AGROECOLOGICAL SOIL STATUS IN AGROECOSYSTEMS WITH MONOCULTURE

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ABSTRACT

The article presents original results of research. The dynamics of the balance and NPK use efficiency of the typical Ukrainian farm for monoculture cultivation during 2016–2018 has been calculated. Laboratory analysis of soil (pH value, humus content, N, P_2O_5 and K_2O) and grain (N and P_2O_5 content) was conducted in 2019. The negative dynamics of basic nutrient balance in the soil was revealed for 2016–2018 (nitrogen deficiency ranged from –30,6 to –130,9 kg/ha/year, phosphorus – from –25,8 to –62,4 kg/ha/year, potassium – from –34,3 to –244,5 kg/ha/year) and intensive pressures on the soil (NUE = 77,0–260,3%, PUE = 171,3–1902,3% and KUE = 115,8–1429,8%). Soil pH was found on average 5,6 (category: close to neutral), the nitrogen content averaged 99 mg/kg (very low level), P_2O_5 content – 208 mg/kg (high level) and K_2O – 119 mg/kg (medium level) on the farmland areas. The ratio between nitrogen, phosphorus and potassium content in the soil of the studied land areas on average reaches 1:0,9:1,2 while the scientifically sound norm is 1:0,9:0,8. The average humus content is 1,93% (low level). The calculated indicators of nitrogen and NUE balance only in 2017 met the recommended standards of the UN Economic Commission for Europe. The PUE and KUE values in 2016 exceeded the average rate of phosphorus and potassium removal from the soil – 22 and 12 times, respectively. Changes of acidity over the last three years indicate the acidification of the soil environment, which is quite natural: only nitrogenous mineral fertilizers are applied to the soil, which is physiologically acidic, soil liming is not carried out, the green manure crops are not sown, organic fertilizers are not applied, and in crop rotation was a monoculture. The widespread practice of plowing crop residues into the soil without applying phosphorus and potassium fertilizers for three years does not meet the crop requirements for phosphorus and potassium and creates high one-way pressure on the soil. Consequently, relatively high sunflower and maize yields are generated from the existing high and medium content of these elements in the soil. The tendency of decreasing humus content in soil has been noticed.

Keywords: agroecosystem, soil, monoculture, fertility, sunflower, maize, NPK, nitrogen emission.

INTRODUCTION

According to Barbieri et al. (2017), the intensity of agricultural land management for crop production is a major driver of global environmental change and sustainability of the agricultural system. Crop rotation is an important factor in land use and a key strategy for monitoring the level of agroecological pressure on soil and crop yield indicators. But in the last 50 years, the world's crop rotation has been greatly simplified.

Understanding the complex relationships between soil, plant and management practices is necessary to develop sustainable agricultural production systems. According to Riedell et al. (2009), crop rotations affect soil nutrient content, crop yields, and grain' chemical composition. For the nowadays exist a worldwide tendency to grow crops in short rotation or monoculture (Bennett et al., 2012). This practice is becoming increasingly common due to economic market trends, technological progress, government policies and high consumer needs. The land use intensity in the future will have to be further increased to meet the needs of growing crops for both bioenergy and food production, and multiple-field crop rotation cannot be considered to be viable or practical.

The advantages of monoculture cultivation are that the farmer needs to provide growing conditions for only one high-yielding crop to obtain the maximum amount of production per unit of land area, which increases the profit for the farmer.

The social goal of increasing world food production has led to the widespread use of pesticides, mineral fertilizers and water, and a shift to monoculture farming (Lichtfouse et al., 2009). At the same time, the positive effect of high crop yields was quickly counterbalanced by negative environmental impacts – soil erosion, groundwater pollution, eutrophication of rivers, overuse of water, development of weeds and diseases resistant to chemical control.

