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Assessment of main fertility indicators of dark gray podzolized soil at the long-term systematic application of fertilizers

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Goal. Based on observations in the system of range agroecological monitoring to identify changes in the natural cycle of nutrients and toxic elements due to anthropogenic factors. **Methods.** General scientific methods of materialist dialectics, scientific abstraction, analysis and synthesis, lo-gical thinking, and special: range agroecological monitoring, mathematical and statistical. **Results.** The results of studies conducted on dark gray podzolized soil of the Right-Bank Forest-Steppe with long-term application of mineral fertilizers and the background of by-products of the predecessor during 1987 – 2017 are shown. It is fixed that humus content has increased by 0.2 – 0.3%, while the indices of exchange and potential acidity, as well as the amount of the absorbed bases compared to the ecotope without the use of fertilizers, have dropped. That is the indication of the acidifying action of the applied fertilizers and the need for liming. The number of compounds of light hydrolysis and mineral nitrogen in fertilized ecotopes was at very low and low levels. When applying a double dose of mineral fertilizers N75P74K83 on the background of organic levels, the content of mobile phosphates and potassium was respectively very high and high, which provided optimal conditions for pho-sphorus and potassium nutrition of crop rotation plants. None of the ecotopes exceeded the maxi-mum allowable concentration (MAC) and the background content of mobile forms of lead, cad-mium and nickel for the soils of Ukraine. The content of copper in the soil was low and medium, and the content of zinc was very low and low. **Conclu-sions.** During long-term anthropogenic loading for 30 years in the grain-crop rotation of the Right- Bank Forest-Steppe with the application of 232 – 349 kg/ha NRK on the background of plowing of by-products of plant growing there was an expanded reproduction of fertility of dark-gray podzolized soil as to humus, mobile forms of phosphorus and potassium. But a tendency was observed of accumulation of mobile forms of cadmium with a simultaneous deepening of copper and zinc deficiency.

Key words: *agroecological monitoring, agro landscape, ecotope, biogenic and toxic elements.*
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The growing anthropogenic impact poses a threat to the biosphere, therefore its regulation in order to maintain the normal functioning of the biosphere as a global socio-ecosystem is a priority task of modern society [1]. Long agro-industrial pressing can cause transformations of natural properties and a partial loss of the self-healing capacity of soils. Failure to comply with environmental requirements leads to depletion of the soil, its pollution, loss of humus, acidification, salinization, overconsolidation, erosion processes. The level of soil fertility is changing, which is a criterion for assessing the ecological state of agricultural land and largely depends on the technology of growing crops. Nowadays, researchers are considering the issue of soil degradation not only from the position of view of its erosion or loss of fertility, but also from the point of view of preventing the consequences of deteriorating the balance of the ecosystem [2-6].

The guarantee of ecological safety is possible on the basis of environmental monitoring, which is a complex system of observation, assessment and forecast of changes in its state under the influence of anthropogenic factors. Depending on the criteria, different types of monitoring are distinguished, one of which is agroecological. It contains an observation system, a comprehensive assessment for the study of agricultural landscapes and agroecosystems, taking into account abiotic and socio-economic factors, monitoring and predicting changes in soil fertility, their ecological state in order to manage their productivity [7].

A decrease in the level of soil fertility of arable lands is a consequence of a decrease in the volume of application of organic, mineral and lime fertilizers, a violation of crop rotation, ignoring the law of returning basic nutrients to the soil, etc. [8]. World experience convinces that extensive farming without the use of fertilizers inevitably leads to a gradual depletion of soil fertility and a decrease in the productivity of crops grown [9]. In modern farming systems, fertilization, on average, compensates for only 40% of the nutrients removed from the soil by the crop. The annual deficiency of phosphorus and potassium compounds in the soil is more than 40-60 kg / ha [10]. A decrease in the nitrogen content in the soil for fertilization is caused by the intensification of humus mineralization processes, an increase in crop removal by crops, unproductive losses due to leaching and emission [11]. With an increase in fertilizer doses, the removal of a significant part of the phytomass of the crop

also increases, which leads to a decrease in the level of humification, the removal of trace elements from the soil by crops increases, the natural ratio between them and trace elements in the soil environment is disturbed, and soil acidity increases. Soil acidification leads to a decrease in the productivity of agricultural crops, the effectiveness of mineral fertilizers, and an increase in the accumulation of pollutants in plants.

