.2 times more reverse action coefficients compared to ploughing. With surface tillage, there were 1.2–1.5 times less weak correlation coefficients compared to ploughing.

The total amount of even correlation coefficients (Table 1), defining the second order relations (X_4–X_{12}), was as follows: with ploughing – 22 %, with subsurface tillage for 22–32 cm − 39 %, with subsurface tillage for 10–12 cm – 44 %; for 5–6 cm – 50 %. There were 36 % of correlation coefficients of the medium and strong levels, defining first order relations (X_1–X_3) and (X_1–X_3) × (X_4–X_{12}) at ploughing, and 57–83 % in case of surface tillage. Of these, there were 41–54 % at ploughing and deep subsurface tillage and 50–60 % – at minimal surface tillage for 5–12 cm. The dependence between the humus content, content of structural separates and water-resistant aggregates with the size of 2–5 and 0.5–3 mm at ploughing had a reverse relation: $R_{X4-X1} = -(0.2 \pm 0.9)$ and $R_{X1-X8} = -(0.54 \pm 0.06)$ at deep subsurface tillage: $R_{X1-X4} = -(0.59 \pm 0.05)$ and $R_{X1-X8} = -(0.45 \pm 0.05)$. At minimal tillage for 5–12 cm the relation between parameters was direct at the level of medium and strong correlation: $R_{(X1-X4 \text{ and } X8)} = +(0.51–0.91) \pm 0.07$.

The ratio between the content of the mentioned fractions of agronomically valuable aggregates and structural separates to field humidity at ploughing and deep surface tillage was reverse – at the level of values of strong correlation: $R_{(X3-X4 \text{ and } X8)} = -(0.69–0.79) \pm 0.05$ i $R_{(X3-X4 \text{ and } X8)} = -(0.55–0.71) \pm 0.07$ respectively, whereas at tillage minimization up to 5–12 cm: $R_{(X3-X4)} = -(0.50 \pm 0.07)$ and $R_{(X3-X8)} = -(0.48–0.25) \pm 0.03$, which testifies to the weakening of the relation of water resistance of the structural state and the humidity factor and enhancing the impact of the humus condition of chernozem on quality indices of chernozem structuredness (Table 1).

The correlation relation between structure density (X_2) and constituents of the structured composition (X_4–X_{12}) confirms the weakening of its force down to the level of weak correlation in ploughing conditions.

Table 1. The impact of tillage system on the percentage distribution of correlation coefficients of different strength and orientation between agrophysical indices in 0–100 cm layer of typical medium-humic light loamy chernozem

Value of correlation coefficient	Tillage for 22–32 cm	Subsurface tillage for		
		22–32 cm	10–12 cm	5–6 cm
R ≥ ±0.45	29.2	43.1	52.8	46.0
R ≥ +0.45	16.7	15.3	32.0	22.2
R ≥ -0.45	12.5	27.8	20.8	24.0
R < ±0.45	70.8	56.9	47.2	54.0

A reliable reverse correlation was found between the structure density and field humidity (R = −(0.65 ± 0.07)). At subsurface tillage the amount of strong correlation relations increases with transition from deep tillage to the minimal one, and the relation between field humidity and structure density in humus-containing horizon weakens. The reverse dependence at the level of strong correlation occurs between the structure density (X_2) and variables X_6; X_7 (content of fractions 0.5–0.25 mm and < 0.25 mm), which are formed less at surface tillage compared to the variant of systematic ploughing.

Self-organization principles, determined on typical medium-humic light loamy chernozem, are manifested during the formation of structural-aggregate composition of typical low humus light loamy chernozem in case of long-term (for over 36 years) implementation of ploughing, subsurface and surface tillage and keeping the wild fallow.

Table 2 presents the matrices of even correlation coefficients between agrophysical indices for different ways of tillage of typical low humus light loamy chernozem and percentage correlation of even correlation coefficients of different strength and orientation in matrix fields.

It was determined that long-term ploughing impacted the re-distribution and percentage ratio of even correlation coefficients between the constituents of the mixture of structural separates (X_1−X_9), aggregation formation index (X_{10}), structure density (X_{11}) and content of $CaCO_3$ (X_{12}). The total amount of correlation relations (R ≥ ±0.45) was 72.7 %, and that of reliable ones – 66.7 %. The direct action relations were 39.7 %; reliable ones – 38.0 %, reverse action relations – 33.0 % and 26.7 % respectively. With long-term surface tillage the total amount of correlation relations (R ≥ ±0.45) decreased 1.22 times, and that of reliable ones – 1.1 times. There were 1.47 times fewer direction action relations and 1.45 times fewer reliable ones. The reverse action relations remained as they were at systematic ploughing.

With long-term surface tillage, the total amount of correlation relations of direct and reverse action (R ≥ ≥ ±0.45) decreased 1.15 times, and that of reliable ones – 1.06 times. Here the direct action relations were 1.35 times fewer, and reliable relations of reverse action – 1.31 times more, which is an indirect evidence to the enhanced agrophysical self-organization of the 1 m layer of typical chernozem, which changes towards the formation of the structural condition at long-term preservation of wild fallow. The ratio of the number of direct action relations and reverse action relations was as follows: 1.21:1 (ploughing), (0.80−0.85):1 (subsurface and surface tillage) and 0.92:1 (keeping wild fallow). The ratio of reliable relations of different orientation was as follows: 1.5:1, 1.25:1, 0.85:1, 0.75:1 respectively.

Table 3 presents the matrices of even correlation coefficients between the humic condition, agrophysical, agrochemical and physical-chemical indices in 1 m deep layer of chernozem. It was revealed that at systematic ploughing and subsurface tillage the total amount of correlation coefficients (R ≥ ±0.45) was 75.2–78.3 %,

Table 2. Long-term (for 36 years) impact of tillage system on the percentage distribution of correlation coefficients of diffe-rent strength and orientation between agrophysical indices in 0–100 cm layer of typical medium-humic light loamy chernozem

Value of correlation coefficient	Tillage for 22–32 cm	Subsurface tillage for		Wild fallow for 36 years
		22–32 cm	10–12 cm	
R ≥ ±0.45	*72.7	60.0	64.5	62.0
	66.7	61.0	62.8	52.6
R ≥ +0.45	39.7	27.0	29.5	29.5
	38.7	34.0	28.8	22.6
R ≥ –0.45	33.0	33.0	35.0	32.0
	26.0	27.0	34.0	30.0
R < ±0.45	27.3	40.0	35.5	38.5

Note. *Here and in Table 3 above the line – total amount of correlation relations; below the line – % of reliable correlation relations.