There are many publications on the negative effects of long-term monoculture cultivation. In particular, reduced crop yields and grain quality characteristics decreased organic carbon and nitrogen content in the soil and increased field weeds (Woźniak, 2019; Woźniak et al., 2019). Studies by Gan et al. (2015), Wrighta et al. (2015), Mayer et al. (2019) and Zhao et al. (2018) show that a monoculture negatively affects water, nutrient and biological regimes of the soil, lowers soil pH and organic matter content.

According to the publication of Bargues-Ribera et al. (2020), only the use of crop rotation allows minimizing crop losses from pests and diseases.

In order to increase crop yields, organic production and soil restoration in regions with intensive agriculture, important areas of agricultural practice are intercropping (mixed crops) and mulching.

The experiment of Zhang et al. (2015) showed that, compared to the common monoculture of maize, mixed crops of maize and soybean had a significant advantage in yields, savings, arable land utilization rate, and reduction of nitrate accumulation in the soil. Also, intercropping reduces the use of nitrogen fertilizers per unit of arable land and increases the relative biomass of maize harvest residues.

The combined use of straw mulch and nitrogen fertilizers according to Akhtar et al. (2019), makes it possible to improve effectively the state and functionality of the soil – the activity of urease, invertase, alkaline phosphatase and catalase increases by 1,8, 2,1, 2,0 and 1,4 times respectively. The availability of soil nutrients is also increasing: nitrogen by 28%, phosphorus by 45%, potassium by 55%. The organic carbon content of the soil increases by 1,2–2,9 times.

Bajorienė et al. (2013) revealed a positive linear correlation ($r=0,994$, $P\leq 0,01$) between the amount of organic carbon entering the soil with mulch (peat, sawdust, straw and grass) and the organic carbon content of the soil. The study also found that mulching with a layer 10 cm thick increases the organic carbon content in the soil by 35-52% compared to a 5 cm mulch layer.

Kachmar et al. (2018) consider that the main factors causing environmental risks and are at the same time the sources of destructive processes on the lands for agricultural purposes in Ukraine are agrarian lands (25,0–41,7%). Many factors contribute to this situation, in particular, a deformed land management system, high level of land trust fund development, unbalanced cropping systems, especially for the scientifically sound placement of the crops in crop rotation practice and rational fertilizer systems. This leads to a decrease in soil fertility, destabilizes the ecological balance in agricultural landscapes and low crop yields.

Today short-term crop rotations with intensive high-yielding crops have also become common in Ukraine, namely maize, sunflower and soybean. An important issue, therefore, is to ensure a deficit-free balance of humus and nutrients as a condition for maintaining soil fertility. The problem of preserving soil fertility in Ukraine remains a

very topical resulting from significant plowing of lands, the dramatic increase in the number of landowners and land users, non-compliance with scientifically sound crop rotations and soil protection measures that lead to the development of such degradation processes as dehumidification, preconsolidation and soil erosion.
Based on research findings of Ukrainian research institutions (Kaminsky, 2015) it has been established that the continuous cultivation of maize in Ukraine results in a decrease of 14,5 rel.% of humus, whereas for monocultivated soybean this figure reaches 8,5 rel.% compared to its placement in crop rotation. Scientifically based replacement of crops in the crop rotation systems in different climatic and weather conditions provides significant yield advantages of yield over permanent crops. In particular, 10% for low-humidity grain maize, 42% for soybeans and 22% for sunflowers are found in the sub-zone where there is insufficient moisture on black soils. Only in crop rotations, the use of organomineral fertilizer system ensures the formation of a positive balance of phosphorus and potassium in the plant-fertilizer system.
Studies by Goulding et al. (2007), García-Ruiz et al. (2012) and Carmo et al. (2017) demonstrated that the calculation of nutrient balance in crop production is one of the main tools for monitoring their circulation, assessing the effectiveness of existing production technology and the basis for the development of agricultural production planning measures.
As a result, monoculture farming has significant negative effects, which need to be minimized by the above-mentioned agronomic techniques and laboratory control of the agroecological state of the soil, because otherwise the existing soil ecological systems will be irreversibly damaged.
The aim of the research is to determine the influence of monoculture cultivation on the agroecological state of the soil according to the main fertility indicators and the balance- calculation method on the example of a typical farm in Ukraine.

