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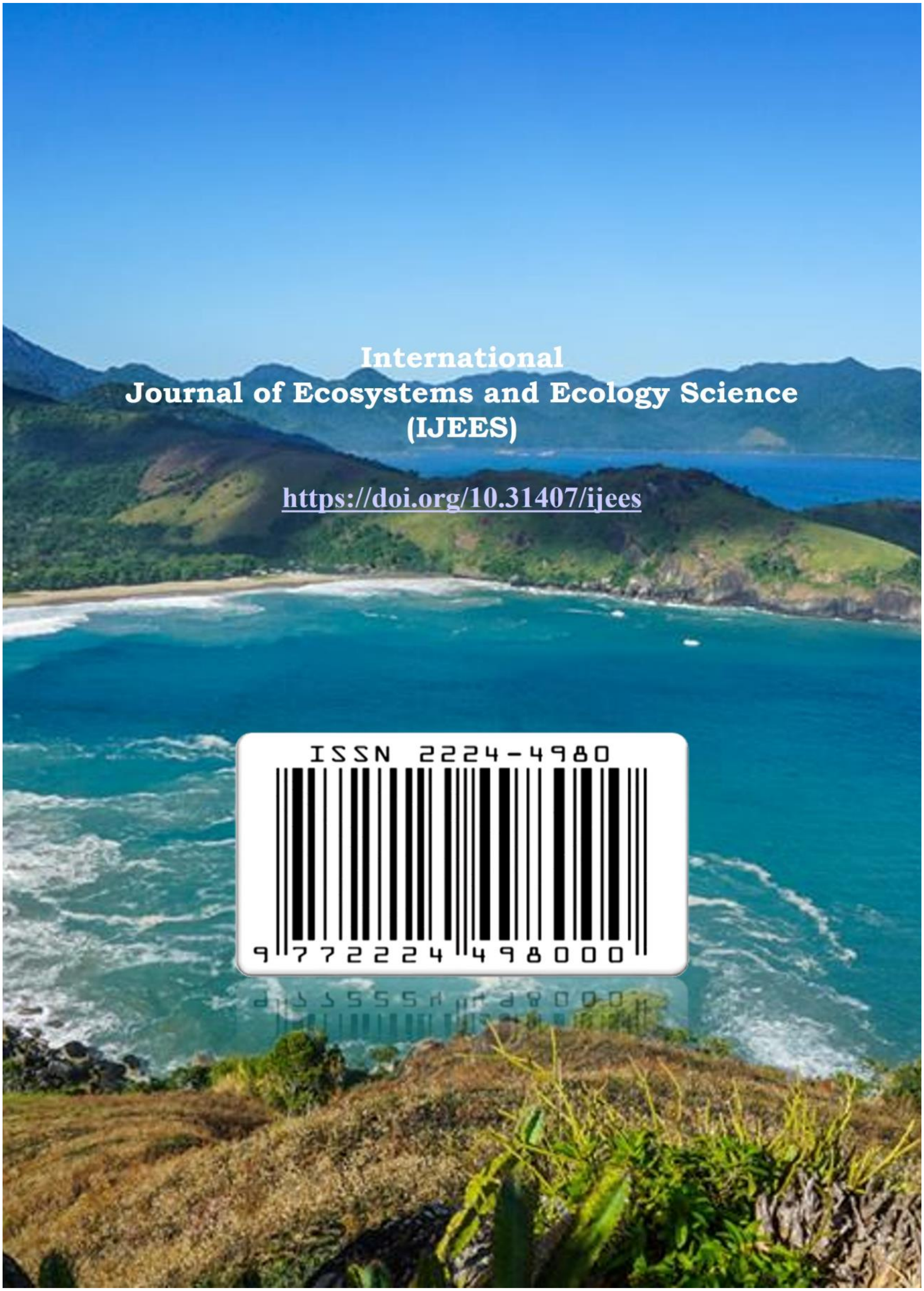
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AGROECOLOGICAL ASSESSMENT OF GRAY FOREST SOILS UNDER INTENSIVE HORTICULTURE

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ABSTRACT

Agricultural use of the land fund requires monitoring of its fertility, degree of erosion, and level of pollution. The aim of this study was to determine and evaluate the main agrochemical parameters of the soil, as well as the most dangerous heavy metals on agricultural land, which were used for perennial plantations (an intensive apple horticulture). The use of soils for intensive gardening for 14 years (2008-2022) led to an increase in exchangeable potassium by 6.58 times, mobile forms of phosphorus by 14.6 times, calcium by 31.1%, exchangeable magnesium by 18.8% %, molybdenum by 11.2%, sulfur by 46.3%, zinc by 18.4%, lead by 3.1%, cadmium by 2.5%, mercury by 34.5% and a decrease in easily hydrolyzed nitrogen by 12, 9%, humus by 0.06%, boron by 8.6%, iron by 17.9% and copper by 6.8% compared to fallow soil.