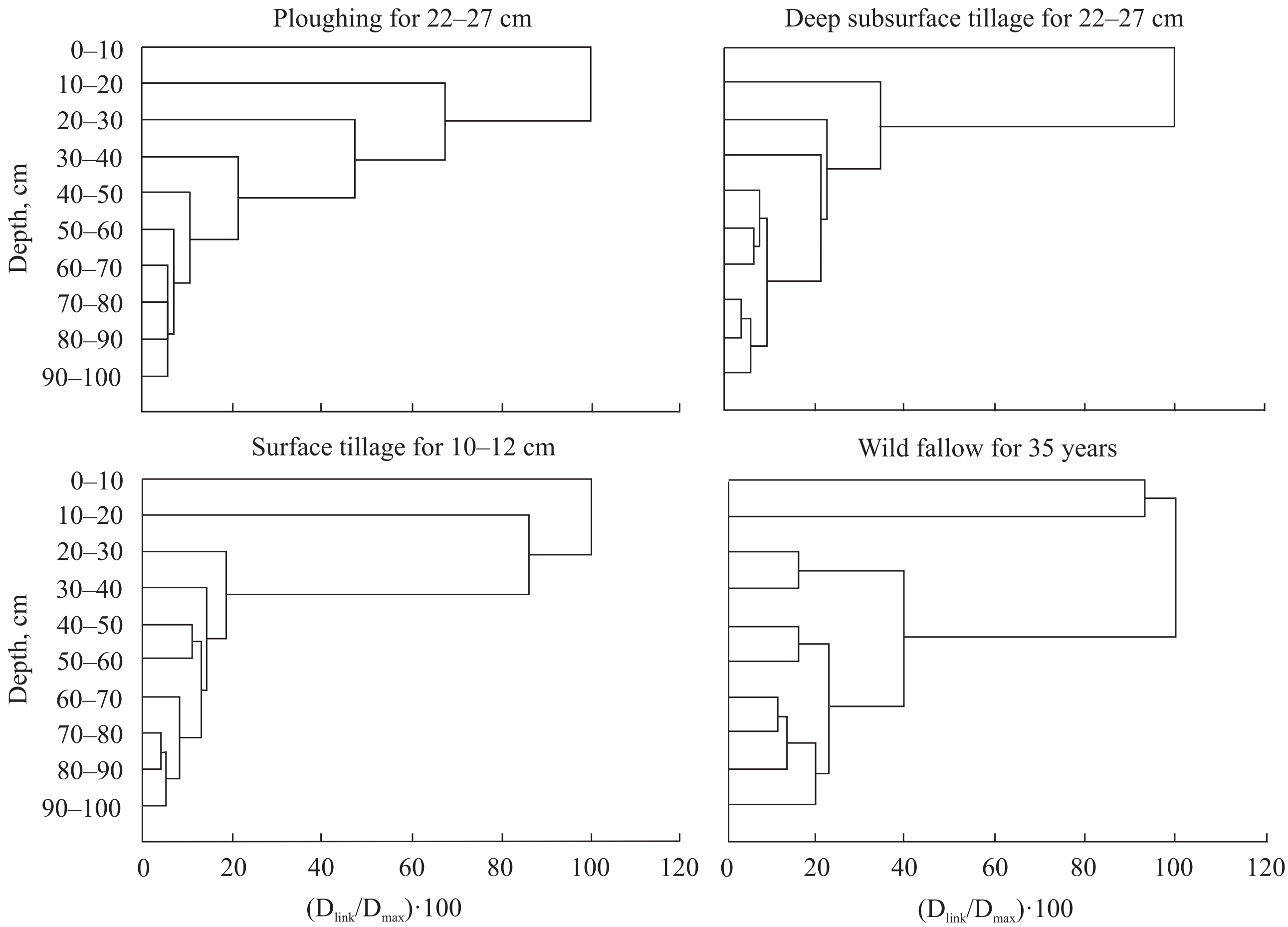

Fig. 1. The dendrograms of similarity degree between 1 m soil layers of typical low humus light loamy chernozem depending on the ways of tillage (2010–2012)

and the amount of reliable relations – 44.0–46.0 %. The direct action relations were 49.0–51.3 %; reverse action relations – 25.6–27.0 %, and reliable relations – 32.0–33.0 and 12.0–13.0 % respectively.

With systematic surface tillage the total amount of correlation relations of direct and reverse action ($R \geq \geq \pm 0.45$) was 1.17–1.22 times higher than for deep tillage, and that of reliable ones – 1.24–1.30 times higher. There were 1.88–1.22 times more direct action relations and the number of reliable ones was the same. There were 1.20–1.25 times more reverse action relations, and 1.69–1.83 times more reliable ones, which is an indirect evidence to enhanced processes of self-regulation and self-organization of agrophysical, humic, agrochemical and physical-chemical conditions towards keeping wild fallow for 36 years.

The ratio of the number of reverse action relations ($R \geq -0.45$) and the number of reliable ones while keeping wild fallow was 1.10:1; at ploughing and subsurface tillage – 2:1; at surface tillage – 1.5:1. The ratio of direct action relations to the reverse action relations was 2:1, 1.9:1, 1.85:1 and 1,35:1, 2.6:1, 1.59:1 according to the total amount of reliable relations (Table 3).

24 parameters of calculating even correlation relations were used in the classification of similarity values between 10-cm layers of the 1 m layer of typical low humus chernozem. At systematic ploughing, a soil profile without clearly expressed features of 10 cm soil layers grouping into subhorizons is formed (Fig. 1). There is gradual (declining) distribution in terms of similarity of some 10-cm soil layers in the humus bedrock down to the depth of 60 cm, and a subhorizon-cluster is formed in the lower part of the 1 m layer (soil layer of 70–100 cm), where the similarity between 10-cm-deep layers is the lowest.

The systematic surface tillage leads to enhancing the differentiation of the 1 m layer by the qualitative estimation of 10-cm-deep soil layers. Soil layers of 0–20 cm and 20–40 cm are referred to a separate cluster. A subhorizon cluster with different properties and similarity degree with the 50–70 cm layer is formed at the depth of 70–100 cm. The character of changes in the similarity degree for the 1 m layer has a more expressed differentiation compared to the profile at systematic ploughing (Fig. 1). The differentiation of 1 m layer by the qualitative condition of similarity of specific soil layers is expressed in the highest degree at systematic surface tillage.

The formation of structural-aggregate condition is based on the periodicity of subordinate local processes (SLP) with phase transitions. The flows of external energy, spent on the dissipation processes in the soil system, depend on the intensity of external conditions, state of typical chernozem and water saturation of its porous medium. Moisture redistribution in the porous space of chernozem promotes the formation of autowave processes of the changes in its thermodynamic state and is the essence of the energy dissipation process in soil [11].

Long-term surface tillage improves the agrophysical condition of the humus horizon (0–70 cm) due to the increase in the volume of aggregate pores by 15–20 %, which is directly related to the increase in the content of aggregates and 2–5 mm structural separates (dry) by 15–18 % . The abovementioned process is oriented towards the formation of agrophysical state at long-term preservation of typical chernozem of different granulometric composition and humus content in the state of long-term fallow (10–36 years). Permanent ploughing results in the destruction of natural organization of agrophysical state of chernozem, which is a manifestation of agrophysical degradation.

The re-grouping of aggregates and separates from small fractions to the mentioned sizes defines the textural porosity which reflects the boundary level of soil density at drying and determines the volume of pores, containing the resources of soil biota activity. Agrophysical self-regulation leads to the increase in the homogeneity of the porous space and the formation of a certain amount of their prevailing sizes, remarkable for structural separates of 2–5 mm.

The macroporosity is optimized and the ratio of sizes of pores with moisture to the volume of pores with air is stabilized (1.1–1.7 to 1 regarding total moisture content and 1–1.4 to 1 regarding the reserves of productive moisture) which ensures the stability of optimal ratio with time. The humus horizon of chernozem acquires its optimal ratio of water preserving and water lifting capability, and the loss of productive moisture reserves is reduced by 25–30 %, which enhances the degree of chernozem hydromorphism as an automorphous system due to higher (by 25–76 mm) reserves of productive moisture in the soil in July compared to the traditional agriculture system.