MATERIALS AND METHODS

For carrying out the assessment and optimization of the soil nutrient condition in short-term crop rotation to increase crop yields on the fields of the State Enterprise "Experimental farm Tuchynske" of Hoshchanskyi district of Rivne region (50°35'22.3"N, 26°18'18.3"E) according to the map of the field, samples of soil and vegetable products were collected (grain of maize and sunflower seeds).
On land areas 1, 2, 3, 4, 6, 10 the experimental plots with grain maize were laid and on land area 7 – with sunflower. Soil samples were collected from these experimental plots (ISO 10381-2:2002), in which soil pH was determined under laboratory conditions (ISO 10390:2005); humus content (ISO 10694:1995); nitrogen content (ISO 11261:1995); phosphorus (ISO 11263:1994) and potassium (ISO 11260:1994) content.
The nitrogen and phosphorus content of vegetable products was determined after wet ashing by the Ginsburg method. The content of total nitrogen – by the Kjeldahl method (ISO5983: 1997), phosphorus – by the spectrometric method (ISO 6491:1998).
On the farmlands during 2016–2019 grain maize, grain sunflower and soybeans (in 2017), (that is monoculture) were grown. The land areas do not change places – maize is sown after maize (hybrid DK 4014) and sunflower after sunflower (Neoma hybrid). The sowing rate of maize is 80 thousand seeds/ha, sunflower – 70 thousand seeds/ha, soybeans – 500 thousand seeds/ha. The type of soil is a dark-gray podzolic.
Only liquid ammonia and carbamide urea were used as fertilizers on the farm. Phosphorus and potassium mineral fertilizers and organic fertilizers have not been applied to crops.
The initial data for calculating the basic nutrient balance in crop production were the official records of the experimental farm – forms of statistical observation: 4-sh (annual) "Sowing areas of crops"; 9-sh (annual) "Report on the use of fertilizers and pesticides" and 29-sh (annual) "Report on the area and gross harvest of crops, fruits, berries and grapes" for the period 2015–2018.
The total nitrogen balance of the crop was calculated as the difference between the sum of nitrogen inputs in crop production (mineral fertilizers, seeds, atmospheric deposition, nitrogen biofixation by legumes and mineralization of by-products of predecessor plants) and the sum of the nitrogen output with the main crops and their by-products. The nitrogen balance of in crops per unit area was calculated by dividing the total nitrogen balance by the harvested crop area. Nitrogen use efficiency (NUE) in crop production was calculated as the ratio of the sum of nitrogen output flows to the main plants and their by-product to the sum of the input nitrogen flows (mineral fertilizers, seeds, atmospheric deposition, nitrogen biofixation by legumes and mineralization of by-products of predecessor plants), expressed in % (ECE/EB.AIR/120, 2014; Methodology and Handbook Eurostat, 2013).

The total balance of potassium and phosphorus in crop production was calculated as the difference between the sum of the potassium and phosphorus input flows in crop production (seeds and mineralization of by-products of predecessor plants) and the sum of the nitrogen output flows with the main plants and their by-products. The balance of potassium and phosphorus in the sowing per unit area was calculated by dividing the total balance of potassium and phosphorus by the harvested area of crops. The potassium (KUE) and phosphorus (PUE) use efficiency in crop production was calculated as the ratio of the sum of potassium and phosphorus output flow with the main plants and their by-products to the sum of potassium and phosphorus input flows (seeds and mineralization of by-products of predecessor plants), expressed in % (Banerjee et al., 2018; Dhillon et al., 2019; Handbook Eurostat, 2007).