Keywords: soil, intensive horticulture, fallow, degradation, agrochemical indicators, heavy metals, soil fertility, apple orchard.

INTRODUCTION

Ukraine is an industrial-agrarian country that has huge land potential and is one of the leading exporters of the main varieties of agricultural products. According to the data of the monitoring of trade volumes of agricultural goods for 2021, Ukraine ranks fourth among countries importing to the EU (Agriculture..., 2022). One of the most important tasks of our society is the protection and rational use of land, since food products obtained from the use of land account for 98% (FAO, 2021). Soil is the main component of the biosphere, therefore reproduction, maintenance of its fertility at an optimal level and protection is a prerequisite not only for soil development, but also for ecological safety and sustainability of the natural environment. That is why many scientists from different countries of the world are dealing with the issue of food security (Rutten et al, 2011; Mazur et al, 2014; Razanov et al, 2020; Symochko et al, 2020; Lacey et al, 2021; Razanov et al, 2022). Currently, agricultural production in Ukraine is aimed at achieving maximum economic benefits without proper measures to increase soil fertility and costs for the protection of land resources. The main problem of soil resources in Ukraine, as well as in other countries with an underdeveloped system of soil protection, which poses a threat to national security, is soil degradation. The land fund of Ukraine is 60.4 million hectares and is characterized by an extremely high level of development. About 70 percent of the land fund of Ukraine is agricultural land (Consept..., 2022). In connection with the excessive load on land resources, a complex of global and regional environmental problems arises in agricultural production, namely: loss of natural fertility by soils, their degradation, depletion, spread of wind and water erosion, pollution of the environment by chemicals, radionuclides, heavy metals, livestock waste, etc. This leads to the deterioration of the quality of agricultural land (Kaminskyi et al, 2018; Razanov et al, 2017; 2020;2022; Dursun et al 2022; Mazur et al, 2014). Soil degradation is one of the greatest problems facing humanity, a global challenge of the 21st century that is closely related to key aspects of human security and well-being (Voloshchuk, 2017). The international community has been trying to fight land degradation and desertification for decades, but the problems are still unresolved and remain persistent. Therefore, they have become the main objects of research and are considered by various researchers from all over the world (Ayub et al, 2020; Hussain et al, 2021; Lal, 2015). Hussain (2021) describes the link between food security and land degradation, where the effect of land degradation goes far beyond food security. Soil degradation refers to the deterioration of soil properties, fertility, and quality, which is caused by a change in the conditions of soil formation due to the influence of natural or anthropogenic factors and is accompanied by a decrease in humus content, destruction of the structure, and a decrease in soil fertility (Symochko et al, 2021). According to research by Baluuk (2017; 2021), the most characteristic degradation processes in soils in Ukraine are: losses of humus with an intensity of 0.42–0.51 t/ha per year and nutrients, especially phosphorus and potassium; erosion losses of the upper fertile layer; over-compaction, destruction of the structure, lumpiness and crust formation; soil acidification; secondary salinization and salinization of irrigated soils; activation of peatlands; pollution by radionuclides (11.1% of arable land), pesticides (9.3%) and heavy metals (8%). In recent decades, more and more attention has been paid to the stability of soils due to their intensive use in agriculture. Intensification of agriculture, on the one hand, makes it more efficient and profitable, provides an opportunity to solve the food problem in the world and develop agribusiness. However, on the other hand, it leads to depletion of soil resources and increased degradation. Therefore, special attention is paid to the intensification of production as one of the causes of soil degradation. Intensification of agricultural production and intensive technologies, characteristic of most of Ukraine, are the cause of significant losses, irrational use of natural resources and soil in particular (Alhameid, 2017; Razanov et al, 2017). It is usually based on the use of a significant amount of chemical fertilizers, root and feeding fertilizers, herbicides, fungicides, insecticides, and plant growth regulators are widely used. In this regard, intensive agriculture can have serious impacts on soil, namely soil pollution (e.g. heavy metals and agrochemicals), acidification, nitrification, desertification, reduction of soil organic matter, soil compaction and erosion. Such degradation can be a consequence of improper agricultural practices such as excessive fertilization, improper use of pesticides, and the use of heavy machinery (Wang et al., 2014; Muriithi, 2015; Tkachuk et al, 2021). Moreover, Wang (2014) shows a different concentration of copper in the soil not only within one garden, but also within one tree, depending on the location of sampling. Changes in land use, intensive farming systems and poor land management practices cause a number of problems, in particular, a decrease in the content of organic carbon in the soil, which negatively affects their fertility and efficiency of use. One of the ways to solve these problems is to implement ecological principles of agroecosystem management to obtain ecological and economic benefits (Alhameid et al, 2017; Symochko 2020). A significant part of Ukraine's food balance is made up of horticultural products. Horticulture is a traditional branch of agriculture in Ukraine, which has a centuries-old history, and the natural and economic potential of the country contributes to the formation of high yields of fruit crops. The apple tree is the main fruit crop both in Ukraine and, in particular, in the forest-steppe zone. Apple trees occupy half of the total area of fruit and berry plantations in Ukraine. More than half of apple orchards are located in Vinnytsia, Khmelnytskyi, Chernivtsi, Transcarpathian and Lviv regions. These regions account for more than 60% of the domestic gross harvest of apples. An important condition of modern agriculture, including horticulture, is maintaining the proper ecological state of soils and preserving their fertility with obtaining high-quality crops (Kozak, 2007; Burliai et al, 2013; Kopytko et al, 2017). The technological impact on the soil in intensive horticulture is significantly greater compared to intensive crop production (Muriithi, 2015; Pasichniak et al, 2020). After all, gardens are a perennial monoculture, with repeated spraying of fruit plants 9-12 times during the entire growing season and more per season with plant protection products and a large amount of applied mineral fertilizers to obtain maximum profits. Disadvantages are the significant alienation of biomass with the crop and cut branches. All this leads to a decrease in fertility, the main indicators of the soil and environmental pollution. And as a result, signs of irreversible degradation processes in the soil begin to appear. There are several studies in other countries of the world that can confirm the changes in the agro-ecosystem due to intensive farming during the operation of the garden (Ibrahim, 2012; Paladino et al, 2020), in particular the study of acidity and ionic reactions in the soil of the gardens, which confirm large structural changes , which occurred, as a result, in soils (Sánchez Navarro et al, 2020), surface water pollution (Muriithi et al, 2015), increased heavy metal content (Brunetto et al., 2017).