Consequently, the use of organic and mineral fertilizers, chemical ameliorants, scientifically grounded crop rotations is necessary to further increase the efficiency of agricultural production. However, it is necessary to pay attention not only to search ways to increase the productivity of agricultural crops, but also to take care of maintaining soil fertility.

The aim of the work is, based on observations in the system of polygon agroecological monitoring, changes in the natural cycle of biogenic and toxic elements, caused by an anthropogenic factor, have been revealed.

Materials and research methods. General scientific methods of materialistic dialectics, scientific abstraction, analysis and synthesis, logical thinking, and special methods were applied: polygon agroecological monitoring - to determine changes in the quantitative and qualitative characteristics of dark gray podzolized soils under the influence of anthropogenic load, mathematical and statistical methods - based on the methods of mathematical statistics of the reliability of the results obtained and functional dependencies between various factors and processes. For studies related to assessing the state of the soil, as one of the main components of the agroecosystem methods of chemical, physicochemical analysis were used using modern methods of atomic absorption spectrophotometry, flame photometry, mathematical and statistical analysis in accordance with the requirements of the quality management system in accordance with DSTU 3973-2000.

The research was carried out in the agrolandscapes of the Forest-steppe zone on the basis of the long experience of the department of adaptive intensive technologies of grain crops and corn of the NSC "Institute of Agriculture of the NAAN" (village Chabany, Fastovsky district, Kiev region), which was founded in 1987 and received several reconstructions. The crop rotation is grain drilled. The soil of the experimental plots is dark gray podzolized light loamy. The fertilization system provides 12 variant (ecotopes), including areas without the introduction of mineral fertilizers and with different saturation of crop rotation with fertilizers. The observation was carried out in variants less modified by reconstructions: 12 – without fertilizers (control), 2 – double dose of mineral fertilizers ($N_{75}P_{74}K_{83}$), 5 – triple dose of mineral fertilizers ($N_{113}P_{111}K_{125}$), 6 – single application of phosphorus fertilizers "in stock" (4700 kg/ha P_2O_5) to achieve a phosphate capacity factor of 400 mg P_2O_5 per kg of soil and potassium fertilizers - (2100 kg/ha K_2O) to achieve a potassium capacity factor of 400 mg K_2O per kg soil and annual application of double dose of mineral fertilizers ($N_{75}P_{74}K_{83}$). We analyzed the soil of the experimental plots of the hospital selected 30 years after the experiment.

Results and its discussion. It was found that on the dark gray podzolized soil of the right-bank forest-steppe with prolonged application of mineral fertilizers against the background of the aftereffect of the by-product of the predecessor during 1987–2017. The humus content increased by 0.2–0.3% (with a slight variation of *V*=7.6%), but the exchange rates worsened by 0.4–0.6 units. respectively, for insignificant variation (*V*=5.4%) and potential (hydrolytic) acidity (Hg) – by 0.94–1.49 meq/100 g of soil, but with a high coefficient of variation of 32.2%, the amount of absorbed bases (S) by 0.6–0.7 meq/100 g of soil with insignificant variability (*V*=3.5 %) compared to the ecotope without the use of fertilizers, where the humus content was 1.52%, salt pH – 5.6, Ng – 1.08 meq/100 g of soil, S – 12.1 meq/100 g of soil, which indicates the acidifying effect of the applied fertilizers and the need for liming (Table 1). Indeed, the assimilation of soil nutrients and fertilizers, the mineralization of organic matter, the effectiveness of fertilizers applied, the yield and quality of agricultural crops largely depend on the reaction of the soil environment (salt pH). In the absence of liming, the process of degradation of the soil absorption complex will deepen, accompanied by a decrease in crop yields and an increase in the mobility of pollutants in the soil.