The decrease in the structure density and the increase in total porosity in 50–120 cm chernozem layer are related to the accumulation of organic substance, the change in carbonate form (the content of granular calcite, which has other properties compared to calcite-lublinite, is reduced in the soil volume unit) and enhanced profile biogenicity due to the enhanced degree of hydromorphism of soil conditions. The process of dissolving cementing compounds and the presence of excessive pressure of soil air at subsurface tillage creates conditions for the transfer of solid particles, which fluff chernozem depth of the whole humus horizon, especially its middle part (50–75 cm).

Table 3. Matrices of even correlation coefficients between fertility indices in 1 m layer of typical low humus chernozem at different ways of tillage (2010–2012)

Value of correlation coefficient	Tillage for 22–32 cm	Subsurface tillage for		Wild fallow for 36 years
		22–32 cm	10–12 cm	
R ≥ ±0.45	*78.3	75.2	92.0	75.0
	46.0	44.0	57.0	54.0
R ≥ +0.45	51.3	49.0	60.0	50.0
	33.0	32.0	35.0	31.0
R ≥ –0.45	27.0	35.6	32.0	25.0
	13.0	12.0	22.0	23.0
R < ±0.45	21.7	25.7	10.0	27.0

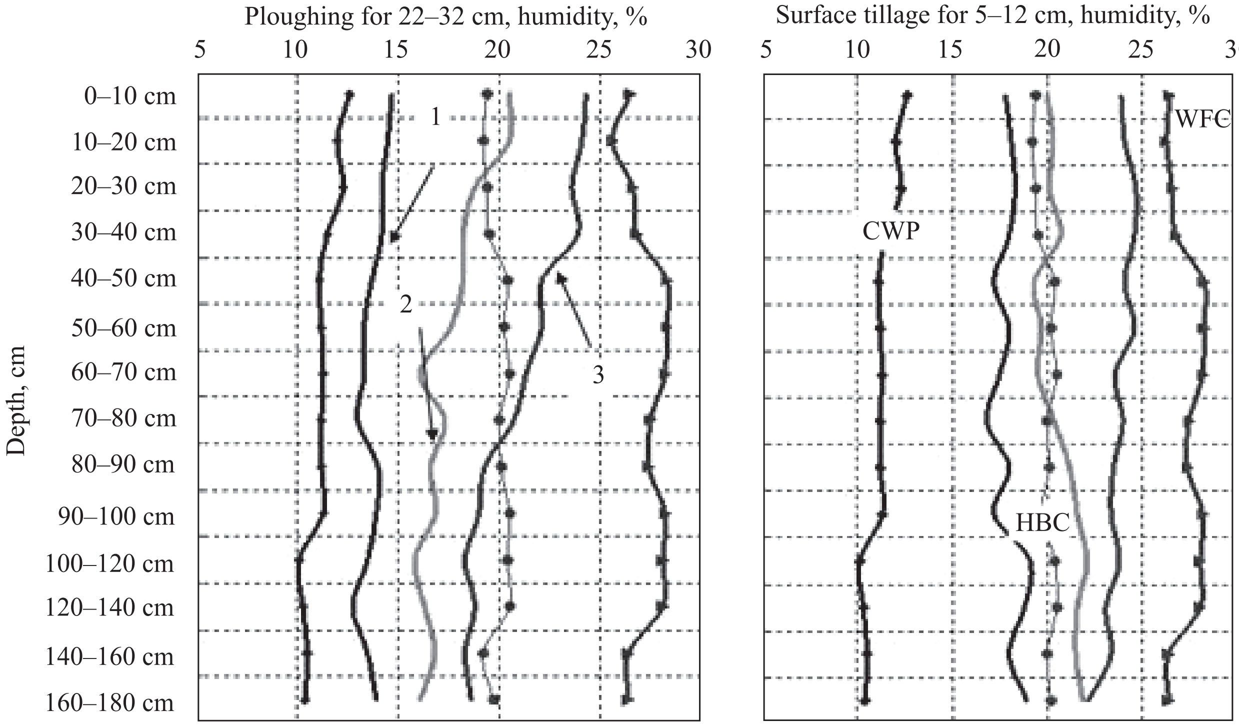

Fig. 2. The impact of the tillage system of typical chernozem of the Left-Bank Forest-Steppe of Ukraine on profile distribution of field moisture (%) per a crop rotation: 1 – dry conditions; 2 – optimal moisturization; 3 – excessive moisturization

At ploughing, when macropores prevail in the porous space, there is a process of chernozem drying – blowing away of CO_2 and moisture from soil. In conditions of subsurface tillage, the optimum of the structure of the porous medium of chernozem promotes the saturation of CO_2 soil solution and its acidification, which conditions the change in conditions of carbonate equilibrium and regulates the motility of micro- and macroelements in their most optimal ratio.

In conditions of surface tillage, there is a stable relation between the tension of external conditions and dissipativity of chernozem, which ensures the subordination of local processes of self-regulation in the agroecosystem: the activity of kinetic soil medium of chernozem is stabilized [12, 13].

The range of the thermodynamic condition, limiting homeostatic plateau of typical chernozem resistance to the environmental elements in the interval of moisture, available for plants, is scheduled by the irregularity of porous space transition, and the above-mentioned condition is a fundamental property of chernozem, which ensures the irreversibility of the action of cyclic elements of external flows of energy and substance [14, 15].

The self-development of soil medium in time and space should be ensured by the stability of chernozem in the mentioned thermodynamic state, which defines the periodicity of processes in the soil-plant-atmosphere system. This condition of chernozem is ensured when the moisture in the chernozem layer does not drop to the values of WP and is mostly manifested in the interval of humidity of delayed growth (MDG)–HBC–75 % WFC. The study of the impact of different tillage systems on the water saturation of soil layer of chernozem demonstrated that permanent surface tillage with a strong tendency towards the minimization of tillage leads to the mentioned range of water saturation in the 0–100 cm layer in the driest summer period, whereas with systematic ploughing it decreases down to the values under CW (Fig. 2).

Due to the enhanced volume of aggregate pores in the 0–100 cm chernozem layer and higher and more stable saturation of this volume with soil moisture, there is separation of some volume of soil air from atmosphere by water membranes, as the air perceives the fluctuation of environmental thermodynamic conditions, changing its volume.

The integrity of the interaction of elementary volumes of pressed air is manifested in the change of its thermodynamic state due to the transition of generalized soil meniscus, which leads to autowave thermodynamic processes and is the essence and agent of self-regulation process of soil processes in chernozem layer in conditions of soil-protective technologies. The result of cultural soil formation in agroecosystems depends on the prolonged duration of the mentioned chernozem condition during the vegetation period. At ploughing and deep subsurface tillage the permanence of soil formation in agroecosystems is disrupted by the drying-up of the chernozem layer in June–August, whereas at surface tillage the enhanced biogenicity in the chernozem layer is maintained during the whole vegetation period.