MATERIALS AND METHODS

The starting hypothesis of this work is that intensive gardening causes changes in the main parameters and properties of the soil, which can lead to acceleration of soil degradation. The idea is to use these parameters as indicators of the soil's responses to its intensive management and thus the ability to assess the possible degradation it may undergo as a result of such management. In this way, the land of the agricultural enterprise was studied, which until 2008 was one field of arable land and was used for crop cultivation, and after 2008 (which became the starting point of our study on the impact of intensive horticulture on the soil), one part of the land was used for a quarter of an apple orchard intensive type (experiment), and the other was left as a fallow (control), that is, a type of land that is land that was in agricultural use, but was not used for growing agricultural crops for 14 years. The research was conducted in the central part of the Vinnytsia region of Ukraine, which belongs to the Right Bank Forest-Steppe. Vinnytsia is a powerful and promising region from the point of view of assessing its land-resource potential: in terms of the specific weight of land resources in its total natural-resource potential (79.11%), Vinnytsia ranks first among other regions for the average level of this indicator in Ukraine - 44.38% (Tsytsiura et al, 2017). The research was carried out in the conditions of the agricultural lands of the agro-enterprise. The total area of agricultural land of the farm is more than 3.700 hectares. A large part of agricultural land is occupied by horticulture, which is 17.6% of the total amount. The soil cover of the farm, on the basis of which the research was conducted, is uniform and represented by gray forest soils. Gray forest soils form the basis of its land resources here. Possessing a number of favorable properties, these soils are extremely vulnerable to anthropogenic influence and are quickly transformed with irrational use. The object of research was the soils of agricultural lands used under perennial plantings of an intensive apple orchard and fallow within one field for the period from 2008 to 2022. The subject of research is to study the influence of intensive gardening on the content of such indicators in the soil as: humus, acidity, easily hydrolyzed nitrogen, exchangeable potassium, mobile phosphorus, exchangeable calcium, magnesium. The content of mobile compounds of chemical metals was also determined: Boron (B), Molybdenum (Mo), Sulfur (S), Cobalt (Co), Iron (Fe), Copper (Cu), Zinc (Zn), Lead (Pb), Cadmium (Cd) and Mercury (Hg). The soil test material for further laboratory analyzes was sampled in 2008, 2013, 2018, and 2022 at a depth of 0–20 cm with a special probe using the envelope method at the depth of plowing (0–20 cm). Materials from own research, data from state statistical materials, reference data from scientific publications were used. The study was conducted in accordance with the methodological guidelines of the DSTU of the industry. The content of mobile phosphorus and exchangeable potassium was determined by the Kirsanov method. To determine the content of the main heavy metals in the soil samples in the laboratory, the grouping of soils was used according to the content of mobile forms of microelements, which were determined in the extract of an acetate-ammonium buffer solution. During agro-ecological soil monitoring, generally accepted methods were also used to determine the intensity of lead, cadmium, zinc, copper, and mercury contamination. Research materials were processed using generally accepted statistical methods with the definition of Student's criterion. At the same time, the average arithmetic values (M), the mean square deviation (m) and the reliability of the difference between the average values (criterion P) were calculated. To show the probability in the tables, the notation $P<0.05$ is used; $P<0.01$; $P<0.001$ in the paper, respectively, marked with asterisks (*, **, ***).

