тужність гумусового горизонту, ґрунт ущільняється, внаслідок чого зменшується пористість, спостерігається зниження за профілем вмісту гумуса, фосфору та калію. Всі ці фактори призводять до зменшення родючості ґрунтів.

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ORGANIC CARBON STOCKS AND LOSSES IN SOD-PODZOL SOILS OF THE CENTRAL POLISSYA AGROCENOSES OF UKRAINE

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The article presents the results of studying organic carbon reserves and losses in sod-podzol soils of Polissya agrocenoses over a 30-year-long period. Based on the results of long-term observations conducted on the monitoring sites of the state network by the Institute of Soil Conservation of Ukraine, the scale of the organic matter loss was determined, the main determinants and their structure were identified.

It was revealed that among the main factors causing the loss of soil organic matter the following should be highlighted: the system and intensity of their use during crop growing, temperature increase and carbon dioxide emission.

It was found that at the beginning of the investigated period, the reserves of organic carbon, depending on the particle-size distribution and hydromorphic rate of sod-podzol soils, fluctuated in the range from 20.5 to 29.6 t/ha. The average loss values in these soils, calculated per 1 hectare of arable land, are about 120 kg.

It was determined that annual CO_2 emission losses in sod-podzol soils during the study period varied in the range from 3.7–6.9 to 5.5–10.2 kg/ha/year^{-1}. It is shown that soil organic matter losses occurred simultaneously with the permanent decrease in fertility indicators.

It was found that in the general pattern of the loss of soil organic carbon, average annual emissions account for 3.–8.5 % of the average annual C_{org} loss from 1 ha of arable land. The rest of the factors causing soil losses make up about 90 % of the loss total value of the organic matter.
Key words: *organic carbon, CO_2 emissions, sod-podzol soils, monitoring sites of the state network.*

Трофименко П.І., Трофименко Н.В. Запаси та втрати органічного вуглецю дерново-підзолистими ґрунтами агроценозів Центрального Полісся України

У статті висвітлено результати досліджень запасів і втрат органічного вуглецю дерново-підзолистими ґрунтами агроценозів Полісся за 30-річний період. На основі результатів тривалих спостережень структурами Інституту охорони ґрунтів України, проведених на моніторингових ділянках державної мережі, встановлено масштаби втрат органічної речовини, виявлено основні зумовлюючі чинники та їхню структуру.

Показано, що серед основних зумовлюючих чинників втрат ґрунтами органічної речовини можна виділити такі: спосіб та інтенсивність їх використання під час вирощування сільськогосподарських культур, підвищення температури повітря та емісійні викиди діоксиду вуглецю.

Встановлено, що на початку досліджуваного періоду запаси органічного вуглецю, залежно від гранулометричного складу та ступеня гідроморфності дерново-підзолистих ґрунтів, коливалися в інтервалі від 20,5 до 29,6 т/га. Середні величини втрат цими ґрунтами у розрахунку на 1 га ріллі становлять близько 120 кг.

Визначено, що річні емісійні втрати CO_2 на дерново-підзолистих ґрунтах у межах досліджуваного періоду коливалися в діапазоні від 3,7–6,9 до 5,5–10,2 кг/га/рік$^{-1}$. Показано, що втрати ґрунтами органічної речовини відбувалися одночасно з перманентним зниженням параметрів показників їхньої родючості.

Встановлено, що в загальній структурі втрат ґрунтами органічного вуглецю на щорічні емісійні викиди у середньому припадає від 3,1 до 8,5 % від величини середньорічних втрат Сорг з 1 га ріллі. При цьому на решту зумовлюючих втрати ґрунтами чинників припадає приблизно 90 % загальної величини втрат органічної речовини.
Ключові слова: *органічний вуглець, емісія CO_2, дерново-підзолисті ґрунти, моніторингові ділянки державної мережі.*

Трофименко П.И., Трофименко Н.В. Запасы и потери органического углерода дерново-подзолистыми почвами агроценозов Центрального Полесья Украины

В статье отражены результаты исследований запасов и потерь органического углерода дерново-подзолистыми почвами агроценозов Полесья за 30-летний период. На основе результатов длительных наблюдений структурами Института охраны почв Украины, проведенных на мониторинговых участках государственной сети, установлены масштабы потерь органического вещества, выявлены основные обусловливающие факторы и их структура.

Показано, что среди основных обусловливающих потери почвами органического вещества факторов следует выделить: способ и интенсивность их использования при выращивании сельскохозяйственных культур, повышение температуры воздуха и эмиссионные выбросы диоксида углерода.

