UDK 631.34

THE WAYS TO ECOLOGICALLY BALANCED DEVELOPMENT OF AGROECOSYSTEMS IN THE FOREST-STEPPE ZONE OF UKRAINE

M.V. Kapshtyk, O.V. Demydenko, Candidates of Agricultural Sciences

Ecologically balanced agroecosystem may be achieved by self-organization and controlled evolution of soil fertility and by changing the intensity and direction of the processes of energy and matter transformation in soil. Our studies have shown that the best conditions for this purpose were created by employing soil-protecting systems of crop production with non-plough tillage and annual application of 12–14 t ha^{-1} of organic manures and 111–246 kg ha^{-1} of mineral fertilizers.

Soil degradation reproduction of soil fertility, Chernozem soils, minimum and non-plough soil tillage, soil organic matter, ecologically balanced agroecosystem,soil-protecting systems of crop production, consulting.

To give ecological reasons to the systems of crop production in the Forest-Steppe Zone of Ukraine it is necessary to elucidate the laws governing the changes of soil properties, especially soil biology, occurring under the influence of farming practices. The essence of sustainable farming lies in the strengthening of micro-organisms' role in the reproduction of soil fertility by the systems of fertilizing and soil tillage in crop rotations [10,11].

From our point of view a fundamental soil researches must solve a complicated and important task: to detect the laws of energy and mass exchange in agroecosystems and to create a theoretical basis for the development of practices and methods of soil management in agricultural systems. Intensity and direction of the transformation of energy and matter in agro-ecosystem are determined by the structure and composition of crops in crop rotation and the systems of fertilizing, soil tillage and plant protection [10,11].

A system of fertilizing is a means of intensity regulation in a small (biological) cycle of substances pertaining to an agroecosystem. The cycle is being disconnected by the subtraction of substances with yields. The level of energy subtraction and its re-supply in an agro-ecosystem is determined by a crop rotation which is a means of formation of structure and composition of a phytocaenosis with a purpose of ensuring maximal productivity and stability in time [1].

Self-organization and self-reproduction of an agro-ecosystem are directly related to the organization and evolution of soil productivity. Therefore, the system of soil tillage is a factor of influence on the changes of potential and effective soil fertility with an optimal energy supply in a man-controlled process of soil formation. It must stimulate a multiparametral self-regulation of soil fertility in time and space so as to sever the connections which function on the principles of self-regulation [11]. It means that the system of soil tillage must model the natural processes of soil formation. Such a system allows regulation of the transformation of energy and organic matter in soil controlling its input and losses by mineralization [10,11].

Materials and methods. Our research has been carried out on a stationary field test plot. The dominant soil of the plot was typical chernozem, a clay loam with moderate organic matter content formed in loess. The plot was situated in " Ukraine" farm, Karlivka district, Poltava region. The region represents the southern part of the left-bank province of the forest-steppe zone of Ukraine. The soil was characterized by the following characteristics in the upper 0–10 cm layer: 5.5 % of organic matter (organic carbon content multiplied by 1.724), total nitrogen 2170 and total phosphorus 1500 ppm; soil pH was 7.1. Available P_2O_5 and K_2O extracted by 1% $(NH_4)_2CO_3$ were 180 and 150 ppm respectively. Hydrolysable nitrogen determined in 1 N H_2SO_4 was 70 ppm.

A ten-field crop rotation has been used in experiments with the following crop sequence: occupied fallow, winter wheat, sugar beat, peas, winter wheat, corn for grain, corn for silage, winter wheat, sugar beet and sunflower.

Soil organic matter content has been determined by combustion of soil samples with concentrated H_2SO_4 in a 1:1 mixture with $K_2Cr_2O_7$ [2]. Humification coefficient of plant residues were determined by using the samples of residues according to the procedure proposed by G.Ya. Chesnyak [3]. Newly formed organic substances were extracted from the soil by 0.1 N NAOH [2]. Humic acids were determined by precipitation with 1 N H_2SO_4, heating to +80…+90 ^{0}C and subsequent dissolution in O.1 N NaOH. Organic carbon in dried sediments has been determined as a total organic carbon in soil by combustion in a mixture of a concentrated H_2SO_4 and 0,4 N $K_2Cr_2O_7$. Soil micro-organisms consuming organic and inorganic nitrogen were determined in fresh samples according to procedure described by E. Z.Tepper [5] and I. P. Babyeva & G. M. Zenova [6]. The amount of ATP in soil samples was determined by method developed by J.Oades and D. Jenkinson [7]. Nitrifying and ammonifying bacteria were determined using, respectively, elective culture medium proposed Vinogradskyi and meat-and-pepton agar according to a procedures described by D. G. Zvyagintsev [8]. The amount of actinomycetes and fungi were determined by methods described also by above mentioned author.