Table 4 presents the values of even correlation coefficients of the relation between the content of elements of agronomically valuable structure of chernozem and hydrothermal coefficient of Selianinov (HTCS) in April–August. With minimal tillage, the elements of the structural state of chernozem in humus horizon weaken their relation to hydrothermal conditions of the first half of crop vegetation in the crop rotation, and with ploughing, the correlation coefficients become stronger up to medium and high values.

At long-term (over 10–36 years) minimal surface tillage, the soil profile of chernozem acquires more autonomous properties regarding the impact of climatic factors, which is manifested in the ability to preserve the optimal parameters in the ecologically appropriate range of values, which corresponds to the conditions of cultural soil formation in agroecosystems of the Left-Bank Forest-Steppe of Ukraine.

The restoration of energy-wise appropriateness of creating the pore medium of typical chernozem of the Left-Bank Forest-Steppe of Ukraine under the impact of long-term (10–38 years) surface tillage should be deemed as the process of implementing the “memory” about the natural morphogenetic structure of spatial soil form of typical chernozem of a high self-organization degree, which is in direct correlation with the process of enhancing the residual features of natural soil formation and accumulative orientation of fertility indices in time. The extension of the amplitude of the tolerant fluctuation of thermodynamic condition, not sufficiently saturated with soil moisture of the porous space and the development of the process of autowave intercorrelation in soil with boundary autowaves of climatic parameters and informational interaction of typical chernozem with modern anthropogenic complex of the external and climatic impacts is the essence of self-regulation and a basic mechanism of reflecting the extensive restoration of typical chernozem fertility in agroecosystems of the Left-Bank Forest-Steppe of Ukraine.

The fertility of typical chernozem in a wide sense is an integrated systemic index of soil processes and properties, reflecting the specificities of soil function-

Table 4. The impact of the tillage system on the value of even correlation coefficients between the components of agronomic structure in the 0–40 cm soil layer and the hydrothermal coefficient in April–August on typical chernozem of the Left-Bank Forest-Steppe of Ukraine

Size of aggregate fractions, mm	Ploughing for 22–32 cm	Subsurface tillage for	
		22–32 cm	5–12 cm
For dry sowing			
> 5	R = −0.65 ± 0.03	R = −0.53 ± 0.03	R = −0.45 ± 0.03
> 3	R = −0.65 ± 0.02	R = −0.55 ± 0.02	R = −0.43 ± 0.02
2–5	R = −0.70 ± 0.05	R = −0.60 ± 0.05	R = −0.41 ± 0.05
0.5−2.0	R = 0.65 ± 0.04	R = 0.55 ± 0.04	R = < 0.40 ± 0.03
0.5−3.0	R = 0.70 ± 0.05	R = 0.50 ± 0.05	R = < 0.40 ± 0.03
*d_{st}	R = −0.67 ± 0.05	R = −0.43 ± 0.05	R = < 0.40 ± 0.03
For wet sowing			
0.5−3.0	R = 0.63 ± 0.03	R = 0.65 ± 0.03	R = −0.41 ± 0.03
0.50−0.25	R = < 0.40 ± 0.03	R = < 0.40 ± 0.03	R = < 0.40 ± 0.03
0.25	R = 0.66 ± 0.05	R = +0.66 ± 0.05	R = −0.55 ± 0.05
Water resistance coefficient	R = −0.81 ± 0.05	R = −0.75 ± 0.05	R = −0.53 ± 0.05
**d_{wt}	R = 0.68 ± 0.03	R = 0.65 ± 0.05	R = 0.45 ± 0.05

Note. *d_{st} and **d_{wt} – the average geometric diameter of structural separates and water-resistance aggregates respectively.

ing, its internal structure and external relations in agroecosystems. In the general form the structure of soil fertility model in agroecosystems may be defined as the estimation of the condition of the complicated soil system by the combination of features, carrying the information about fertility [1].

The order of switching-on the self-regulation of soil fertility may be different, but it is determined by the main impact, playing the role of the "trigger" mechanism, forming the mechanisms of reverse relations in the soil, which give the non-living system the guarantees of stability in terms of environment. If soil as a system loses the ability of perceiving the informational code of self-development, there is a start of degradation process, when the "untouchable" reserves of soil self-organization are consumed. The restored capability of the soil medium to respond to the flows of informational impacts is the impulse for further development of soil due to the functioning of reverse relations of the higher order. An important agent of "imposing" chernozem self-development is the wrapping of root, after-harvest and post-cut remains and manure into the 0–15 cm soil layer and specific conditions of biogenic organic substance transformation into humus. With time the systematic surface tillage restores the morphological structure of chernozem, which is materialized in enhancing the morphological features of natural soil formation.

This is achieved by restoring the natural state of the humus profile of chernozem [16]. The essence of chemical restoration of the morphological "image" of the soil form of chernozem is manifested in the clear interrelated correspondence between the spatial structure of the organic matter of humus, the chemical landscape of soil biocatalysts, and the orientation of morphogenesis conditions of typical chernozem. The restored natural status of the organic matter of chernozem humus is a matrix, defining the "image" of morphological soil forms. The formation of self-organized spatial soil forms may be considered as the main nature law, similar to the fundamental principles of mechanics, biology, chemistry, thus, the criterion of restoring soil fertility is the accumulative orientation of the main fertility indices and the increase in the residual features of natural soil formation in agroecosystems. The task of the systematic soil tillage in the agroecosystem is for the energy of potential fertility to be maximally transformed into the energy of efficient fertility [6, 17].

Table 5. The percentage distribution of even correlation coefficients in matrix fertility models

Value of correlation coefficient	Tillage for 22–32 cm	Subsurface tillage for	
		22–32 cm	5–12 cm
R > ± 0.50	29	35	40
R > 0.50	15	17	21
R > −0.50	14	18	19
R > ± 0.50	71	65	60

The parameter structure of typical chernozem fertility model was studied by us in the agroecosystem. The combination of functionally related parameter characteristics reflects the fertility model in the general form. The matrices of even correlation coefficients contain 29 variables, which may be divided into the following blocks: agrophysical, humic, agrochemical, aqueous, and climatic. The analysis of the percentage content of correlation coefficients above R = ±0.50 of different orientation demonstrates (Table 5) that at ploughing, the total number of correlation coefficients is 1.21–1.39 times lower compared to surface tillage for 22–32 and 5–12 cm. There were 1.4 times fewer direct correlation coefficients and 1.36 times fewer reverse action coefficients compared to minimal surface tillage. The comparison of correlation matrices highlights different degrees of dissipation of correlation coefficients in matrix fields. The intensity of chernozem tillage enhances the chaotization degree of correlation relations in different blocks of parameters. The agrophysical block is the most resistant block of soil parameters. Intense tillage leads to chaotization of correlation relations in the matrix field, and at surface tillage, the orderliness of orientation and the force of reverse relations increases. A similar regularity is observed between the indices of humic, agrochemical and aqueous blocks of soil parameters of fertility.

It is noteworthy that there are 23 strong correlation relations between the values of HTCS ($X_{27–28}$) and the amount of precipitation in April-August (X_{29}) and other fertility parameters at ploughing. Of these, nine have reverse orientation and 14 – direct one at deep subsurface tillage – 19, 13, and 6; and at the minimal one – 7, 4, and 3 relations respectively, which testifies to weaker impact of climatic factors on the stability of chernozem fertility parameters at minimal tillage in agroecosystems.