RESULTS AND DISCUSSION

The results of studies on the study and changes of the main elements of plant nutrition in fallow soils (Table 1) showed that over 14 years, the content of easily hydrolyzed nitrogen increased by 13.6%, exchangeable potassium by 11.4%, mobile phosphorus by 9.7%, humus by 0.01%, exchangeable calcium by 3.9% and exchangeable magnesium by 7.0%. In soils used for intensive horticulture, during this period the content of exchangeable potassium increased by 7.3 times, mobile phosphorus by 15.8 times, exchangeable calcium by 36.3% and magnesium by 26.1%, while easily hydrolyzed nitrogen and humus , on the contrary, decreased by 1.8% and 0.01%, respectively.

Table 1. Impact of intensive horticulture on the main nutrients of plants in the soil.

Indicators	Agricultural lands, as of 2008, before their use for:		Agricultural lands after 14 years of their use for:	
	fallow	intensive horticulture	fallow	intensive horticulture
Easily hydrolyzed nitrogen, mg/kg	181.2±1.17	182.4±1.21	205.8±2.21	179.2±1.78***
Exchangeable potassium, mg/kg	48.3±0.04	48.5±0.06	53.8±0.607	354.4±3.28***
Mobile phosphorus, mg/kg	23.7±0.12	24.1±0.11	26.0±0.28	380±2.96***
Acidity, pH unit.	4.64±0.013	4.64±0.014	4.74±0.057	5.39±0.057***
Humus, %	1.53±0.017	1.52±0.016	1.54±0.018	1.48±0.014*
Exchangeable calcium, mmol per 100 g	10.2±0.14	10.2±0.14	10.6±0.11	13.9±0.147***
Exchangeable magnesium, mmol per 100 g	1.14±0.016	1.15±0.011	1.22±0.014	1.45±0.014***

Soil acidity did not change during the period of research in fallow soils, but decreased by 16.2% under intensive horticulture. Analyzing the changes in the main nutrients of plants during the research period, it should be noted that the content of exchangeable potassium, mobile phosphorus, exchangeable calcium and exchangeable magnesium in the soils that were used for intensive gardening increased by 6.58 times, 14.6 times, 31.1 % and 18.8%, and easily hydrolyzed nitrogen and humus decreased by 12.9% and 0.06%, respectively, in comparison with the soils that were under fallow. Characterizing the content of mobile compounds of some chemical elements and their accumulation in soils as a result of intensive horticulture (Table 2), certain changes were noted. In particular, in fallow soils, the content of boron increased by 5.6%, molybdenum by 12.6%, sulfur by 7.7%, cobalt by 11.5%, and iron by 8.1% over 14 years of research. In soils used for intensive horticulture, the content of molybdenum, sulfur, and cobalt increased by 25.3%, 58.2%, and 11.5%, respectively, but boron and iron, on the contrary, decreased by 4.2% and 10.9%. At the same time, it was found that the molybdenum and sulfur content was 11.2% and 46.3% higher in soils that were used for intensive horticulture, and boron and iron were lower by 8.6% and 17.9%, respectively, compared to the soil, which was under the fallow.