Установлено, что в начале исследуемого периода запасы органического углерода, в зависимости от гранулометрического состава и степени гидроморфности дерново-подзолистых почв, колебались в интервале от 20,5 до 29,6 т/га. Средние величины потерь данными почвами в расчете на 1 га пашни составляют около 120 кг.

Определено, что годовые эмиссионные потери CO_2 на дерново-подзолистых почвах в пределах исследуемого периода колебались в диапазоне от 3,7–6,9 до 5,5–10,2 кг/га/год$^{-1}$. Показано, что потери почвами органического вещества происходили одновременно с перманентным снижением параметров показателей их плодородия.

Установлено, что в общей структуре потерь почвами органического углерода на ежегодные эмиссионные выбросы в среднем приходится от 3,1 до 8,5 % от величины среднегодовых потерь Сорг с 1 га пашни. При этом на остальные обусловливающие потери почвами факторы приходится примерно 90 % общей величины потерь органического вещества.
Ключевые слова: *органический углерод, эмиссия CO_2, дерново-подзолистые почвы, мониторинговые участки государственной сети.*

Formulation of the problem. The organic matter of the Polissya soils is a significant carbon tank, which directly participates in the formation, transformation and displacement of its streams in the process of the biosphere cycle. Despite the fact that in absolute figures it is inferior to the carbon stocks of the Ukrainian Forest-Steppe and Steppe, however, it plays an important role in the concentration of CO_2 regulation in the atmosphere.

Since 1990, after the completion of drainage reclamation, the nature of human impacts on soils compared to the previous period has changed significantly. Within a context of the long-term land relations reform, the land structure was significantly changed as well. There was a natural and anthropogenic transformation of agricultural lands with the corresponding redistribution of soils in their structure. A part of the agricultural land with low natural fertility has gradually transformed into shrub and forest planting. Instead, significant agricultural land areas in the process of their intensive usage are under a significant agro-environmental impact.

Especially clearly the enhancement of anthropogenic load is observed on soils of agricultural landscapes. Landowners' and land users' exploitation of soil-land resources for the crop production in Ukraine takes place without proper state control, which leads to deterioration of their agro-ecological status. Many of the agrarian producers use their available land without proper land-based justification such as worked out and certified land management projects. And those producers, which implement such projects, do not always keep to the recommended structure of sown areas. In this case the scientifically grounded crop rotation saturation limits of intercrops and industrial crops is broken, that leads to increase of organic matter salinity in soil. Due to the above, and taking into account the significant increasing the average temperature in Ukraine, dangerous conditions are being created for strengthening the mineralization process and loss of soil organic matter.

It is known that the climate change framework agreements for the period from 1990 to 2015 commit particular countries, including Ukraine, to store and replenish in advance the carbon storage tanks, to ensure its sequestration in soils and to reduce the emission of CO_2 to the atmosphere. According to the previous consideration, and taking into account the varying intensity of their use at certain stages of their evolution, there is an urgent need for an objective assessment and inventory of the soil losses amount of organic matter.

Analysis of recent research and publications. By the opinion of many scientists, the solution of this problem is possible either in the case of direct systematical measurement of carbon streams, or by determining the reserves of C-CO_2 at certain time intervals [4; 5; 8; 12; 13; 15].

Both of these approaches are acceptable for applying, but none of them can claim the exceptional results objectivity. The first of these is advisable to apply in cases of necessity to determine the volume of emissions ↔ sequestration of organic carbon within the growing season, the season, the calendar year, the month and day, depending on the specific observation tasks. The second is more efficiently to use in case of necessity to set parameters of the organic carbon balance in the soil for a longer period – from several years to decades. In this case, the applying of each of them requires qualitatively determined soil characteristics at the beginning and at the end of the research period obtained on the basis of objective methods of field measurements and laboratory analysis.

In accordance with the Act of Ukraine "On Land Management" (2003), land tenure should take place in the context of sustainable land use. Based on the above, an important part of the rational use of soil and land resources is proper accounting of soil organic matter and its losses in the process of use.

The purpose of research. Taking into account the above, the aim of the research was to: assess the extent of carbon stocks and losses by the world's soils and to establish trends for further changes in the flow structure of this element in the biosphere. To determine the dynamics of organic matter stocks in sod-podzol soils of Zhytomyr Polissya of Ukraine, which are back-soil for this natural-climatic zone and determine the extent of organic carbon losses in the process of their prolonged use.