At ploughing and deep subsurface tillage, the agrophysical condition of the 0–30 cm chernozem layer is determined by hydrothermal conditions and the amount of precipitations in the warm period of the year, which testifies to the aridization of soil conditions and the manifestation of agrophysical degradation. The realization of natural and efficient fertility and productivity of the agroecosystem depends on the condition of climatic factors more and less at the systematic ploughing and deep subsurface tillage, respectively. At subsurface tillage, chernozem acquires some autonomy, and potential and efficient fertility is not limited in its realization, which defines the level of agroecosystem productivity and conditions of extensive restoration of chernozem fertility.

Different tasks of managing the fertility, isolation and selection of corresponding determinant variables, character of applied determinant impacts requires three subsystems of management [1]:

optimization of natural fertility ($F_{m.opt.}$);

operational management of fertility ($F_{m.oper.}$);

extensive restoration of fertility ($F_{m.rest.}$).

The subsystems should be interrelated and at the same time be the constituents of productive process management in the agroecosystem (Fig. 3).

The system of managing the chernozem restoration in the agroecosystem (Fig. 3, Table 6) as a subsystem involves the informational-estimating systems and management technology, ensuring the operational control over parameters, processing, analysis of the data obtained, working out of some determinant impacts and the technology of their application.

The determinant impact in the extensive restoration of typical chernozem fertility is the system of soil-protective technologies of cultivating agricultural crops with the minimization of chernozem tillage in the agroecosystems down to 5–12 cm. The optimization of the processes of natural fertility of chernozem in the agroecosystem is related to enhancing the self-organization process of the soil system, which has direct impact on self-regulation processes of soil fertility. In its turn, a non-high level of self-regulation ensures simple restoration of fertility, and high level of self-regulation ensures the management of restoration of chernozems fertility or extensive restoration of their fertility. Strict management of fertility may have a high economic effect, but only for a relatively short time period. In case of large scales of strict management, there are conditions of disrupting the natural resources potential of the territory – high ploughness (84 %) of Ukraine's territory and anti-natural ways of soil tillage – annual deep intense ploughing (with a plough) [18, 19].

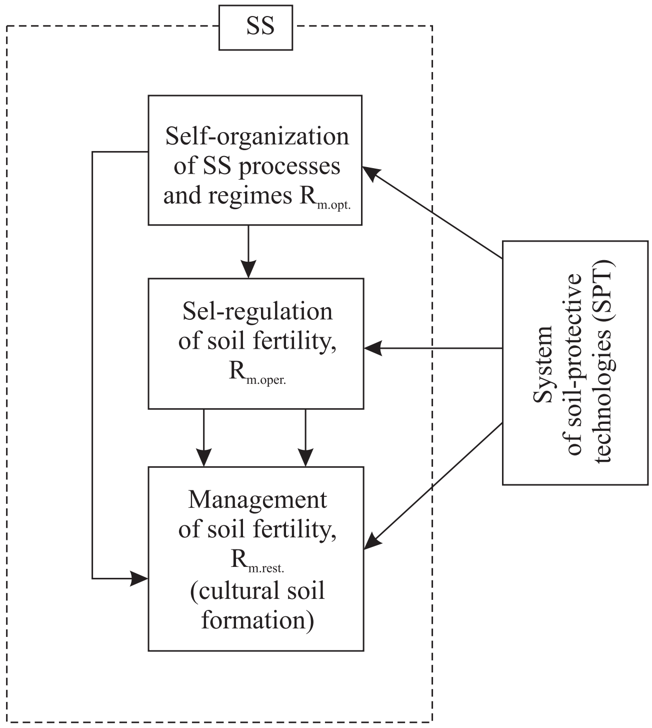

Fig. 3. Block-scheme of extensive restoration of typical chernozem of the Left-Bank Forest-Steppe of Ukraine

Extensive restoration of fertility is solved via gradual optimization of natural fertility and operational management of fertility. The main strategic task while developing the management systems in the process of restoring soil fertility of chernozem is to enhance natural soil formation in agroecosystems, to select corresponding managing effects, to forecast management results in time during the period of soil development in the agroecosystem.

Chernozem reclamation in the agroecosystem as soil formation is ensured by simple or extensive restoration of soil fertility [20, 21] and is diagnosed by the content of total humus, mobile forms of phosphorus and potassium on an obligatory condition of the increase in their content and directed seasonal rhythmicity. Only on this condition there is cultural soil formation, ensuring the preservation and improvement of other soil parameters of fertility. The reclamation should be perceived as a modified sod-forming process of soil formation with substance accumulation, the degree of manifestation of which depends on the farming standards.

The systematic application of soil-protective technologies corresponds to the logics of optimal sustainable management of natural resources in the highest degree and at the first approximation it is a reasonable extension of the process of managing the agroecosys-

Table 6. The system of managing the fertility of typical chernozem of the Left-Bank Forest-Steppe of Ukraine

Optimization of natural fertility and restoration of potential fertility ($F_{m.opt}$)	Simple restoration of fertility ($F_{m.oper}$)	Extensive restoration of fertility ($F_{m.rest}$)
Aim		
To optimize the manifestation conditions for potential fertility of chernozem due to the restoration of the natural sequence of regimes and processes to weaken internal and external limitations of efficient fertility manifestation and agroecosystem productivity (self-organization).	To provide the conditions of crop growth based on the restoration of inner properties of the soil system, enhancing the reverse relations between different hierarchy levels in soil to achieve homeostatic balance in the system of external interactions (self-regulation).	The self-maintenance of the energy-wise appropriate state of chernozem due to the manifestation of a high autocorrelation level between self-organization, self-regulation of soil structures of different hierarchy, directed towards the realization of energetic code (memory) of natural soil formation for extensive restoration of chernozem fertility and increase in the agroecosystem productivity (management).
Determinant soil characteristics		
Restoration of seasonal and annual cycles of humus. Accumulation of detritus and humus. Re-grouping of structural separates and aggregates by increasing size. Changes in the agrophysical structure of humus horizon of chernozem. Change in oxidation-reduction potential (ORP), pH. Optimization of gas regime. Change of nutrition orientation: a) nitrogen; b) phosphor; c) potassium. Optimization of moisturization regime for crop vegetation. Expanding the period of biological activity of chernozem.	Intercorrelation of seasonal periodicity of humus and water resistance of micro- and macroaggregates in time. Intercorrelation of oxidation-reduction conditions and nitrogen-phosphor nutrition. Intercorrelation between ORP, gas regime and mineralization of organic matter. Restoration of heterotrophic fixation of carbon by saprophyte microorganisms of soil. Provision of hydromorphism parameters of soil layer of chernozem as a soil formation factor. Optimization of acid-alkali balance of the soil solution. Enhancing the intercorrelation of biochemical processes in soil. Self-regulation of the microbiological condition of the soil. Optimization of nitrogen-carbon circulation in agroecosystems.	Restoration of an interrelation between the physiological periodicity of growth and development of crops, restored periodicity of the activity of soil microorganisms of different trophic levels and self-regulated mechanism of the main processes and regimes in soil (activation of seasonal periodicity of the small biological circulation of the matter, energy, and biophile elements in the agroecosystem). Stimulation of motility, form and increase in the content of carbonates (regradation). Enhanced autocorrelation in nitrogen-carbon circulation and the impact of effects of N and CO_2 on the activation of soil formation towards natural systems.
Determinant impacts		
The system of soil-protective (for 5–12, 22–32 cm) tillage with mulching of the field surface with by-products. The introduction of the optimal dose (10−14 t/ha of manure or 5−7 t/ha of by-products) of organic and mineral fertilizers ($N_{60–65}$ $P_{60–65}$ $K_{65–70}$) and their surface covering. Compliance with scientifically grounded system of crop rotations. System of plant protection. System of melioration. Organization of territory.	Gradual reduction in the intensity and depth of soil-protective tillage to 5–12 cm. Optimization of the ratio of organic and mineral fertilizers (t/kg of active substance): 1:(15−30) − simple expansion of fertility; 1:(8−15) − extensive restoration of soil fertility (intense biologization of the processes of cultural soil formation). Reduction of chemical pressing on soil microflora – limitation of the use of pesticides. Organization of territory.	Maintenance of non-deficient balance of organic matter, energy, and biophile elements in agroecosystems. Application of highly productive varieties of agricultural crops. Application of growth biostimulators for agricultural crops. Improving the interrelation and interinfluence of phytocenoses of agroecosystems with natural ecosystems by applying soil-protective tillage of chernozem. Organization of territory.

