

Scientific and methodological approaches to the sustainable management of soil resources of the Steppe of Ukraine in irrigation

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The purpose. Development of scientific-methodical approaches to sustainable control over soil resources of Steppe of Ukraine in conditions of irrigation. **Methods.** Monitoring probes, methods of synthesis, analysis. **Results.** It is displayed that in conditions of the heightened anthropogenic load on soils, exacerbations of ecological situation, development of degradation processes, aridization of climate it is necessary to use principles of stable control over edaphic resources which are directed on confinement of edaphic systems in optimum or close to them parameters. The system of sustainable control over irrigated soil resources includes 5 interdependent blocks: informational, organizational, technological, economic, normative-methodical provision. Sustainable control should be based on the complex, integrated evaluation procedures of ecological-agromelioration state of irrigated soils, on mapping out of directions of their intelligent use, on measures on protection and increase of fertility of soils, restoration and spread of areas of irrigation in conditions of climate fluctuations. Assessment of the level of giving eco-system services by typical chernozems and dark-chestnut soils of objects of probes is carried out. It is fixed that non-irrigated typical chernozems with good ecological-agromelioration state are characterized by high level of eco-system services, and irrigated with satisfactory and unsatisfactory states — medium and low. The level of giving services by chestnut soils — virgin, non-irrigated and irrigated with suitable water — is evaluated as high, and irrigated soils of Ingulets system — as medium. For chernozem inferred from irrigation they developed prognostic models of change of its properties. **Conclusions.** Sustainable control over irrigated soils is directed on optimization and stabilization of regimes of operation of soils, execution by soil of ecological functions, giving eco-system services, level recession of degradation of the soils, the balanced land-use and solution of questions of food safety of the country.

Key words: *soils, irrigation, degradation, ecological-agromelioration state, eco-system services.*

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Under increasing anthropogenic loading on soil cover, climate aridization, development of desertification processes, the issue of sustainable management of soil resources is especially important in view of regional natural and socio-economic conditions, which is aimed at balanced development of soils, prevention and reduction of degradation levels, maintenance of important ecological functions, and ecosystem services, improvement of the state ("health") of soils, and also adaptation to arid conditions. The soils are the basis for food production and many important ecosystem services (supplying, supporting, regulatory, cultural), therefore efforts should be directed towards the conservation or enhancement of soil resources to ensure food, water and energy security [1, 2].

The implementation of the principles of sustainable management of soil resources in order to protect, maintain and provide sustainable production (FAO Pillar 1) is one of the strategic and priority areas for the activities of the Food and Agriculture Organization of the United Nations (FAO), the Global Soil Partnership (GSP). Their efforts are aimed at active knowledge sharing on this issue as an important tool for ensuring sustainable development of society, as well as developing ways to overcome barriers that hinder their implementation [2]. For this purpose, it is established WOCAT (a global network on Sustainable Land Management (SLM) that promotes the documentation, sharing and use of knowledge to support adaptation, innovation and decision-making in SLM). The FAO and GSP experts developed the Voluntary Guidelines for

Sustainable Soil Management [2], which were approved by the 115th Session of the FAO Council (Rome, 05.12.2016), and focused primarily on the need to restore degraded soils and improve their properties.

Therefore, one of the priority tasks for Ukraine as an agrarian country is the introduction of world practices of sustainable management of soil resources for solving food security issues, preservation and rational use of natural resources, adaptation to climate change. Particular attention should be paid to irrigated soils, their role grows in conditions of climate aridization. Irrigated soils suffer from increased anthropogenic load and require its normalization, reducing environmental risks, which increases the significance of research on the development of scientific and methodological approaches and principles of sustainable management to ensure rational and balanced use, increase of agro-resource potential and soil fertility. This issue is especially relevant for the regions of our research - Donetsk and Kherson regions, their landscapes are subject to a powerful influence of man-made (the territory of environmental risks, the operation of the combined forces) and climatic factors that affects the quality of soils and agricultural products [3-5] and complicates the management of soil resources and agricultural production.