The scheme of field experiment included 4 systems of tillage: (1) mold board ploughing to the depth 20-30 cm depending on a crop grown (CT) ; (2) non-plough tillage to various depth depending on a crop (NPT_1); (3) shallow non-plough tillage to the depth 10–12 cm for all crops (NPT_2) and (4) minimum tillage to the depth 5-7 cm for winter wheat and 10–12 cm for the other crops(MT). The scheme included 4 systems of fertilizing with the following rates per hectare of a crop rotation per year : (a) control variant without any fertilizers (NF); (b) farm manure (12 t ha^{-1}) + N_{37} P_{39} K_{35} (F1); (c) farm manure (12 tha^{-1}) + N_{62} P_{62} K_{55} (F2) and (d) farm manure (12 tha^{-1}) + N_{86} P_{86} K_{74} (F3).

Experimental results.

Humification coefficients of plant residues

The employment of crop rotations always presupposes a well grounded sequence of crops. Soil formation is very much dependent on the chemical composition of plants, especially the content of nitrogen [9]. The first group is made up by the crops, which contain little nitrogen in their residues (grain crops). The second group includes those crops, which have a noticeable nitrogen content in their residues. These are annual and perennial legumes, sugar beet, corn, sunflower and others.

The amount of humus formed from various residues under conditions of conventional (ploughing) and non-plough systems of tillage differ. Conventional tillage (ploughing) causes the coefficient of humification to grow with depth. On the fields with small grain straw they changed from 17.4 to 18.7, while on the fields with alfalfa they reached 20 to 21.9% (Table 1). Surface tillage was characterised by high humification coefficients in 10–20 cm layer of soil.

1. Coefficients of humification of residues and farmyard manure, %.

Substrates	Soil layers, cm					
	0-10		10-20		20-30	
	CT	NPT_1	CT	NPT_1	CT	NPT_1
After 6-year period of tillage system application						
Wheat straw	16.1	17.0	17.6	19.3	17.7	17.9
Residues of alfalfa	17.9	19.3	18.3	20.6	18.9	19.4
After 8-year period of tillage system application						
Wheat straw	16.1	16.6	18.0	19.8	18.2	18.4
Residues of alfalfa	17.8	19.0	19.9	22.0	19.6	20.6
Manure	15.8	16.2	18.2	20.0	17.8	18.2

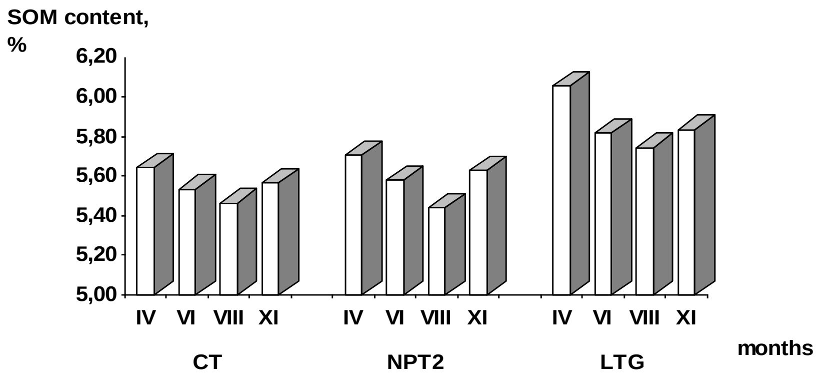
For small grain straw it was 20,4 and for alfalfa residues – up to 24%. Soil aeration and wetness are the main factors determining the humification coefficients at various depths on the variants with non-plough soil tillage. On the variants with straw they grew up by 1.6–2.7 % while on the variants with alfalfa they increased by 2.0–2.2 %.

The depth of farm manure incorporation also affected the humification coefficients. On the variants with conventional plough tillage the highest values of these coefficients were observed in 20–30 cm layer of soil (17–17.8 %), while on the plots with a non-plough tillage it grew by 1.6–1.8 % in the 10–20 cm layer and reached 19–20 %. Mineral fertilizers applied with farm manure ($N_{120}P_{120}K_{130}$ +12 tha^{-1} of farm manure) have increased the humification coefficients of both straw and alfalfa by 1.5–2.2 and 1.6–1.8 % respectively. Shallow incorporation of plant residues and manures on a background of the same fertilizing system increases the intensity of humification (K_g) as compared with ploughing in the layers of the soil: 0–10 and 10–20 cm by 1.2–

2.2 for alfalfa, by 0.2–1.6 for small grain straw and by 0.4–1.8 % for farm manure.