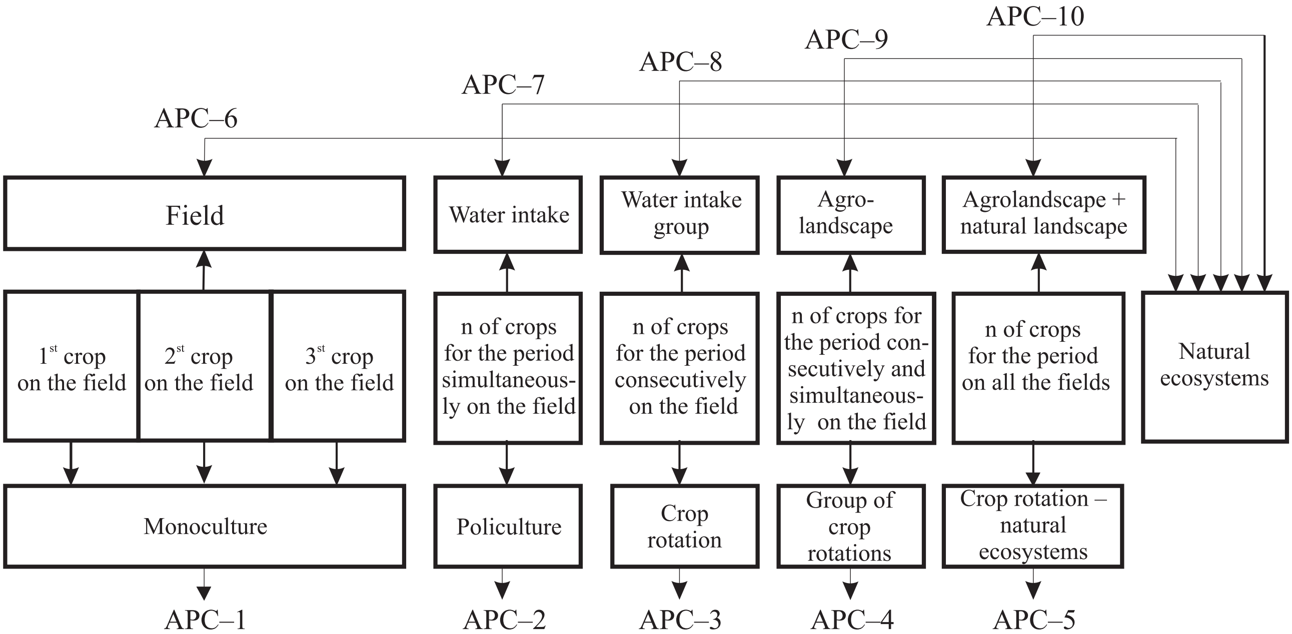

Fig. 4. The scheme of interrelations and interaction of agrophytocenoses of agroecosystems with natural ecosystems by applying soil-protective agriculture

tem organization phenomenon using biocenotic principles and should be viewed as a natural message of noosphere, the development laws of which are formed in the process of conscientious human activity using systemic laws of biogeocenosis organization with qualitatively determinant role of social factors [22–31].

The agriculture system may be managed via the regularity of facial humus formation both towards enhancing the xeromorphism of moistened chernozem (systematic intense tillage) and towards enhancing facial humus formation via increasing the moisturization degree of the soil layer in the seasonal and annual cycles under the impact of systematic application of soil-protective technologies in the agroecosystem. The principle of managing the facial humus accumulation of typical chernozem of the Left-Bank Forest-Steppe of Ukraine should be perceived as one of the laws of adaptive agriculture with increasing dryness of the climate of the Forest-Steppe zone of Ukraine.

In the agronomic (technological) sense, the restoration of chernozem fertility in the agroecosystem should be perceived as an enhanced capability of soil under the impact of agrotechnical (agriculture system, cultivation technologies) meliorative events and organization of the territory to provide for the needs of agricultural crops in ecologically relevant factors of life and enhancing the soil resistance to degradation factors [30].

Chernozem restoration in the agroecosystem is a wider notion than restoration of its fertility, it covers two aspects: extensive restoration of fertility and cultural soil-formation in the agroecosystem.

Cultural soil-formation should be viewed as enhancing the cumulative impact of the biological factor of soil-formation in conditions of agricultural exploitation of typical chernozem via improving hydrothermal soil conditions, which results in enhancing residual morphological features, accumulative orientation of regimes and processes of natural soil-formation, and the restoration of functional-ecological and facial regularities of humus formation in agroecosystem conditions.

The restoration of chernozem fertility in the agroecosystem – chernozem restitution of the capability (with anthropogenic and technogenic effects and the impact of external forces of natural-climatic origin) to preserve its parameters in the optimal ecologically and agroecologically approved range of values at the impact of cultural soil formation. It promotes keeping the balance of the very agroecosystem via enhancing the self-organization, self-regulation, and self-preservation of processes and regimes, ensuring extensive restoration of chernozem fertility in the agroecosystem.

Soil-protective agriculture with contour-meliorative organization of territory in the structural-landscape organization of the agroecosystem is a significant factor, affecting the character, orientation, and self-organization of energy- and mass-exchange in the complicated network of interactions and interrelations from a specific field to large territories, including agrolandscapes, natural landscapes and their combination.

The more structural-landscape elements of the agroecosystem will be covered with soil-protective agriculture, the more optimal the productivity and stability of agroecosystem functioning will be in general. There is a process of self-organized restoration of the programmed evolution of the agroecosystem productivity per unit of cumulative energetic resource in time and space (Fig. 4).

The application of soil-protective technologies allows approximating the logics of human activity in the agroecosystem to the logics of biogeocenosis functioning, when remote consequences of human impact on environment will not contradict the nearest and previous aims. The transition to qualitatively new technologies in production with the closed cycle of substance and energy exploitation will promote the reduction in spending the environmental resources, and new expenses will be related only to extensive restoration of soil fertility and increased productivity of the agroecosystem.