The research purpose is the development of scientific and methodological approaches to the sustainable management of the soil resources of the Ukrainian Steppe under irrigation conditions.

The research methodology. The methodological basis of research is monitoring research, systematic, statistical analysis, forecasting. On the basis of generalization, synthesis and analysis of data of long-term monitoring studies (2001-2017), field experiments, stock materials, there were developed scientific and methodological approaches to sustainable management of soil resources of the Steppe under irrigation conditions.

The research object is the irrigated soils of Donetsk (chernozem ordinary heavy loamy / light clay) and Kherson regions in the zone of the Ingulets irrigation system (dark chestnut, chestnut-meadow alkaline light clay soils).

Monitoring surveys of irrigated lands were carried out using the "keys-analogues" method in accordance with [6]. The comprehensive evaluation of the state of irrigated land by combining information was carried out according to the following indicators: quality of irrigation water according to agronomic and environmental criteria, groundwater level, degree of salinity, alkalinity, soil contamination, nutrient content and humus.

The quality of irrigation water was estimated according to agronomic and environmental criteria according to DSTU 2730:2015, DSTU 7286:2012; salinity - according to DSTU 7943-7945:2015, DSTU 7908-7909:2015; composition of absorbed cations by Tyurin method according to DSTU 7604:2014; total humus content according to DSTU 4289:2004; content of available forms of heavy metals (acetate-ammonium buffer solution with pH-4,8) according to DSTU 4770.1:2007– 4770.9:2007.

The exponential smoothing method was used to develop predictive models of changes in the properties of chernozem ordinary, that is withdrawn from irrigation.

Research results. The arid climate causes the expansion of the territory with a deficit of natural moisture content, the area of which over the past 30-50 years has increased by 8 million hectares [7].

Under such conditions, the role of irrigation as a stabilizing factor of agrarian production is very important in order to increase the agro-resource potential of soils and productivity of crops to ensure the country's food security. Irrigated lands are a guarantor of the stability of the agrarian sector development in arid climate, therefore the restoration and expansion of irrigated areas, its further development and sustainable management of irrigated soil resources are among the priority tasks of the agrarian sector of Ukraine's economy.

In our understanding, *sustainable management of soil resources* is defined as a complex of interconnected blocks (information, organizational, technological, economic, regulatory and legal support) and management decisions that ensure optimization and stabilization of soil functioning regimes, the implementation of soil ecological functions and providing ecosystem services, reducing level of soil degradation, balanced land use and addressing food security issues in the country. Sustainable management of soil resources is an important tool for achieving the goals of sustainable development of the country. Its main objective is the maintenance of soil systems in optimal parameters. Sustainable use implies the absence of degradation or the achievement of its neutral level, ie, the regulation of the load on soils and taking into

account the establishment of a dynamic equilibrium between the anthropogenic loading on the natural environment and its ability to self-renovation by determining the limit values of the stability potential [8, 9].

Sustainable adapted land-use methods under irrigation should take into account the interactions between soil, water and crops and aim at preventing or eliminating soil degradation, improving agricultural productivity and mitigating the effects of climate change [2, 10].

Nowadays, the term "climate-smart agriculture" is widespread in the world, an alternative approach to land management and increasing agricultural productivity under the new climate change realities, which was first supported in 2010 at the first global, agricultural, food security and climate change conference in Hague. It is based on three main directions: sustainable increasing productivity of agriculture and incomes; adaptation and increase of resistance to climate change; reduction and / or removal of greenhouse gas emissions.

Sustainable development is based on systematic, integrated land-use management and three interrelated principles: economic, social development and environmental protection.

Thus, in modern conditions, a new land management strategy is needed. It would balance the state of the natural ecosystems and the needs of society, and ensure the ecological and social stability of agro-industrial production, especially in regions with high technogenic and environmental loads, which include the objects of our research.