Seasonal Dynamics of Soil Organic Matter. Soil-protecting crop production systems have increased the content of newly formed organic matter in soil by 2.9-3.7% in 0–20 cm layer compared with conventional tillage (ploughing) where the increases were 1,7–2,0%. There were the increases in the contents of humic and fulvic acids. The ratio between their carbon was 0.76–1.69 at the plots with non-plough tillage and 1.0–3.0 at the plots with mold-board ploughing [10]. Shallow incorporation of crop residues did not only increase the humification coefficients, but increased the yearly and seasonal amplitudes of soil organic matter content in soil. On the plots with non-plough tillage this amplitude was 0.22–0,32% in layer 0-20 cm while on the plots with conventional tillage it was within 0.14-0.20%, reaching even 0.30–0.37% on the plots with long-term grassland (Figure 1). The amplitudes were decreasing with depth on non-plough tillage while on ploughing they reached 0,23–0,24% in the layer of soil 10–20 cm.

Seasonal dynamics of soil organic matter was higher that its possible formation by 80%. We explain this phenomenon by the contribution of root exudates and microbiocaenosis of the soil and by the mechanisms of CO_2 of the soil air transformation in soil humus detected by collegues from our university [11].



Soil Organic Matter content in 0–20 cm layer of soil under influence of various systems of land management

The dynamics of a calcium salt of ATP in soil was opposite to the dynamics of soil humus. This testifies to the fact of energy transformation from one form to another. The process is self-regulated and optimises the conditions of humus formation in soil. These processes are very pronounced in natural ecosystems and in agro-ecosystems with systematic use of conservation technologies of crop production. A yearly diapason of soil organic matter transformations discovered by us is equivalent to application of 350–400 t ha^{-1} of farm manure [10,11].

The Ratio of Various Groups of Soil Microorganisms. The system of soil tillage effects the numbers of micro-organisms and their activity in 0–30 cm layer of soil (Table 2). A non-plough tillage, as compared to conventional mold-board ploughing, caused an increased multiplication and activity of microorganisms in 0–10 cm layer of soil.

2. Effect of fertilization and tillage systems applicated for 7 years on the population of soil microorganisms. Absolute values in units ·per 1 g of soil [12].

Variant	Microorganisms on SAA $\times 10^7$	Microorganisms on MPA $\times 10^7$	SAA : MPA	Actynomycetes $\times 10^6$	Fungi $\times 10^3$
Layer 0-10 cm					
CT, NF	1.85	0.85	2.18	3.45	3.54
NPT_1, NF	2.37	1.24	1.91	4.15	4.37
CT+ F	37.9	13.9	2.73	45.1	6.58
NPT_1 +F	59.8	23.2	2.58	83.4	8.34
Layer 10-20 cm					
CT, NF	0.687	0.332	2.04	0.315	2.31
NPT_1, NF	0.612	0.327	1.87	0.321	2.75
CT+F	1.79	0.73	2.45	6.83	3.45
NPT_1 +F	1.48	0.62	2.14	6.1	4.18

CT – conventional tillage; NPT_1 – non-plough tillage

NF – non-fertilized; F 3– manure + NPK

On the plots with no fertilizers there was an increase in the quantity of nitrogen by 1.3 times compared with ploughing, while on the plots with organic and mineral fertilizing this increase reached 1.6 times. The same was true for the bacteria using organic nitrogen. On the plots without fertilizing their amount increased 1.5 times, while on the fertilized plots the increase was 1.7 `times. Positive effects of mineral fertilizers was observed on the plots which received no more than 280 kg ha^{-1} of NPK. But there was a significant increase in the amount of soil micro-organisms which caused a 1.2–1.5 times increase of organic matter mineralization as compared with plots with no fertilizing. The application of N_{110} P_{110} K_{110} reduced the amount of actinomycetes and ammonifying bacteria in soil and increased the amount of fungi and nitrifying bacteria which caused an activation of mineralization processes.