To calculate inputs of N, P_2O_5 and K_2O to soil with seeds from mineralization of by-products of predecessor plants, nitrogen biofixation by legume crops, atmospheric N deposition and nutrient removal from the soil with the harvest of studied crops used the results of own laboratory analyzes and coefficients from literary sources (Chaban et al., 2014; Chumak et al., 2012; Degodyuk et al., 2013; Petrichenko et al., 2014; Razumenko, 2017; Ukraine's Greenhouse gas inventory 1990–2017, 2019).

To calculate the nitrogen balance on the experimental farm took into account the level of N_2O–N, NH_3–N i NO_x–N emissions from the soil as a result of ammonification, nitrification and denitrification from the application of mineral nitrogen fertilizers and mineralization of plant residues according to calculated methods (Guidelines for National Greenhouse Gas Inventories, 2006).

RESULTS

It was found that during 2016–2018 within the mineral nitrogen fertilizers 82,2–217,2 kg N/ha/year was introduced into the soil for grain maize; for grain sunflower – 75,2–90,1 kg N/ha/year (Table 1) and received the following crop yields (Table 2).

Table 1. Application of nitrogen mineral fertilizers to crops on the experimental farm, 2016–2018

Culture	N was applied to the sowing area by years					
	2016		2017		2018	
	in total, c	kg/ha	in total, c	kg/ha	in total, c	kg/ha
Grain maize	933,8	82,2	911,0	123,4	3197,9	217,2
Grain sunflower	682,7	90,4	1103,0	90,6	604,2	75,2
Soy	–	–	95,0	49,2	–	–
Total	1676,5	85,4	2109,0	98,2	3802,1	167,0

Table 2. Production of main crop products (grains) on the experimental farm, 2016–2018

Culture	Main crop production produced					
	2016		2017		2018	
	in total,t	c/ha	in total,t	c/ha	in total,t	c/ha
Grain maize	10403,8	86,1	6448,8	87,4	13260,3	90,0
Grain sunflower	1223,8	16,2	2190,6	18,0	1680,0	20,9
Soy	–	–	394,5	20,4	–	–
Total	11627,6	59,2	9033,9	42,1	14940,3	65,6

According to the results of agrochemical soil survey of the farm in 2019, the recommended values for the application of nitrogen fertilizer, depending on the studied fields for grain maize are 142–154 kg/ha to achieve the planned yield of 10 t/ha; for grain sunflower 80–86 kg N/ha – for a yield of 4 t/ha. However, in 2017, the recommended nitrogen norm of 90,6 kg/ha was applied to the soil for grain sunflower with mineral nitrogen fertilizers and the yield was only 1,8 t/ha. In 2018, the more recommended nitrogen norm of 217,2 kg/ha was applied to the soil for grain maize and yielded only 9,0 t/ha. Also, the data below show that the recommended values for nitrogen fertilizer application to soil regarding the planned crop yields according to the agrochemical soil survey do not provide a positive nitrogen balance in crop production.

During 2016–2018, in addition to nitrogen fertilizer application, agricultural land also received nitrogen from other sources – seeds, mineralization of crop residues, N biofixation by legumes and atmospheric nitrogen deposition (Table 3).

Table 3. N inputs to the soil of the experimental farm from nitrogen biofixation (NBF) and precipitation (P), 2016–2018

Culture	N input to the harvested agriculture lands by years, c					
	2016		2017		2018	
	NBF	P	NBF	P	NBF	P
Grain maize	–	42,3	–	25,8	–	51,5
Grain sunflower	–	26,4	–	42,6	–	28,1
Soy	–	–	23,2	6,8	–	–
Total	–	68,7	23,2	75,2	–	79,7

On average, during 2016–2018, the farm received 3907,2 c N/year or 1,8 c N/ha/year, including nitrogen mineral fertilizers – 64,7%, mineralization – 32,6%, precipitation – 1,9%, nitrogen biofixation – 0,6%, and seeds – 0,2%.

The source of P_2O_5 and K_2O on the farm is only seeds and mineralization of by-products of predecessor plants.
P_2O_5 on average for 2016–2018 was released to the soil in the amount of 544,3 c/year or 0,3 c/ha/year on the farm, including mineralization – 99,6% and seeds – 0,4%.