The soil-protective agriculture corresponds to the logics of optimal nature management in the highest degree, and is a relevant step towards qualitatively new state of farmer's conscience, which is a reasonable continuation of the process of acquiring the agrocenosis organization phenomenon, based on biogeocenotic principles, and in the first approximation should be viewed as a natural message of noosphere, the development laws of which are formed on the basis of optimal synthesis of natural and social factors in the process of conscientious human activity using systemic laws of natural environment at the determinant role of the social factor.

CONCLUSIONS

The determinant and governing impact in restoring the fertility of typical chernozem in the Left-Bank Forest-Steppe of Ukraine should be soil-protective technologies of cultivating agricultural crops, based on surface tillage. The technologies and methods of using natural energetic resources of the agrolandscape (the combination of soil-protective technologies), aimed at ensuring the ecologic stability of chernozem and the restoration of its natural state in the agroecosystems lead to the formation of conditions, when the volumes of the used energy of potential fertility of chernozem do not exceed the level, above which the loss of agroecosystem starts, and the volumes of disposal of efficient fertility do not exceed the compensatory volume of energy of ecologically safe quality due to anthropogenic input into the agrosystem. There are conditions to solve the main problem of agriculture – rational use of chernozem fertility with extensive restoration of its fertility and simultaneous simulation of natural soil formation (restoration) of chernozem in the agrocenosis.

The energy-wise appropriateness of creating the pore space of chernozem in conditions of soil-protective agriculture should be deemed as the thermodynamic code of soil formation or the process of implementing the "memory" about the morphogenicity of spatial soil form of chernozem of a high self-organization degree, which is in direct correlation with the process of enhancing the residual features of natural soil formation and accumulative orientation of fertility indices. The extension of the amplitude of the tolerant fluctuation of thermodynamic condition, not sufficiently saturated with soil moisture of the porous space and the development of the process of autowave intercorrelation in soil with boundary autowaves of climatic parameters and informational interaction of chernozem with modern anthropogenic complex of the external impact is the essence of homeostasis or self-regulation and a basic mechanism of reflecting the extensive restoration of chernozem fertility in the agroecosystem.

The soil-protective agriculture system should be viewed as a complex of technologies and methods of systemic or ecologically reasonable use of anthropogenic and natural energetic resources due to the fact that the volumes of using the energy of potential fertility of chernozem do not exceed the level, above which the loss of agroecosystem starts, and the volumes of disposal of efficient fertility do not exceed the compensatory volume of energy of ecologically safe quality due to anthropogenic input into the agrosystem. It creates the background to solve the main problem of agriculture – rational use of chernozem fertility with its simultaneous extensive restoration, which ensures more complete use of the bioclimatic potential with optimal exploitation of natural and anthropogenic resources of the territory.

Саморегуляція та управління відтворенням родючості чорноземів типових в агроценозах

О. В. Демиденко [1], В. А. Величко [2]

e-mail: dem006@yandex.ua; agrovisnyk@ukr.net

[1] Черкаська державна сільськогосподарська дослідна станція ННЦ «Інститут землеробства НААН України» Вул. Докучаєва, 13, с. Холоднянське, Смілянський р-н, Черкаська обл., Україна, 20731

[2] ННЦ «Інститут грунтознавства і агрохімії імені О. Н. Соколовського» НААН України Вул. Чайковського, 4, Харків, Україна, 61024

Мета. Дослідити процес посилення самоорганізації та саморегуляції чорнозему у напрямку природної організації під впливом довгострокового ґрунтозахисного безполицевого обробітку та визначити його вплив на підсилення здатності чорнозему адаптуватися до змін зовнішнього середовища, зберігаючи агроекологічну стійкість агроценозу Лівобережного Лісостепу України. **Методи.** Польовий, лабораторний, розрахунковий, математико-статистичний. **Результати.** На основі комплексних багаторічних (1992–2015 рр.) досліджень показано, що сукупність ґрунтозахисних технологій вирощування культур в аґроценозах є фактором впливу на характер, спрямованість та саморегуляцію енерго- і масообміну у складній мережі взаємодій та взаємозв'язків чорноземів в аґроценозах. Детермінуючим і управляючим впливом у відтворенні родючості чорноземів типових лівобережного Лісостепу України є ґрунтозахисні технології вирощування сільськогосподарських культур, які базуються на безполицевому обробітку. Енергодоцільність побудови порового простору чорнозему в умовах ґрунтозахисного обробітку слід розцінювати як термодинамічний код грунтотворення або процес реалізації "пам'яті" про морфогенетичність просторової грунтової форми чорнозему високого рівня самоорганізації, що прямо пов'язано з процесом підсилення залишкових ознак природного грунтотворення і акумулятивною спрямованістю показників родючості. **Висновки.** Ґрунтозахисна система землеробства повинна розглядатися як комплекс методів та прийомів системного або екологічно доцільного використання антропогенних та природних енергетичних ресурсів. Створюється умова вирішення основної проблеми землеробства – раціонального використання родючості чорноземів з одночасним її розширеним відтворенням, що забезпечує більш повне використання біокліматичного потенціалу при оптимальному використанні природних та антропогенних ресурсів території Лівобережного Лісостепу.

Ключові слова: ґрунтозахисний обробіток, система обробітку, агроценоз, природна родючість, саморегуляція, самоорганізація, культурне ґрунтоутворення.

Саморегуляция и управление воспроизведением плодородия черноземов типичных в агроценозах

А. В. Демиденко [1], В. А. Величко [2],

e-mail: dem006@yandex.ua; agrovisnyk@ukr.net

[1] Черкасская государственная сельскохозяйственная опытная станция ННЦ «Институт земледелия НААН Украины» Ул. Докучаева, 13, с. Холоднянское, Смилянский р-н, Черкасская обл., Украина, 20731

[2] Национальный научный центр «Институт почвоведения и агрохимии имени А. Н. Соколовского» НААН Украины Ул. Чайковского, 4, Харьков, Украина, 61024

Цель. Исследовать процесс усиления самоорганизации и саморегуляции чернозема в направлении естественной организации под влиянием долгосрочного почвозащитного безотвального рыхления и определить его влияние на усиление способности чернозема адаптироваться к изменениям внешней среды, сохраняя агроэкологическую устойчивость агроценоза Левобережной Лесостепи Украины. **Методы.** Полевой, лабораторный, расчетный, математико-статистический. **Результаты.** На основе многолетних комплексных (1992‒2015 гг.) исследований показано, что совокупность почвозащитных технологий выращивания культур в аґроценозах является фактором влияния на характер, направленность и саморегуляцию энерго- и массообмена в сложной сети взаимодействий и взаимосвязей чернозема в аґроценозах. Детерминирующим и управляющим воздействием в воспроизводстве плодородия черноземов типичных Левобережной Лесостепи Украины являются почвозащитные технологии выращивания сельскохозяйственных культур, которые базируются на бесплужной обработке. Энергоцелесообразие построения порового пространства чернозема в условиях почвозащитного возделывания следует расценивать как термодинамический код почвообразования или процесс реализации "памяти" о морфогенетической пространственной почвенной формы высокого уровня самоорганизации, что прямо связано с процессом усиления остаточных признаков природного почвообразования и аккумулятивной направленностью показателей плодородия. **Выводы.** Почвозащитная система земледелия должна рассматриваться как комплекс методов и приемов системного или экологически целесообразного использования антропогенных и природных энергетических ресурсов. Создается условие решения основной проблемы земледелия – рационального использования плодородия черноземов с одновременным его расширенным воспроизводством, что обеспечивает более полное использование биоклиматического потенциала при оптимальном использовании природных и антропогенных ресурсов территории Левобережной Лесостепи.