Setting objectives. To solve the research tasks the following tasks were set:

– on the basis of the literature analysis, estimate the world's soil reserves and organic carbon losses;

– on the basis of long-term monitoring observations of the Zhytomyr branch of Institute of Soil Conservation of Ukraine and own studies of fertility indicators of sod-podzol soils of Zhytomyr Polissya to evaluate the parameters of organic carbon (Corg) reserves and losses;

– to establish the main determinants of soil organic matter losses and, based on the revealed mechanism, to determine the outstanding characteristics of their further rational use.

Presentation of the main research material. Given the need to address the above problems, we have chosen the way of direct stocks and the losses determination of organic carbon from Polissya soils. Preference is given to this method for solving the research due to the ability to use long-term monitoring data observations at points of state network of the former USSR, now Ukraine from 1987 to 2016. Based on these data of soil fertility indicators, the paper attempts to provide assess the scale of organic matter losses by Polissya soil.

The values of average air temperature determination is based on the source [10].

Organic carbon stocks detection for a 0–20 cm layer is based on humus content in soils with the van Bemmelen factor considering. The gross stocks of Corg in the soil were determined by the formula:

$$C_{org} = 58\, A \cdot B \cdot P$$

where Corg – gross stocks of soil organic carbon; t/ha;

A – horizon thickness, which is taken into account, m;

B – volume weight of soil, g/m^3;

P – humus content, %;

58 – the number that provides the recalculation of the humus content value in soils (%) to the size of the Corg stock in tons of organic carbon per hectare.

The total reserves of organic carbon in the soil reservoirs of the world vary widely, depending on their geographical location, belonging to a certain land, the use method and other factors.

In absolute term, for the most saturated by air upper layer of soil (0–30 cm), which is most actively involved in carbon biosphere cycle, the Corg reserves are 680 PG (pentagrams/billion tonnes) or $6.8 \cdot 10^{11}$ tons [2]. According to data provided by the authors, in the crop land soils, sand grasslands and mosaic of natural vegetation areas is concentrated 190 PG of carbon.

It is easy to calculate that in the world soils of agricultural lands in a layer 0–30 cm is concentrated about 28 % of the world's soil carbon stock.

In this case, the emission of CO_2 by the soil cover of the whole planet is estimated within the range of 37.5-70 gigaton (Gt) of C-CO_2 [3; 6]. Some authors [6] estimate the volume of global CO_2 emissions from soils to the atmosphere at the rate of 59.2–60.5 Gt per year. While Houghton and Skole indicate a value of C-CO_2 as 60.3 Gt [3].

Based on these data, we calculated the annual carbon emission volumes of the world soils, ranged from 0.0197 to 0.0368 % of its total stock in its most aerated soil layer. According to many scientists, increasing the concentration of CO_2 in the atmosphere, which is observed for a long period is a consequence of global warming [3; 9; 14]. Taking into account the global trend of the greenhouse intensification, in the near future the increasing of CO_2 emissions from Ukrainian soils is possible due to the growing average air and soil temperature.

Therefore, scientific researches, related to changes in the production regime of carbon dioxide by soil due to climate transformations in various natural climatic zones of our country, represent an important scientific problem.

World trends in reducing the content of organic matter in soils due to the influence of various factors extend to the territory of Ukraine as well. According to the materials of the "National report about the soil fertility status of Ukraine" in 2010, there is a permanent decrease in humus content of the soil cover. According to the authors' conclusions for the period from 1986 to 2005, the decrease of the organic matter content in the soils of the Polissya of Ukraine is mainly due to a sharp decrease in the annual volumes of organic fertilizers [1]. Some part of the carbon lost, in the form of CO_2 emission, came to the atmosphere. However, determining the volume of carbon dioxide losses by soil in Ukraine requires a proper scientific (theoretical and methodological) justification.

Within the Zhytomyr Polissya, the background types of soils are sod-podzol soils with different particle-size distribution and hydromorphism rate. It is known, they are characterized by a weak humus accumulation, low base saturation and acidic reaction of the soil environment. At the same time, their territorial distribution within the land masses boundaries of agrarian enterprises is characterized by exceptional diversity type and complex configuration of soil areals.