The system for the sustainable management of irrigated soil resources should include the following main units and elements (Figure 1):

1. *Information unit* - collection and analysis of operational information, monitoring and evaluation of the ecological and agro-amelioration status of irrigated land; constant updating of operational information on the state of soil of the reclamation fund, creation of soil informative databases, cartographic materials;

2. *Organizational unit*- coordination of activities of organizations in the field of irrigation, land reclamation with the aim of solving problems on reducing anthropogenic loading on soils, preventing and eliminating the development of degradation processes, increasing soil fertility and the efficiency of irrigated agriculture;

3. *Technological unit* - organizational and economic measures - organization of ecologically safe functioning of irrigated agro-landscapes, planning system of differentiated agro-technical and agro-melioration measures;

- hydrotechnical measures - maintenance of proper state of hydraulic structures, irrigation network, reconstruction of irrigation systems;

- agrotechnical measures - optimization of the system of cultivation of agricultural crops and soil tillage with adaptation to the soil and climatic conditions;

- agro-amelioration measures - optimization of fertilizer system, soil reclamation, integrated space-differentiated measures for rational use, protection and increasing soil fertility, combating degradation processes, development of plans for integrated water and land management with the participation of local communities, water users and land users;

4. *Economic unit* - financial support for implementation of soil protection measures; creation of a mechanism of economic incentives for land users who carry out agro-amelioration measures to increase the fertility of irrigated soils;

5. *The unit of normative-legal support* - creation of the legal base in the field of irrigated agriculture, land reclamation.

The proposed system of sustainable management is intended for three levels of organization: national one - restoration and development of irrigation in Ukraine as the main factor for eliminating the deficit of natural moisture in conditions of climate change; departmental one - for the services of the State Agency for Water Resources and other services involved in monitoring, assessment of soil condition, water sources; regional one - for representatives of local communities, landowners for the sustainable management of agricultural production and the introduction of measures for the protection and increase of soil fertility.

An important component of the system of sustainable management is the information unit. The key to the planning of agricultural production and the use of irrigated land, especially in conditions of increased man-made load, is the availability of operational, accurate and complete (complex) information about their condition, which serves as the basis for planning, developing the directions of their balanced, rational use, formation of soil and

information databases, as well as the introduction of spatially differentiated measures for the protection and increase of soil fertility [11]. To obtain a more accurate and integrated assessment of the condition of irrigated soils, we propose two scientific and methodological approaches. One of them is based on a systematic analysis of interrelated elements of irrigated agroforestry using geoinformation systems (GIS), mathematical approaches to combining, analysis of available information (terrestrial, remote); the second - on the definition of ecosystem services that the soil provides to society and the environment, depending on their qualitative state. The offered approaches are the strategy of complex management of land, water and other natural resources and allow revealing more effective and rational directions of integrated use in conditions of climate change and growing environmental risks.