Ключевые слова: почвозащитная обработк, система обработки, агроценоз, естественное плодородие, саморегуляция, саморганизация, культурное почвообразование.

REFERENCES

1. *Aparin BF*. Evolution of soils and problems of managing their fertility. *Vestnik s.-h. nauki*. 1989;(9):74–9.
2. *Bulatkin GA*. Optimization of productivity of agrocenoses. *Vestnik s.-h. nauki*. 1990;(4):30–7.
3. *Volodin VM*. On extensive reproduction of soil fertility. *Vestnik s.-h. nauki*. 1989;(6):24–9.
4. *Shcherbakov AP, Kislykh EE*. To the formation of the general theory of efficient fertility of soils. *Vestnik s.-h. nauki*. 1989;(8):25–9.
5. *Shcherbakov AP, Volodin VP*. A new approach to the development of fundamental studies in agriculture. *Zemledelie*. 1989;(9):33–9.
6. *Shcherbakov AP, Volodin VM*. Bioenergetic conception as the basis for soil fertility assessment and control. *Pochvovedenie*. 1990;(11):90–103.
7. *Shcherbakov AP, Kislykh EE*. Efficient fertility of soils: methodological aspects. Moscow, Agropromizdat. 1990;72 p.
8. *Shcherbakov AP, Volodin VM*. Main provisions of sustainable agriculture theory. *Vestnik s.-h. nauki*. 1991;(1):42–9.
9. *Druzhinin DL, Vaniarkho VG*. Synergetics and methodology of systematic studies. *Sistemnye issledovania. Metodologicheskie problemy*: yearbook 1988. Moscow, Nauka. 1989;283–303.
10. *Nikolis G, Prigozhin I*. Self-organization in non-balanced systems. Moscow, Mir. 1979;512 p.
11. *Korinets VV*. Method of estimating the energetic efficiency of the main soil treatment. *Resursosberegaiushchie sistemy obrabotki pochvy*. Ed. I. P. Makarov. Moscow, Agropromizdat. 1990;235–43.
12. *Demydenko AV, Kapshtyk MV, Shykula NK*. Minimal treatment of typical chernozem as a factor of self-regulation of agroecosystems. *Problemy ispolzovania zemli*. Kyiv. 1995;70–1.
13. *Shykula MK, Demydenko OV*. The main principles of multiparameter self-organization and the discretion of the change in fertility in agrocenosis with soil-protec-tive agriculture. *Vidtvorennia roduchosti hruntiv and hruntozahysnomu zemlerobstvi*. Ed. M. K. Shykula. Kyiv, Oranta. 1998;300–85.
14. *Kolomiets SS*. Environmental characteristics of soil. *Visnyk agrarnoyi nauky*.1999;(12):9–13.
15. *Vidtvorennia* roduchosti hruntiv u hruntozahysnomu zemlerobstvi. Ed. M. K. Shykula. Kyiv, Oranta. 1998;680 p.
16. *Shykula NK, Balaiev AD, Demydenko AV, Dolia NN*. Biological agriculture as the way of restoring soil fertility. *Biokonversia organicheskih othodov i ohrana okruzhaiushchei sredy*: Materials on Int. Sympos. (Kyiv, November 28–30, 1994). Kyiv, Izd. ekolog. fonda. 1994;53–4.
17. *Mazur GA*. Humus and soil fertility. *Agrokhimia i hruntoznavstvo:* interdepart. themat. collection (special issue for the 6th Congress of UTGA). Kharkiv. 2002;27–33.
18. *Nosko BS, Chesniak GYa, Kukoba V.* Optimization of regimes and properties of chernozems of Ukraine. *Vestnik s.-h. nauki*. 1986;(7):53–8.
19. *Nosko BC*. Ways of maintaining black soil of Ukraine. *Visnyk agrarnoyi nauky*. 2003;(1):24–8.
20. *Grigoriev GI, Fridland VM*. On elaborating the soil classification by their cultivation. *Izmenenie pochv pri okulturivanii, ikh klassifikatsia i diagnostika*. Ed. I. N. Antipov-Karatayev. Moscow, Kolos. 1965;171–93.
21. *Nazarenko GV*. Targeted seasonal rhythmicity of typical chernozem and its determining factors. *Zemelno-otsenochnye problemy Sibiri i Dalneho Vostoka*: thesis of a conf. report. Barnaul. 1986;40–41.
22. *Demydenko OV, Shykula MK.* Humus state of typical black earth of Left-bank Forest-Steppe. *Visnyk agrarnoyi nauky*. 2004;(2):5–11.
23. *Demydenko OV*. Root system of field crops as a function and criterion of conditions of restoring soil formation of chernozem in agroecosystems. *Visnyk Cherkaskoho instytutu agropromyslovoho vyrobnytstva*: Interdepart. themat. collection of scientific works. 2006;(6):45–56.
24. *Demydenko OV, Shykula MK.* Time factor and restoration of chernozem fertility in agroecosystems. *Visnyk agrarnoyi nauky*. 2006;(2):13–7.
25. *Demydenko OV, Dyshlevyi VA*. Optimization of norms and doses of fertilizers depending on the depth and ways of soil tillage for winter wheat. *Visnyk Cherkaskoho instytutu agropromyslovoho vyrobnytstva*: Interdepart. themat. collection of scientific works. 2007;(7):163–72.
26. *Demydenko OV, Shapoval IS, Tonkha OL, Velichko VA, Boyko PI.* Humus state of black earth at different methods of machining in agro-ecosystems of Left-Bank Forest-Steppe. *Visnyk agrarnoyi nauky.* 2014;(4):58–62.
27. *Medvedev VV*. Soils and Ukrainian society in XXI century. *Agrokhimia i hruntoznavstvo*: interdepart. themat. collection (special issue for the 6th Congress of UTGA). Kharkiv. 2002;1–16.
28. *Tykhonenko DG, Gorin MO, Sydorenko VI*. Low lying landscape geosystems as an arena of late Cainozoic soil formation in the context of the period of conceptual fundamentals of land use. *Agrokhimia i hruntoznavstvo*. Kharkiv. 1998;(Is. 1):19–25.
29. *Tykhonenko DG, Gorin MO, Sydorenko VI*. Methodology of searching for strategies of land use while studying pedogenesis and cultivating soils of low lying landscapes. *Agrokhimia i hruntoznavstvo:* interdepart. themat. collection (special issue for the 6th Congress of UTGA). Kharkiv. 2002;40–53.
30. *Shykula MK, Demydenko OV, Andriyako YuV*. Management of the innovative activity while introducing soil-protective agriculture. *Vidtvorennia roduchosti hruntiv u hruntozakhysnomu zemlerobstvi*. Ed. M. K. Shykula. Kyiv, Oranta. 1998;634–45.
31. *Hryshyna LA, Orlov DS*. System of indices of humus state of soils. *Problemy pochvovedenia*. Moscow, Nauka. 1978;42–47.