According to the national report materials "About the soil fertility status in Ukraine", the area of sod-podzol soils is 2511.2 thousand hectares, including 2209.9 thousand hectares on arable land. Their share in the soils structure in view of agricultural land and arable land, is respectively (6.03 % and 6.81 %). And according to the data of the Institute "Ukrzemproekt" (now – the Institute of Land Management), based on the results of soil surveys of 1957–1961 and the materials of the soil surveys correction in 1967–1980, their share in the overall structure of the soil cover of the Polissya zone is 28.8 % [11].

On the territory of Zhytomyr region, 60 monitoring sites of the state network were backfilled, in which long-term monitoring of soil fertility indicators is carried out. The majority of them (40) are located within the Zhytomyr Polissya [7]. During the research the materials were used from Zhytomyr Branch SI Institute of Soil Conservation of Ukraine, from 4 monitoring sites (Table 1).

Table 1

Monitoring sites location

Point №	Soil name	Settlement name, area (district)	Coordinates	
			latitude	longitude
33	sod-podzol glued joint-sandy soil on sandy loam sediments	v. Karvynivka, Romaniv area	50007'20″	28013'21″
3	sod-podzol glued sandy loam soil on sandy loam sediments	t. Baranivka, Baraniv area	50017'18″	27038'19″
10	sod-podzolic glued sandy loam soil on loamy sediments	v. Grozine, Korosten area	50057'00″	28045'00″
7	Sod-podzol gley sandy loam soil on sandy loam sediments	v. Moklyaky, Emilchino area	50051'00″	27052'00″

It should be noted that the determination of the main soil fertility indicators from particular monitoring points was carried out during the agrochemical surveys (now – certification of agricultural land) within the five-year observation tours. However, the frequency of soil sampling at points was not always corresponded to the five-year research cycle. In different monitoring periods, the intervals of soil monitoring for different reasons were unequal and was held over for 3, 4, 5, 6, 7, 8 or 9 years. However, the importance of information about the humus content in soils and other indicators of soil fertility cannot be overestimated.

Soil losses of organic matter occurred simultaneously with a general decrease of their fertility level. As a result of prolonged use, the basic agrochemical parameters of the studied soils were undergone a significant transformation (Table 2).

Table 2

Transformation of soil fertility indicators over a 30-year period in the arable layer, (0-20 cm)

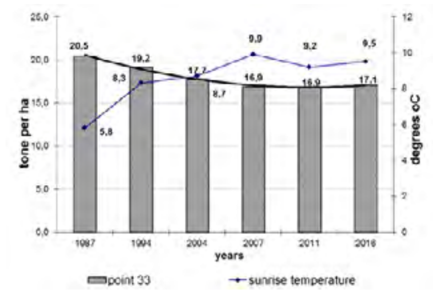
Point №	Soil name	Indicators			
		humus content, %	P_2O_5 content, mg/kg of soil	K_2O content, mg/kg of soil	pH
33	sod-podzol glued joint-sandy soil on sandy loam sediments	$\frac{1,26}{1,05}$	$\frac{143}{94}$	$\frac{80}{46}$	$\frac{6,8}{5,4}$
3	sod-podzol glued sandy loam soil on sandy loam sediments	$\frac{1,31}{1,14}$	$\frac{112}{116}$	$\frac{76}{70}$	$\frac{6,1}{5,4}$
10	sod-podzolic glued sandy loam soil on loamy sediments	$\frac{1,56}{1,31}$	$\frac{99}{108}$	$\frac{97}{79}$	$\frac{5,0}{4,7}$
7	sod-podzol gley sandy loam soil on sandy loam sediments	$\frac{1,68}{1,48}$	$\frac{43}{35}$	$\frac{53}{31}$	$\frac{6,4}{5,1}$

** in the numerator is the data for 1987, in the denominator – for 2016.*

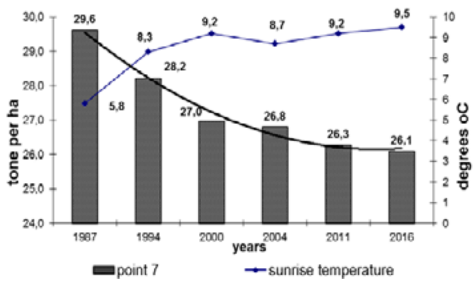
It should be noted that during the studied period main soil indicators, which were systematically monitored, were getting worse. The exception is only the content of P_2O_5 in sod-podzol glued sandy loam soils (points 3, 10) (see Table 2). Obviously, the stable content of this element in the beginning and at the end of the 30-year observation period is associated with the use of increased doses of phosphate fertilizers in the Soviet era (the introduction of phosphate fertilizers “as a stock”). After land improvement activities such as soil liming, there was a pH return of soil solution to their natural value. As a result, part of gross forms of phosphorus was transformed into moving labile forms, as evidenced by the above data.