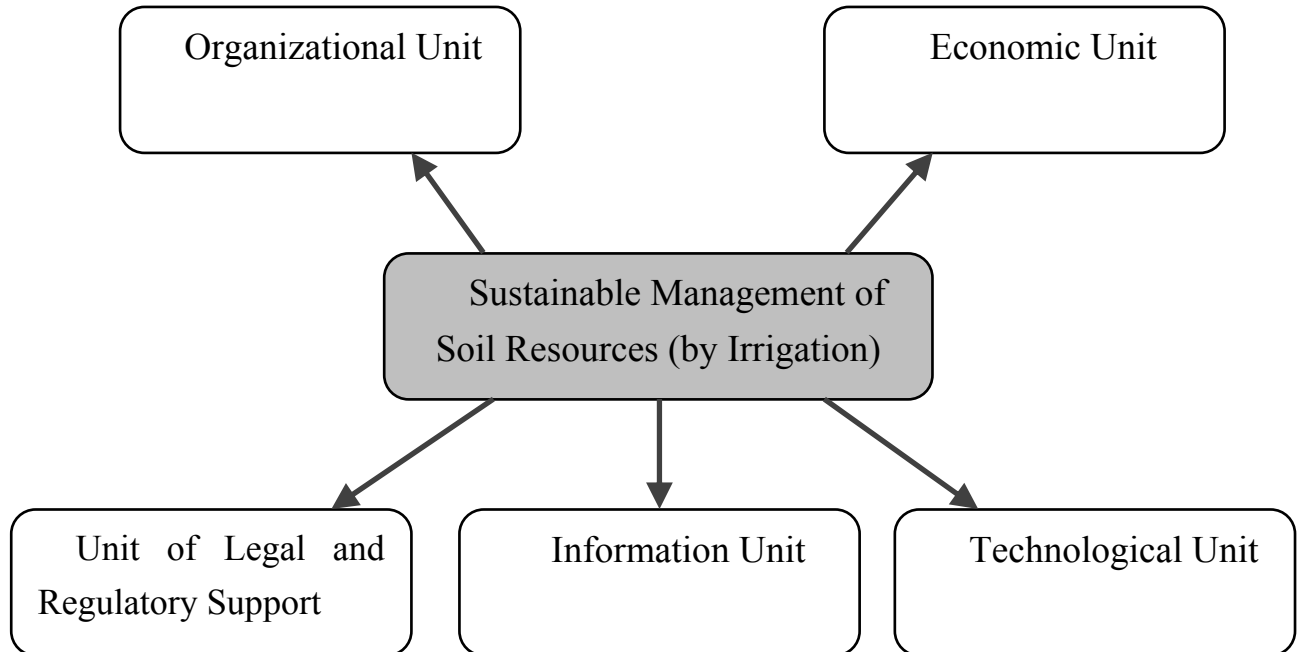
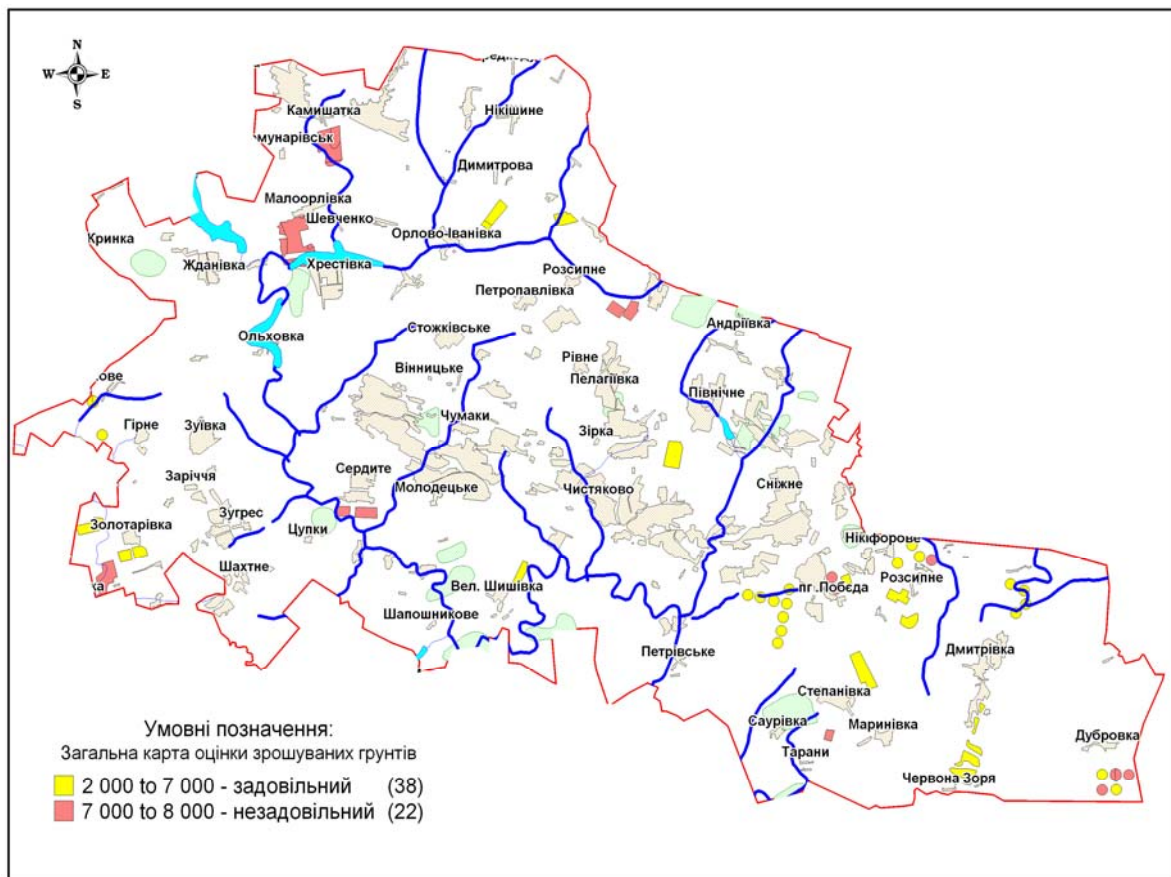