K_2O on average for 2016–2018 was released to the soil in the amount of 3307,9 c/year or 1,5 c/ha/year, including mineralization – 99,9% and seeds – 0,4%.

Table 4 presents the indicators of N, P_2O_5 and K_2O outputs from the soil with the main crop production and also their by-products during 2016–2018.

Table 4. NPK outputs from the soil with the main (numerator) and by-products (denominator) of crop production of the experimental farm, 2016–2018

Culture	NPK outputs from the soil with the main (numerator) and by-products (denominator) of crop production by years, c								
	2016			2017			2018		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Grain maize	1612,6 2208,6	364,1 522,5	405,7 2908,5	999,6 1366,6	225,7 323,1	251,5 1798,9	2055,4 2800,3	464,1 661,6	517,2 3683,1
Grain sunflower	312,1 42,2	154,2 252,8	102,8 1746,5	558,6 73,7	276,0 444,0	184,0 3066,8	428,4 54,9	211,7 332,2	141,1 2294,9
Soy	–	–	–	211,8 11,9	47,3 17,5	57,6 36,1	–	–	–
Total	4175,5	1293,6	5163,5	3222,2	1333,6	5394,9	5339,0	1669,6	6636,3

During 2016−2018, the removal of soil nutrients with the grains of crops increased: N – by 28,7%, P_2O_5 – by 23,3 i K_2O – by 25,1%; with crop by-products: N – by 49,1%, P_2O_5 – by 22,0 i K_2O – by 22,7%.

The consolidated overall balance of NPK of the experimental farm for 2016–2018 is presented in Table 5.

Table 5. The consolidated overall balance of NPK of the experimental farm, 2016–2018

Balance item	NPK indicators by years, c								
	2016			2017			2018		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
NPK input flows									
Mineral fertilizers	1676,5	–	–	2109,0	–	–	3802,1	–	–
Mineralization of by-products of predecessor plants	166,4	66,3	359,5	2217,6	775,3	4655,0	1430,8	784,6	4901,8
Precipitation	68,7	–	–	75,2	–	–	79,7	–	–
Nitrogen biofixation	–	–	–	23,2	–	–			
Seeds	6,2	1,7	1,6	12,4	3,2	3,4	7,4	1,9	1,9
Total	1917,8	68,0	361,1	4437,4	778,5	4658,4	5320,0	786,5	4903,7
NPK output flows									
Removed from the soil with grain	1924,7	518,3	508,5	1770,0	549,0	493,1	2483,8	675,8	658,3
Removed from the soil with by-products of the plants	2250,8	775,3	4655,0	1452,2	784,6	4901,8	2855,2	993,8	5978,0
Emissions of N_2O–N, NH_3–N i NO_x–N from soil	313,5	–	–	255,2	–	–	677,7	–	–
Total	4489,0	1293,6	5163,5	3477,4	1333,6	5394,9	6016,7	1669,6	6636,3
Balance	–2571,2	–1225,6	–4802,4	959,9	–555,2	–736,5	–696,7	–883,1	–1732,6

The NUE and N balance was calculated per unit of crop area and compared to the recommended standards of the United Nations Economic Commission for Europe (UNECE) (Figure 1) and actual performance of the Rivne region, where the Ukrainian and EU experimental farm is located geographically (Figure 2).

The NUE indicator for 3 years in the experimental farm was 77,0–260,3%, and the N deficiency from –30,6 to –139,9 kg/ha/year, which does not meet the recommended UNECE standards for NUE – 60–90% i $N_{balance}$ – 0–50 kg/ha/year. Such negative indicators of NUE and N balance have not been observed at the level of the experimental farm, as well as at the level of the Rivne region and Ukraine as a whole.