Table 2. The influence of intensive gardening on the content of mobile compounds of chemical elements in soils.

Indicators	Agricultural lands, as of 2008, before their use for:		Agricultural lands after 14 years of their use for:	
	fallow	intensive horticulture	fallow	intensive horticulture
Boron, mg/kg	1.43±0.0121	1.44±0.0127	1.51±0.017	1.38±0.011***
Molybdenum, mg/kg	0.087±0.0015	0.087±0.0012	0.098±0.0012	0.109±0.0011***
Sulphur, mg/kg	7.93±0.034	7.9±0.028	8.54±0.089	12.5±0.160***
Cobalt, mg/kg	0.26±0.003	0.26±0.004	0.29±0.004	0.293 ±0.0033
Iron, mg/kg	2.21±0.017	2.2±0.015	2.39±0.024	1.96±0.021***

For the monitoring of heavy metals in soils, were selected metals with a high toxicity class: Cd, Hg, Zn and Pb belong to the 1st class of the most dangerous heavy metals, Cu to the 2nd class of danger. Certain changes in the soil were also detected in the accumulation of heavy metals (Table 3). Thus, in fallow soil during 14 years, the content of copper increased by 6.2%, zinc by 11.8%, lead by 5.6%, cadmium by 2.6% and mercury by 3.8%. In soils used for intensive horticulture, the content of zinc, lead, cadmium, and mercury increased by 32.4%, 8.9%, 5.2%, and 39.6%, respectively, and copper slightly decreased by 1.0%. Along with this, it should be noted that in the soil, which was used under intensive gardening, the content of zinc, lead, cadmium and mercury was higher by 18.4%, 3.1%, 2.5% and 34.5%, respectively, and copper lower by 6.8% compared to fallow soil.

Table 3. The influence of intensive gardening on the accumulation of heavy metals in the soil.

Indicators	Agricultural lands, as of 2008, before their use for:		Agricultural lands after 14 years of their use for:	
	fallow	intensive horticulture	fallow	intensive horticulture
Copper, mg/kg	0.097±0.0006	0.097±0.002	0.103±0.0007	0.096±0.0011**
Zinc, mg/kg	0.34±0.003	0.34±0.004	0.38±0.004	0.45±0.004***
Lead, mg/kg	0.90±0.014	0.90±0.016	0.95±0.011	0.98±0.012
Cadmium, mg/kg	0.077±0.0005	0.077±0.0004	0.079±0.0007	0.081±0.0007
Mercury, mg/kg	0.0053±0.000062	0.0053±0.000054	0.0055±0.000071	0.0074±0.000091***

Analysis of research results showed that fallow soils and soils of intensive horticulture are characterized by a low level of heavy metal contamination. In particular, their concentration in fallow soils was 30 times lower than the MPC for copper, 63.9 times for zinc, 6.5 times for lead, 9 times for cadmium, and 388.9 times for mercury, while in soils used under growing a garden, the correspondence of the concentration of heavy metals to the MPC was slightly different and was 30.9 times for copper, 57.5 times for zinc, 6.4 times for lead, 8.9 times for cadmium, and 328.1 times for mercury. That is, among the indicators studied, significant changes in the soil over 14 years of intensive gardening occurred in such indicators as: exchangeable potassium, mobile phosphorus, sulfur, mercury.

CONCLUSIONS

Long-term monitoring showed that intensive gardening for 14 years led to an increase in exchangeable potassium by 6.58 times, mobile forms of phosphorus by 14.6 times, calcium by 31.1%, exchangeable magnesium by 18.8%, molybdenum by 11.2 %, sulfur by 46.3%, zinc by 18.4%, lead by 3.1%, cadmium by 2.5% and mercury by 34.5%, and a decrease in easily hydrolyzed nitrogen by 12.9%, humus by 0, 06%, boron by 8.6%, iron by 17.9% and copper by 6.8% compared to fallow soil. Agroecological assessment of grey forest soils under intensive gardening allowed us to determine indicators that can be used as additional tools in monitoring studies.

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