Fig. 1 Structural scheme of the system of sustainable management of soil resources by irrigation

Scientific and methodological approaches to combining the information of different services (results of their own monitoring surveys, data of salt sampling and agrochemical land certification) and integrated assessment of irrigated lands are presented on the example of Shakhtarsky district of Donetsk region. The following indicators were selected as the estimated ones: quality of irrigation water according to agronomic and environmental criteria, groundwater level, salinity, alkalinity, soil contamination, nutrient content and humus. For a comprehensive assessment of the condition of irrigated lands, we used the formal approach and the principle of "Liebiah tubes" when there are estimated each indicator, its weighting factor and the optimal interval with the next estimation for each separate field using GIS and cartographic methods.

On the basis of the data processing, it was created a map of the integrated assessment of the irrigated lands of the Shakhtarsky District with the allocation of two groups of lands (Fig. 2). The majority of irrigated lands is characterized by a satisfactory state (70.5%), and 29.5% - unsatisfactory. Limiting factors in this case are the quality of irrigation water, processes of alkalinity, soil contamination. A created map is the basis for developing a system of sustainable management of irrigated land, rational use and introduction of spatially differentiated agro-technical and agromeliorative measures to increase their fertility.

Subsequently, based on the assessment of the state of irrigated lands using integrated approaches to the planning of the development of joint territorial communities with the participation of stakeholders, integrated water and land management plans were developed on the example of the Dmitrov Village Council of the Shakhtarsky District, in which the focus is on coordinated management of water, land and related resources to achieve high levels of social and economic development without causing harm for ecosystems. A very important aspect is the consideration of social factors that should be aimed at increasing living standards, income of the rural population, creating additional jobs, and developing small and medium businesses.



Legend

General map of irrigated soils' assessment

satisfactory

unsatisfactory

Fig. 2 Comprehensive assessment of the state of the irrigated soils of the Shakhtarsky district

Integrated planning measures included consolidation of land sites, design and construction of drip irrigation systems for the "Dzhe relo Skhodu" cooperative and the fruit and berry garden; Reclamation of irrigation systems for irrigation by the "Chelyuskintsev" LLC; measures on anti-erosion arrangement of the territory, protection and increase of soil fertility.