Yields of Crop and Economic Efficiency. The strengthening of biological and microbiological factors of soil fertility in conservation farming does not presuppose any additional expenditures of money or any increase in the price produce. Just the opposite is true: these technologies require less energy for soil tillage. The yields of crops are 15–30% higher as compared with conventional tillage (Table 3) and the price of produce – 30–50% lower [10,11]. And not only in years with droughts. The accummulation of elements of plant nutrition in organic forms decreases the expenditure of mineral fertilizers and their losses caused by soil erosion and denitrification [10].

Soil-protective crop production systems with a non-plough soil tillage model a natural process of soil formation provided there is an optimal supply with energy and fertilizers. They also increase the validity of relations between the various elements of an agroecosystem [10]. Up to date views on crop rotations [1] try to explain that agricultural crops imitate the natural vegetation to a certain extent, but only during a short period of time. Actually we have an artificially created phytocaenosis in an agroecosystem, which regulates the activity of soil microorganisms and thus fulfils the function of a main factor of soil formation. Systematic use of conservation tillage in crop rotations increases the ability of artificially formed phytocaenosis to effect soil formation and to improve the ecological aspects of crop production [10].

3. Winter wheat yield (dt ha^{-1}). Average of 7 years during 1st crop rotation period after various previous crops. Absolute values in dt·ha^{-1}; relative values in comparison to CT, non-fertilized (=100 %).

Soil tillage	System of fertilizing							
	Non-fertilized		$N_{35}P_{30}K_{30}$		$N_{55}P_{45}K_{45}$		$N_{75}P_{60}K_{60}$	
	dt·ha^{-1}	%	dt·ha^{-1}	%	dt·ha^{-1}	%	dt·ha^{-1}	%
CT	39.2	100	43.4	111	44.5	114	48.9	125
NPT_1	37.6	95.9	45.9	117	47.9	122	48.8	124
NPT_2	37.5	95.7	46.4	118	49.8	127	49.2	126
MT	36.5	93.1	43.4	111	45.1	115	47.6	121

An inverse relation between the intensity of nitrification and the accumulation of available phosphorus in soil is caused by many factors. The lowering of soil pH increased the amount of available phosphorus. Optimal conditions for the development of nitrifying bacteria were observed at pH 8.0, while at pH 6.5–6.8 their activity was drastically reduced [10,11]. This, to our mind, is the main reason why the conservation technologies decrease the intensity of nitrification and improve the activity of soil microflora in mobilization of mineral phosphates. Orderly seasonal rhythms of redox conditions and base-acid equilibrium in Chernozem soil subject to soil-protecting crop production technologies regulates the seasonal dynamics of the availability of individual macro- and micro-elements of plant nutrition in soil solution so that the optimal ratios are maintained between them.

To obtain high yields of crops on typical Chernozems is possible at the expense of potential soil productivity created by soil microorganisms in crop rotations, that is, at the expense of root exudates and semidecomposed plant residues. Total organic matter (humus) content in soil is not so important as the amount of “active” products of decomposition which are available for the saprophytic microorganisms. Soil detritus is available for the microorganisms and may be a source of an “ active “ organic matter. The potential productivity of chernozems is directly proportional to the accumulation of detritus in soil.

There exists a close relation between the seasonal changes in soil organic mater content in chernozems and the seasonal physiological rhythms of plant growth [9,10]. It is caused by a dynamic correspondence among the soil, the plant and the atmosphere. The practices of conservation crop production renovate this correspondence and the role of crop rotation can hardly be overestimated in this respect.

Conclusions. Soil-protecting systems of crop production based on a non-plough tillage of typical chernozems model a natural process of soil formation, increase the ecological role of a crop rotation and strengthen the soil-forming role of field crops. Systematic employment of soil-protecting tillage systems increases the abilities of artificially created phytocaenoses to effect soil formation and ecologization of a crop production system. Soil formation dynamics is very much affected by the chemical of plants, especially the content of nitrogen. This is achieved by the rational management of natural and anthropogenic energy resources for the creation of optimal conditions for the binding of solar energy by an agro-ecosystem in the form of organic substances which possess ecologically sound quality. All this leads to the formation of ecologically stable agrolandscapes.