1. Changes in physicochemical and agrochemical indicators of fertility of dark gray podzolized soil with prolonged systematic use of various doses of organic and mineral fertilizers, soil layer 0-20 cm

Experience variant	Nitrogen				Mobile phosphorus, P_2O_5	Exchangeable potassium, K_2O	Humus, %	pH salt.	The degree of saturation of the soil base	Hydrolytic acidity	Sum of basics	Exchangeable calcium, Ca	Exchangeable magnesium, Mg
	easy hydrolysis, N	nitrate, N-NO_3	ammonia, N-NH_4	mineral, N									
	mg/kg								%	meq/100 g			

2	72,8	7,1	5,0	12,1	232,5	165,0	1,82	5,0	84,9	2,02	11,4	5,4	0,9
5	75,6	3,4	4,6	12,7	382,5	202,5	1,74	5,0	81,7	2,57	11,5	5,8	0,8
6	72,8	3,7	5,9	9,6	382,5	153,8	1,75	5,2	85,8	2,02	12,2	6,2	0,9
12	65,7	3,8	8,9	8,0	130,5	110,0	1,52	5,6	91,8	1,08	12,1	6,5	0,9
$\overline{X} \pm S_{\overline{X}}$	*71,7 ± 2,1*	*4,5 ± 0,9*	*6,1 ± 1,0*	*10,6 ± 1,1*	*282 ± 61,6*	*157,8 ± 19,0*	*1,71 ± 0,06*	*5,2 ± 0,1*	*86,0 ± 2,1*	*1,9 ± 0,3*	*11,8 ± 0,2*	*6,0 ± 0,2*	*0,88 ± 0,03*
V,%	*5,9*	*38,7*	*31,9*	*20,7*	*43,7*	*24,1*	*7,61*	*5,4*	*4,9*	*32,2*	*3,5*	*8,0*	*5,7*
S	*4,2*	*1,7*	*1,9*	*2,2*	*123,3*	*38,1*	*0,13*	*0,3*	*4,2*	*0,6*	*0,4*	*0,5*	*0,1*
HIP_{05}	*6,7*	*2,8*	*3,1*	*3,5*	*196,2*	*60,6*	*0,21*	*0,4*	*6,7*	*0,9*	*0,6*	*0,8*	*0,1*

Note: 2 – double dose of mineral fertilizers ($N_{75}P_{74}K_{83}$), 5 – triple dose of mineral fertilizers ($N_{113}P_{111}K_{125}$), 6 – single application of phosphorus and potassium fertilizers "in reserve" (4700 kg/ha P_2O_5 and 2100 kg/ha K_2O), 12 – without fertilizers (control).

In general in the fertilized ecotopes, the humus content remained at a low level (1.75–1.85 %), the soil had a moderately- and slightly acidic reaction of the soil solution (saline pH – 5.0–5.5), an average supply in the amount of absorbed bases (11.4–12.2 meq/100 g soil), slightly acidic degree of hydrolytic acidity (2.02–2.57 meq/100 g soil), increased saturation with bases (81.7–85, eight %). The content of exchangeable calcium compounds had an average supply (5.4–6.5 meq/100 g of soil), magnesium – low (0.8–0.9 meq/100 g of soil). Analysis of the physicochemical parameters of the soil of various ecotopes of the experiment showed that the use of technologies for growing crops of various intensities requires a differentiated approach to land reclamation.

The amount of easily hydrolyzed and mineral nitrogen compounds (NH_4 + NO_3) in the fertilized variants was at very low and low levels, 72.8–75.6 mg/kg and 9.6–12.7 mg/kg, respectively, and differed little from the control ecotope – without fertilizers. In particular, the content of easily hydrolyzed nitrogen was highly stable, which is confirmed by the value of the coefficient of variation V = 5.9%. The variability of the content of mineral nitrogen (NH_4 + NO_3) corresponded to a high level with the corresponding coefficients of variation of 20.7 %, 31.9 and 38.7 %.

The lowest level of mobile phosphorus and potassium in the soil in the experiment was observed in the control without fertilizers (variant 12), but the content of these compounds was at the level of increased supply and amounted to 130.5 mg/kg P_2O_5 and 110 mg/kg K_2O (according to the Chirikov). Low crop yields contributed to the relatively low utilization of phosphorus and potassium compounds from the soil. In addition, there was a replenishment of the phosphate and potassium fund due to the movement of phosphorus and potassium by the root system of plants from the lower horizons of the soil to the arable layer.