A new approach in soil science is the definition of ecosystem services of soils as a function of their ecological and agro-melioration conditions. Within the framework of the project with FAO, a team of authors of the Institute developed a methodology for assessing the ecosystem services of saline soils (for example, the supply service) [12, 13]. Taking into account the improvement of certain methodological approaches, it was tested on irrigated lands of experimental fields of the Northern Steppe (Donetsk region) and the Dry Steppe (Kherson region). Thus, the list of evaluation indicators such as humus content, the degree of soil contamination by heavy metals, microbiological activity of the soil has been expanded, and also we propose to identify two important ecosystem services that are a function of the ecological and agrarian state of the land - supporting service (the medium-forming one - environment of the existence of plants and microorganisms) and supply service (productive one- bioproductivity). The level of service was assessed at high, medium and low grades. The results of the research showed that in the Northern steppe, unirrigated chernozem ordinary of all experimental fields and irrigated soil of the Slavyansk experimental field are characterized by high level, irrigated soils of the Donetsk and Mariinsky experimental fields –medium level, and irrigated soil of the Pervomaisk experimental field – low level. Limiting factors in this case are mainly the quality of irrigation water, salinization, soil contamination by HM, low content of mineral nitrogen, decrease of microbiological activity of the soil.

In Dry Steppe, by virgin, unirrigated and irrigated dark chestnut soils of the Markheevsky experimental field, unirrigated and removed from irrigation soils of the Chornobayevsky and Myrolyubivsky experimental fields are characterized by the high level of provision of ecosystem services. Irrigated soils of Chornobayevsky and Myrolyubivsky experimental fields are characterized by an average level of ecosystem services` provision, due to their ecological and agro-amelioration status - the quality of irrigation water, the close occurrence of groundwater, the development of processes of salinization, insufficient level of nutrition, humus, and microbiological activity.

The results of integrated assessment of the ecological and agro-amelioration status of irrigated lands and the level of their provision of ecosystem services are the basis for planning the work on irrigation renewal and expansion of irrigated land, as well as developing a complex of differentiated, adapted melioration and soil state improvement as one of the unit of the sustainable system management of irrigated soil resources and agro-climatic adaptation to climate change (technological unit).

The reserve for expansion of irrigation areas under conditions of arid climate can be - removed from irrigation lands under conditions of use for irrigation of high-quality water and good environmental and agro-ameliorative conditions.

The results of the conducted studies indicate that in the post-irrigation period there is a gradual restoration of soil properties: the development of desalinization processes, flushing, improvement of agrophysical parameters [14]. Using the method of exponential smoothing, there were developed the predicted models of changes in the indices of previously irrigated water of the 3rd class of chernozem ordinary. Thus, on the basis of the developed models, we can predict that on 24 years after the removing from irrigation by the content of toxic salts (layer 0-25 cm) and water-soluble sodium and potassium the soil will almost reach the level of unirrigated analog. This period is not enough for the desalinization of alkaline soils.

Based on the obtained research results, it was developed a complex of spatially-differentiated measures for their balanced use and increase of the fertility of irrigated soils of the Northern and Southern Steppe zone, which includes engineering, land reclamation, agrotechnical and agromeliorative measures (technological unit) [3]. Soil melioration should be carried out on an innovative basis, comprehensive measures should be adapted to specific conditions, energy-saving and resource-saving, and ensure balanced development of agro-landscapes.

Conclusions

In the current conditions of land relations, to ensure the sustainable development of land reclamation and the efficient use of irrigated soils, the Steppe of Ukraine needs a transition to a new system of sustainable management, which would ensure optimization and stabilization of soil functioning regimes, decrease of degradation level, implementation of soil ecological functions and provision of ecosystem services, balanced land use and food security issues of the country. The sustainable management should be based on complex, systematic, integrated approaches to assessing the ecological and agro-ameliorative state of irrigated soils, planning the directions for their rational use, measures for the protection and enhancement of soil fertility, and the restoration and expansion of irrigation areas under climate change. It is showed the structural scheme of the system of sustainable management of soil resources for irrigation, which includes five interconnected units.

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