References

1. Tscherbakow, A.P. & Volodin, V.M. Osnownyye polozheniya teoriyi ecologicheskogo zemledeliya. *Vesntik selskohosyaistvennoi nauki*, (1), pp. 42–49, 1991.
2. Ponomaryova, V.V. & Plotnikova, T.A. *Methodicheskiye ukazaniya po opredeleniyu soderzhaniya i sostava humusa v pochvach mineralnych i torphyanych,* Academy of Science: Sankt-Peterburg, pp. 1–105, 1975.
3. Chesnyak, G.Ya., K methodike opredeleniya coefficiyenta humificaciyi rastitelnych ostatkow i navoza v chernozemach tipichnych Lesostepi v usloviyach zerno-sveklowichnogo sevo-oborota. *Agrochimiya i pochvovedeniye*, 49, pp. 79–85,1986.
4. Lykov, A.M. & Tulikov, A.M. *Practikum po zemledeliyu s osnovami pochvovedeniya*, Agropromizdat: Moskow, pp. 65–67, 1985.
5. Tepper, E.Z., Shilnikova, W.K. & Pereverzewa, G.I. *Practikum po microbiologiyi*, Nauka: Moskow, pp. 35–175, 1979.
6. Babyeva, I.P. & Zenova, G.M. *Biologiya pochv*, Moskow State University: Moskow, pp. 24–118, 1989.
7. Oades, J. & Jenkinson, D. Adenosin triphosphate content of the soil microbial biomass. *Soil Biology and Biochemistry*, 6(2), pp.11–13, 1979.
8. Zvyagintsev, D.G. *Methody pochvennoi microbologiyi i biochimiyi*, Moskow State University: Moskow, pp.150–304, 1991.
9. Ponomaryova, V.V. & Plotnikova, T.A. *Humus i pochvoobrazovaniye*, Nauka: Sanct-Peterburg, pp.113–148, 1980.
10. Kapshtyk, M.V., Shykula, M.K.& Petrenco, L.R. Conservation non-plough systems of crop production in Ukraine with increased reproduction of soil fertility. *Proc. of the NATO ARW On Soil Quality, Sustainable Agriculture and Environmental Security in Central aand Eastern Europe*, eds. M.J. Wilson & B. Maliszewska-Kordibach. Kluwer Academic Publishers: Amsterdam, pp. 267–276.
11. Shykula, M.K., Balayev, A.D.,Kapshtyk, M.V. et al. Pryrodnyi mechanizm widtvorennya rodyuchosti gruntiv (Chapter 5). *Widtvorennya rodyucosti gruntiw v gruntozachysnomu zemlerobstvi*, ed. M.K. Shykula, Oranta: Kyiv, pp. 207–298.

Екологічно збалансована агроекосистема може бути сформована шляхом самоорганізації і контрольованої еволюції родючості ґрунту і, через зміну інтенсивності і напряму процесів перетворення енергії і речовини в грунті. Наші дослідження показали, що найкращі умови для

цього були створені шляхом використання ґрунтозахисних технологій з безплужним обробітком ґрунту із застосуванням 12–14 т/га органічних добрив і 111–246 кг/га д. р. мінеральних добрив.

Деградація ґрунтів, відтворення родючості ґрунтів, чорноземи, мінімальний і безполицевий обробіток ґрунту, органічна речовина ґрунту, екологічно збалансована агроекосистема, ґрунтозахисні технології, консалтинг.

Экологически сбалансированная агроэкосистема может быть сформирована путем самоорганизации и контролируемой эволюции плодородия почвы и изменения интенсивности и направления процессов преобразования вещества и энергии в почве. Наши исследования показали, что наилучшие условия для этого были созданы путем использования почвозащитных технологий с бесплужной обработкой почвы с применением 12–14 т/ га органических удобрений и 111–246 кг / га д. в. минеральных удобрений.

Деградация почв, воспроизводство плодородия почв, минимальная и бесплужная обработка почвы, органическое вещество почвы, экологически сбалансированная агроэкосистема, почвозащитные технологии, консалтинг.

UKRAINE'S SUNFLOWERS: MODERN DAY TRAGEDY OF THE COMMONS

Rachel McMonagle, B.A. in Environmental Studies;
current U.S. Dept. of State Fulbright Fellow

Ukraine's intensive cultivation of sunflowers has left nutrient-depleted soils and a destructive scenario akin to Garrett Hardin's observations in his essay "The Tragedy of the Commons." While some have endorsed Ukraine's current moratorium on land sales as a means of maintaining Ukrainian agricultural autonomy, the ban is creating complicated relationships between lessees and the long-term fertility of the lands they manage. Although agricultural advisors recommend planting sunflowers sparingly in rotation, the vast majority of farmers are choosing to forgo rotation schemes in order to maximize their short-term profits. Hardin is steadfast in arguing that there are few "technical" solutions; however, in the case of Ukraine's sunflowers there is certainly an attainable solution, built on a combination of technical and moral grounds.

Ukraine, sunflowers, soil quality, agriculture, sustainability.