Calculated amount of organic carbon reserves during the investigated period in sod-podzol soils of different particle-size distribution and hydromorphism rate is presented in Figure 1.

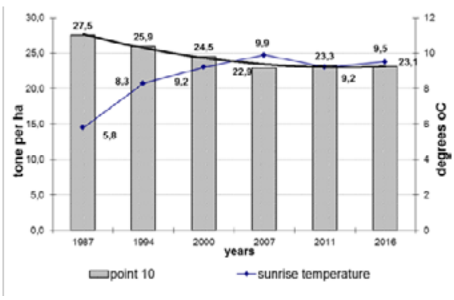
These data indicate relatively low stocks differentiation of organic carbon in arable layer (0–20sm) of particular soils, which mainly depends on their particle size distribution.



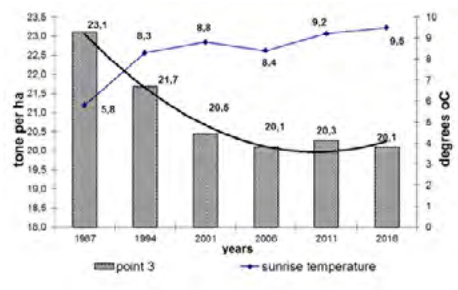
a)



b)



c)



d)

Fig. 1. Dynamics of organic carbon stocks in the arable layer of sod-podzol soils of Zhytomyr Polissya during the 30-year use period, t/ha.
a – SP glued joint-sandy soil, v. Karvynivka; b – SP gley sandy loam soil, v. Moklyaky; c – the SP glued sandy loam, v. Grozine; d – SP glued sandy loam, t. Baranivka.*
SP – "sod-podzol".*

As of 2016 the smallest stock has a sod-podzolic glued joint-sandy soil – 20.5 tons/ha (Fig. 1. "a"). Somewhat higher reserves are characterized by sandy loam soil differences (from 23.1 to 29.6 t/ha) (Fig. 1, "b", "c", "d"). For 30-year period of use there is a permanent reduction in organic carbon stocks for all studied soils.

And during the most large-scale loss of soil organic matter coincided with a gradual increasing in the average temperature in Ukraine (see. Fig. 1). The observed pattern shows that a temperature rise, along with other factors, had a direct enhance effect on the development of Polissya soil carbon losses.

It is characteristic that decline rate in organic matter reserves by sod-podzol joint-sandy soil is visibly smaller compared to the sandy loam soils. The reserves and losses volumes of organic carbon by the soils of Zhytomyr Polissya during the investigated period are presented in Fig. 2.

The above data indicate that the largest losses of carbon from sod-podzol and soddy Polissya soils occurred in the period from 1994 to 2007 and are mainly associated with a decrease in the volumes of organic fertilizers per 1 hectare from 5.8 to 0.4 t/ha [1] and practically full expropriation from the field of nonentity crop output in the form of aboveground plant remains.

According to our calculations over the 30-year period, the average values of organic carbon losses per 1 hectare are from 99.9 to 146.9 kg (see Figure 2), on average

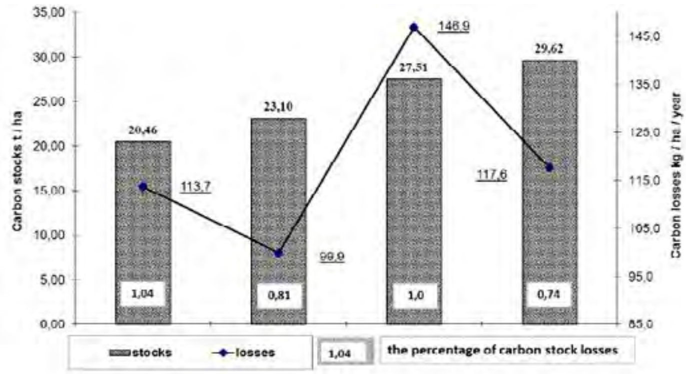


Fig. 2. Reserves and losses volumes of organic carbon by sod-podzol soils of Zhytomyr Polissya, average for the 30-year period of use, t/ha, t/ha / year[1], percent of stock losses, (%), respectively.

**The names of the soils according to the number of points in the table 1.*

(119.8 kg). Absolute values of the average annual loss of Sorg in particular periods of soil use, have a wider range and, depending on the soil differences, fluctuate between 44 and 235 kg/ha / year^{-1}.