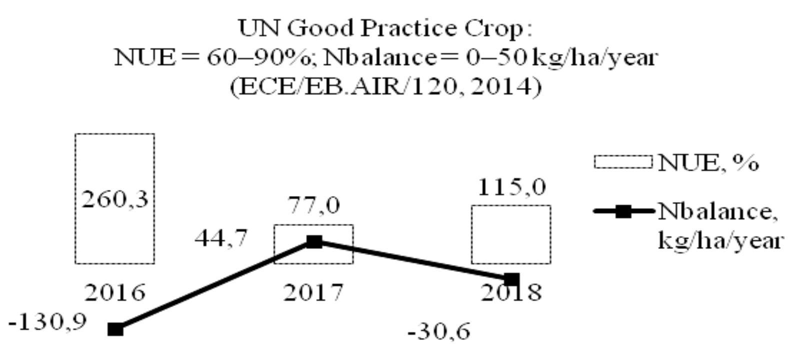

Figure 1. N Balance and NUE in crop production of the experimental farm according to the recommended UNECE standards, 2016–2018

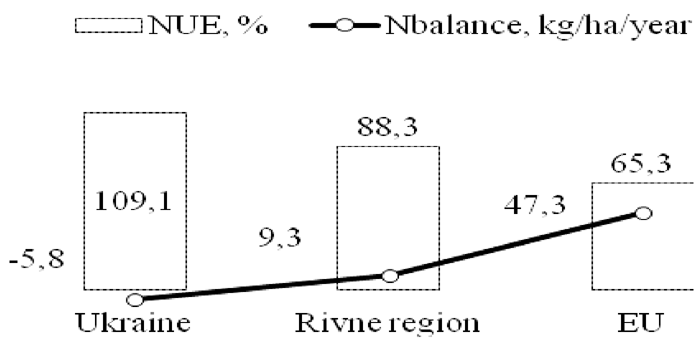

Figure 2. Comparative indicators of N balance and NUE of Ukraine and the EU, 2015 (Moklyachuk et al., 2019)

The PUE indicator for three years was 171,3–1902,3%, phosphorus deficiency was from −25,8 to −62,4 kg/ha/year (Figure 3).

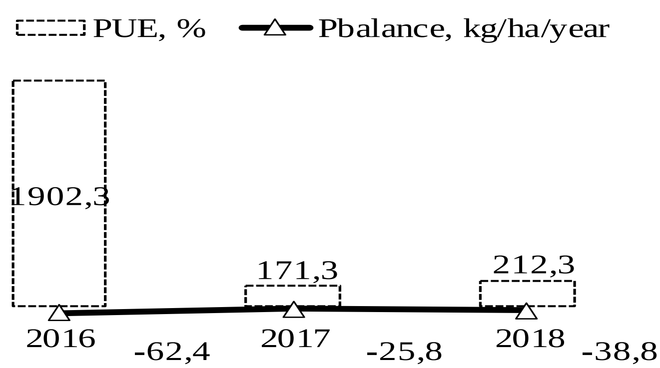

Figure 3. P_2O_5 balance and PUE in crop production of the experimental farm, 2016–2018

The KUE indicator for three years was 135,3–1429,8%, potassium deficiency was from −34,3 to 244,5 kg/ha/year (Figure 4).

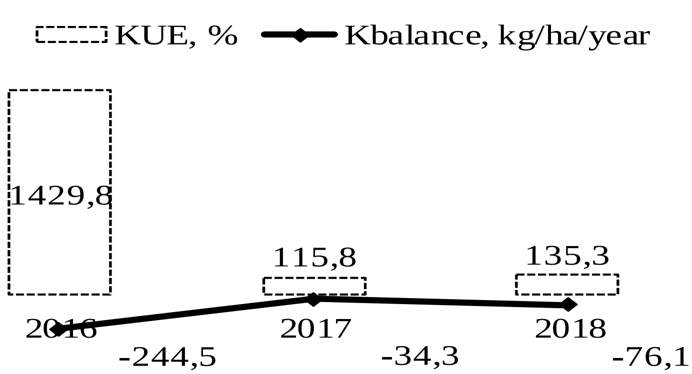

Figure 4. K_2O balance and KUE in crop production of the experimental farm, 2016–2018

Taking into account the detected negative dynamics of nutrient balance in the soil during 2016–2018, the laboratory analysis of soil samples from individual land areas on the pH level, humus content and NPK was conducted in 2019 (Table 6).