Mathematical analysis showed that the content of mobile forms of phosphorus and potassium was characterized by significant variability in the value of the coefficient of variation – respectively 43.7 % and 24.1 %. One-time application of phosphorus fertilizers "in stock" followed by systematic application of mineral fertilizers at a dose of $N_{75}P_{74}K_{83}$ against the organic background provided a very high level of mobile phosphates in the arable layer of dark gray podzolized soils – 382.5 mg/kg P_2O_5. With prolonged use of a triple dose of mineral phosphates – 111 kg of P_2O_5 against the background of $N_{113}K_{125}$ and organic fertilizers, a very high level of phosphorus available to plants was also created in the arable soil layer at a very high level – 382.5 mg/kg P_2O_5. For the introduction of a double dose of mineral fertilizers $N_{75}P_{74}K_{83}$ according to the background of the organic level of the content of mobile phosphates was very high – 232.5 P_2O_5 mg/kg, which provides optimal conditions for phosphorus nutrition of crop rotation plants.

The use of mineral fertilizers against the background of embedding of crop by-products had a significant effect on the accumulation of mobile potassium, ensuring its expanded reproduction in the arable layer of dark gray podzolized soils. One-time application of potash fertilizers "in stock" followed by the systematic application of a double dose of mineral fertilizers ($N_{75}P_{74}K_{83}$) against the background by incorporating crop by-products (variant 6) made it possible not only to create, but also to stably maintain the level of mobile potassium in the topsoil at a high level – 153.8 mg/kg K_2O. With long-term use of a triple dose of mineral potassium (K_{125} against the background $N_{113}P_{111}$) and embedding of crop by-products (variant 5), a very high level of potassium available to plants was created in the topsoil – 202, 5 mg K_2O per kg of soil. The application of a double dose of mineral fertilizers $N_{75}P_{74}K_{83}$ against the background of embedding of crop by-products (variant 2) provided a high level of mobile potassium content in the arable layer of dark gray podzolized soil – 165.0 mg K_2O per kg of soil.

With prolonged systematic application of mineral fertilizers in the crop rotation and incorporation of crop by-products, a tendency to an increase in the content of mobile compounds of trace elements and heavy metals (HM) available for plants was observed in the upper 0-20 cm soil layer, which pass into the acetate-ammonium buffer solution (pHsal. 4.8), in all fertilized variants of the experiment in comparison with the control (table 2).

2. Content of heavy metals and microelements in dark gray podzolized soil for different agrochemical load (layer 0–20 cm), mg/kg

Experience variant	Copper (Cu)	Zinc (Zn)	Lead (Pb)	Nickel (Ni)	Cadmium (Cd)	Manganese (Mn)	Iron (Fe)
	Mobile forms (withdrawal with ammonium acetate buffer solution with pH 4.8)						
2	0,17	0,8	0,7	0,7	0,07	36,8	3,2
5	0,15	1,4	0,7	0,8	0,09	34,6	4,3
6	0,16	1,4	0,7	0,8	0,10	29,4	3,0
12	0,13	0,7	0,6	0,6	0,06	29,0	1,5
$\overline{X} \pm S_{\overline{X}}$	*0,15 ± 0,01*	*1,08 ± 0,19*	*0, 6 8 ± 0,0 3*	*0,73 ± 0,05*	*0,08 ± 0,0 1*	*3 2,4 ± 1,93*	*3,00 ± 0,58*
V,%	*11,2*	*35,1*	*7,41*	*13,2*	*22,8*	*11,9*	*38,4*
HIP $_{05}$	*0,03*	*0,34*	*0,05*	*0,22*	*0,03*	*8,68*	*2,39*
Maximum permissible concentration (MPC)							
	3	***23***	***2***	***4***	***0,7***	-	-

It was found that in one of the variants there was no excess of the maximum permissible concentration and background content of mobile forms of lead, cadmium and nickel for the soils of Ukraine, although the level of variation was medium and significant. It was revealed that the provision of dark gray podzolized soil with microelements, in particular copper, was characterized as low and medium with a level of variation (*V* = 11.2 %), zinc – very low and low with significant variation (*V* = 35.1 %), and behind manganese it is very high with an average level of variability (*V* = 11.9 %).

Conclusions

With a long-term anthropogenic load for 30 years in a grain and row crop rotation in the Right-Bank Forest-Steppe with the use of 232-349 kg / ha NPK against the background of the incorporation of by-products of the predecessor into the soil, an expanded reproduction of fertility of dark gray podzolized soil by the content of humus, mobile forms of phosphorus and potassium occurred, but there is the tendency of accumulation of mobile forms of cadmium with a simultaneous deepening of the deficiency of copper and zinc.

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