For most of the studied soils after a period of maximum loss of organic matter due to the application of intensive crop cultivation technologies, which lasted from 1987, until 2004–2005, there is a period of relative stabilization of its content.

After 2006 in some of the studied soil differences, the actual pause of organic matter losses was noted, and in some periods, even a small accumulation of it. The exception is only sod-podzol gley sandy loam soils on sandy loam sediments, v. Moklyaky, where the loss of Sorg stocks for 1 year period has the highest values and does not stop (see Fig. 1 “b”).

Quite interesting calculations were annual loss rate of C-CO_2 by sod-podzol soils of Ukraine Polissya due to emissions. Taking into account the detected patterns and in respect of certain generalization rate, the annual emission losses of CO_2 on the studied soils over the 30-year period fluctuated in the range from 3.7–6.9 to 5.5–10.2 kg/ha/year^{-1}. And in the general structure of soil organic carbon losses for the study period, annual average emission is from 3.1 to 8.5 % of the average Sorg annual loss from 1 ha of arable land.

It should be noted that the absolute values of soil organic carbon losses do not always allow to evaluate the real extent of the of soil damage hazard in the short and long term. During the intensive use of soil as a means of crop production, it is important to keep the maximum limits of agro-environmental impact that it can withstand. Otherwise excessive load on the soil fatally leads to disturbance of its main functional systems and the general deterioration of agroecological status.

Conclusions and suggestions. Using data on soil fertility indicators from monitoring sites of the Zhytomyr branch of the State Enterprise Institute of Soil Conservation of Ukraine made it possible to investigate the amount of CO_2 stocks and losses of sod-podzol soils of agrocenosis in the Zhytomyr Polissya territory. The reserves of organic carbon at the beginning of the investigated period, depending on the particle-size distribution, and hydromorphic rate of sod-podzol soils, fluctuated in the range from 20.5 to 29.6 t/ha and significantly decreased over the past 30 years. Among the main drive factors of soil organic matter loss, the following should be selected: the method and intensity of their use during the crops cultivation, the rising air temperature and carbon dioxide emissions. The average loss values by these soils per 1 hectare of arable land are about 120 kg. The annual emission losses of CO_2 on the sod-podzol soils during the study period fluctuated in the range from 3.7–6.9 to 5.5–10.2 kg/ha/year-1. Soil losses of organic matter occurred simultaneously with a permanent decrease in the level of their fertility. In the general structure of soil organic carbon losses for the study period, for annual emission there is in average from 3.1 to 8.5 % of the average annual Corg loss from 1 ha arable land. While for the rest of causing soil losses factors it is accounted for about 90% of the loss total value of the organic matter.

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ОБОБЩЕНИЕ ВОЗМОЖНОСТЕЙ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ПРОВОДИМЫХ МЕРОПРИЯТИЙ ПО РАССОЛЕНИЮ ЗАСОЛЕННЫХ ЗЕМЕЛЬ

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В статье приводятся общие сведения о степени и типах засоления земель Кура-Араксинской низменности в республике Азербайджан. Обобщаются некоторые вопросы по улучшению мелиоративного состояния орошаемых земель и организации мелиоративных мероприятий на засоленных землях. Приводятся уточненные площади засоленных и солонцеватых почв по отдельным степям Кура-Араксинской низменности. Проанализировав полученные научно-исследовательские материалы по засоленности и дренированности орошаемых земель в Кура-Араксинской низменности, предлагаются дифференцированные мероприятия по улучшению засоленных земель, учитывающие местные почвенно-мелиоративные условия.

Ключевые слова: *засоление, орошение, минерализация, дренаж, грунтовые воды, мелиоративное состояние, инфильтрация, рассоление, промывка, освоение, урожайность.*

Хасаєв Г.А., Мадяшов А.Г. Узагальнення можливостей підвищення ефективності проведених заходів із розсолення засолених земель

У статті наводяться загальні відомості про ступінь і типи засолення земель Кура-Араксинської низовини в республіці Азербайджан. Узагальнюються деякі питання щодо поліпшення меліоративного стану зрошуваних земель та організації меліоративних заходів на засолених землях. Наводяться уточнені площі засолених і солонцюватих ґрунтів за окремими степами Кура-Араксинської низовини. Проаналізувавши отримані науково-дослідні матеріали із засолености та дренованості зрошуваних земель в Кура-