According to Table 6, the reaction of the soil environment is much to be desired.

Table 6. Agroecological state of the soil by main fertility indicators on the land areas of the experimental farm, 2019

Land area	pH	Humus content, %		N content, mg/kg of soil		Phosphorus content (P_2O_5), mg/kg of soil		Potassium content (P_2O_5), mg/kg of soil	
		indicator	level of support	indicator	level of support	indicator	level of support	indicator	level of support
Area 1	6,2	3,18	increased	127	low	149	increased	91	medium
Area 2	5,4	1,03	low	90	very low	187	high	115	medium
Area 3	5,2	2,10	medium	87	very low	160	high	97	medium
Area 4	6,0	2,09	medium	97	very low	243	high	100	medium
Area 6	5,5	1,81	low	99	very low	230	high	127	increased
Area 7	5,7	1,70	low	105	low	248	high	159	increased
Area 10	5,5	1,59	low	88	very low	241	high	141	increased
Mean	5,6	1,93	low	99	very low	208	high	119	medium
N:P:K				1	–	0,9	–	1,2	–

Soils of only land area 1 turned out to be neutral, close to neutral were soils on land areas 4 and 7. However, when comparing the results of agrochemical certification of fields, which was carried out by the Rivne branch of SI "DERZHGRUNTOKHORONA" in 2016, weak acidic soils were only on land area 3 with an indicator of 5,5. Land areas 2, 6 and 10 have moved from the categories close to neutral and neutral, respectively, to the categories of weak acids, and land areas 4 and 7 – from the category neutral to the category close to neutral. Soils of land area 1 remained in the category of neutral, but acidity decreased by 6 units.

The humus content of soil of studied land areas totaled 1,03–3,18%, which is on average a low level of support.

The soil nutrient content of studied land areas was as follows: N – 88–127 mg/kg, which is on average a very low level of supply; P_2O_5 – 149–248 mg/kg (high level) and K_2O – 91–159 mg/kg (medium level).

Discussion

The development of sustainable land use systems according to Chennamaneni et al. (2014), is the balanced management of nutrients for growing crops, which is to control the ratio between nutrient removal level with yield and soil nutrient reserve. The survey's findings showed that there is a negative balance of P_2O_5, K_2O during 2016–2018 and N in 2016 and 2018, meaning that more nutrients were removed from the soil than get into it.

Spiertz (2010) stated that nitrogen use efficiency (NUE) is aimed at rational use of nutrients in crop production at optimal pressure on the soil.

If NUE values exceed 100%, it will lead to soil depletion through the removal of more nutrients than enter the soil. A value above 70% generally indicates the risk of soil nutrient loss, given that some nitrogen is lost in the environment as a result of emissions of ammonia, nitrous oxide and nitrogen oxides (ECE/EB.AIR/120, 2014; McLellan et al., 2018).

The calculated indicators of N balance and NUE of the experimental farm only in 2017 complied with the UNECE recommended standards (ECE/EB.AIR/120, 2014) and are close to the actual indicators of the Rivne region and the EU. In general, Ukraine has a negative nitrogen balance (Moklyachuk et al., 2019).

According to Lassaletta et al. (2014), environmental losses of nitrogen from emissions of ammonia, nitrous oxide and nitrogen oxides from agricultural lands in most of Europe, Middle East, USA, India and China exceeds 50 kg N/ha/year. In other countries, namely Africa, Australia and the countries of the former Soviet Union – up to 25 kg N/ha/year.

Nitrogen losses from emissions of experimental farmland due to the application of nitrogen mineral fertilizers and the mineralization of by-products of plants during 2016–2018 were estimated to be 5,8–16,3% or 11,9–29,8 kg N/ha/year.

The ecologically safe level of compensation for potassium removal on the black soils of Ukraine according to the paper of Centilo et al. (2018), should be 85% on average, phosphorus – 120%, without decreasing the fertility rate. Thus, the average K_2O and P_2O_5 removal rate from the soil is not more than 115% and 80% respectively.
The calculated values of Phosphorus (PUE) and Potassium (KUE) use efficiency illustrate the level of one-way pressure on the soil as a result of the sudden transition to the monoculture from 2016 and the lack of phosphorus and potassium mineral fertilizers application to the soil. In particular, in 2016, the PUE indicator was 22 times higher than the average P_2O_5 removal rate from the soil, and the KUE indicator was 12 times higher. Plowing into the soil the crop residues of maize and sunflower since 2016 does not eliminate the phosphorus and potassium deficiency, as the removal of these elements with the main product (grain) during 2016–2018 increased by an average of 24,2%, and with the by-product increased by 22,4%.

Changes in acidity over the last three years indicate the acidification of the soil environment, which is quite natural: only nitrogenous mineral fertilizers are applied to the soil, which is physiologically acidic, soil liming is not carried out, the green manure crops are not sown, organic fertilizers are not applied, and in crop rotation is a monoculture.
According to studies by Goulding (2016), Zheng (2010), Wu et al. (2017), Symochko (2020) soil acidity directly affect the growth and development of plants, the activity of soil microorganisms, soil toxicity, the degree of solubility of nutritive elements, availability of phosphorus for plants, as well as the efficiency of the fertilizer applied. The acidic environment of the soil solution limits high crop yields and degrades the quality of the product's quality.

Although only nitrogen fertilizers were used to fertilize the crops, such norms are not sufficient to produce a good crop and to ensure the quality of the grain. The nitrogen content of the farm's soils is low and very low, which affects plant growth and their development and, ultimately, impacts on its yields and quality.
The phosphorus and potassium content of soils characterized by increased and high, as well as medium and increased levels of support by these elements, respectively, due to the large amounts of crop residues that are produced in the soil after the maize and sunflower harvest. Although the studied soils are well provided with phosphorus and potassium, the content of these elements in the soil needs to be continuously monitored. Comparing the data of certification in 2016 with 2019, there is a tendency to decrease the content of these elements in the soil. And the use of phosphorous and potassium fertilizers for the planting of maize and sunflower should never be neglected. It should be noted that there is also a tendency to decrease of humus in the soil.

CONCLUSION

- ✓ Farming is now being carried out in complete disregard of the law of returning nutrients to the soil. High yields are the result of the loss of natural fertility. The current state of the soil cover is the result of the unbalanced and unsystematic application of fertilizers, which are exclusively needed to replenish nutrients and organic matter in soils, and that are used in agricultural production. The ratio between nitrogen, phosphorus and potassium of the studied land areas averages 1:0,9:1,2 while the scientifically sound norm is 1:0,9:0,8.
- ✓ The negative nitrogen balance (from –30,6 to –130,9 kg/ha/year) and the intense pressure on the soil (NUE up to 260,3% in 2016) is determined in the experimental farm. The calculated indicators of N balance and NUE only in 2017 met the recommended UN standards. The nitrogen content in some farmland areas is low and very low.
- ✓ The widespread practice of plowing crop residues into the soil without applying phosphorus and potassium fertilizers for three years does not meet the crop requirements for P_2O_5 and K_2O and creates high one-way pressure on the soil (PUE and KUE up to 1902,3% and 1429,8% respectively in 2016), and high sunflower and maize yields are achieved provided by still existing high and medium content of these elements in the soil.
- ✓ In general, the identified negative dynamics of the soil nutrient balance during 2016–2018 is confirmed by the results of laboratory analysis of soil in 2019. It is necessary to keep more detailed statistics on fertilizer application to soil, sown areas and crop yields at the level of an individual field, which will allow developing more accurate and informative NPK balances.

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