SUSTAINABLE MANAGEMENT OF IRRIGATED SOILS IN UKRAINIAN AGRICULTURE

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Abstract

In the structure of land resources of Ukraine there are significant disproportions, the deepening of which can be a threat to the environment and living environment, as well as the effectiveness of economic activity, sustainable development of the national economy. Irrigation and drainage strategy of Ukraine until 2030 can to ensure sustainable ecologically balanced development of agriculture in Ukraine by modernization, rehabilitation and expansion of irrigation systems. The soil cover of Ukrainian irrigated land is featured a significant dissemination of poorly productive and degraded soils if unsustainable agricultural methods are pursued. Monitoring of the fertility of the irrigated lands, directed to the formation of the models of steady, ecologically safe and economically effective agriculture is required. The complex of measures to manage the fertility irrigated land was developed by authors. Analysis showed that investment along priority irrigation systems would require more than $ 3 billion. The main sources of finance for the of the complex of measures in Ukraine include the following: projects and grants for capacity development of the institutions; international development loans; private investment through leasing, regular bank loans and farmers' own capital.

Key words: irrigation system, irrigated soil, soil management, sustainable management.

More than half of the territory of the Ukraine is located in the zone of insufficient and unstable moistening, therefore irrigated lands located practically in all natural zones and subzones (Gadzalo Y. *et al*, 2018). The country's food and resource supply depends to a large extent on the availability, condition and efficiency of the use of the irrigated land (Bezugliy M.D. *et al*, 2012; Stashuk V. *et al*, 2009). The irrigated lands occupied the greatest area (2.6 mln. ha) at the beginning of the 90's of past century, which is 8 percent of area of plowed land. In recent years in the Ukraine the areas of the irrigated lands have decreased (predominantly spontaneously, without control). Currently, irrigation sector is facing a period of unprecedented challenge. Today, only 500-600 thousand hectares are irrigated in Ukraine. After years of reduced irrigation, the need for rehabilitation and modernization is becoming ever more pressing.

Irrigation and drainage strategy of Ukraine until 2030 (Strategy) was approved of the Cabinet of Ministers of Ukraine in 2019 (Irrigation and drainage Strategy, 2019). It is a nationwide cross-sectoral policy document. Irrigation restoration is a key tool development of the agrarian sector of economy and increase of export potential of Ukraine. It will minimize the impact of climate change on the processes of socio-economic development.

The Strategy notes: whether it will ever be economic to restore irrigation depends on multiple factors including climate change, world markets, the security situation and Ukraine's economic growth. The scope of the Strategy is to ensuring sustainable eco-balanced agriculture development in Ukraine. However, the issues of reservation and restoration of soil fertility during irrigation prevention of their degradation were not reflected in the Strategy.

At present, it has to be admitted that under the influence of the existing system of agriculture in Ukraine, there is often a deterioration of the soil-reclamation state of the land, loss of soil fertility and the imbalance of natural systems in general. The Sustainable Development Goals identify the need to restore degraded soils and improve soil health. At the 39th session of the FAO Conference, members unanimously approved a new edition of the World Soil Charter (Rome, June 6-13, 2015) as an instrument for promoting and institutionalizing the sustainable use of soil resources at all levels

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(FAO, 2015). According to the Revised World Soil Charter (2015): "Soil management is sustainable if the supporting, provisioning, regulating, and cultural services provided by soil are maintained or enhanced without significantly impairing either the soil functions that enable those services or biodiversity".

Voluntary Guidelines for Sustainable Soil Management (FAO, 2017) were developed on account of concerns about the state of soils resulted. In a broader context, the 2030 Agenda for Sustainable Development adopted a number of related targets in 2015 (United Nations, 2015), i.e. those aimed at restoring degraded soil, striving to achieve a land degradation-neutral world and implementing resilient agricultural practices that progressively improve soil quality and minimize soil contamination. Sustainable soil management strongly contributes to collective efforts towards climate change adaptation and mitigation, combating desertification and promoting biodiversity, and therefore has specific relevance to the United Nations Framework Convention on Climate Change - UNFCCC (United Nations, 1992) and United Nations Convention to Combat Desertification - UNCCD (United Nations, 1994).

Our research focuses on the necessary to clarify the soil aspects of the implementation of the Strategy in Ukraine given the current state of irrigated lands, the need to restore and increase the area of irrigated lands, the significant prevalence of degradation phenomena.

MATERIALS AND METHODS

In research we have used international and nationwide cross-sectoral and sectoral policy documents, various reports and different type of articles regarding the irrigated land; agricultural development; food security; land reclamation; environmental security in Ukraine. It helped us to understand and explain the specific phenomena regarding soil resources in irrigation agriculture of our country. In order to estimate their impact on the development sustainability of the national agro-food sector we use the quantitative and qualitative comparative analysis of data of the total area of really irrigated soils, the area of soils promising for the development and restoration of irrigation, the area of degraded irrigated soils, which allowed us to generate some proposals taking into account the provision of national agriculture necessary quality soil resources. The science of economics provides the foundation for sustainable agriculture.

The research method is processing, comparisons, synthesis, conclusions and proposals.

RESULTS AND DISCUSSIONS

Ukraine is one of the most agriculturally developed countries in the world. As of January 1, 2017, the land fund of Ukraine is 60.3 million hectares, or about 6 percent of the territory of Europe. Agricultural lands are about 19 percent of the European ones, including arable land - about 27 percent. Indicator of agricultural land per capita is the highest among European countries and is 0.9 hectares, including 0.7 hectares of arable land (the average European countries - 0.44 and 0.25 hectares, respectively).

The total area of agricultural land is 42.7 million hectares, or 70 percent of the total area of the country, and the area of arable land - 32.5 million hectares, or 78.4 percent of all agricultural land. At the same time, in the structure of land resources of the country and land use there are significant disproportions, the deepening of which can be a threat to the environment and living environment, as well as the effectiveness of economic activity, sustainable development of the national economy as a whole (Vargas R., *et al*, 2018).

Today we can see decline of the irrigation system on account of Economic and political changes after the collapse of the Soviet Union. Ukraine is needed in change to adjust to the new market economy, reverse the decline in the irrigation sector, and improve efficiency of irrigated land. Ukraine must manage its national land and water in the interests of all users and the environment and in line with the United Nations Convention to Combat Desertification (UNCCD), United Nations Framework Convention on Climate Change (UNFCCC), Land Degradation Neutrality, Revised World Soil Charter, Sustainable Development Goals until 2030, It recognizes Ukraine's Association Agreement with the EU and EU Water Framework Directive (EU, 2000 and 2017; FAO, 2015 and 2017; United Nations, 1992, 1994 and 2015).

One of the main goals of the Strategy is to ensure sustainable ecologically balanced development of agriculture in Ukraine. To achieve this goal, it is necessary to modernization the systems that currently work, to make them work better; rehabilitation the systems that used to work but have fallen into disrepair; and expansion the irrigation onto new areas that were not previously irrigated.

1. Modernization of systems that currently work, to make them work better. The economic gain would normally be an increase in profitability per hectare. It is necessary for slight increase investment into modernization with private-sector

investment. Total cost is estimated at $ 1.200 per hectare.

2. Rehabilitation of systems that used to work but have fallen into disrepair, resulting in an increase in irrigated area, so that systems are put back into function in better condition than before. It is need for comprehensive financing with public and private-sector investment. Costs will depend on the degree of deterioration in each case, but could average around $ 2.000 per hectare.

3. Expansion of irrigation onto new areas that were not previously irrigated, by installation of new, modern systems. This is need for comprehensive financing with public, International and private-sector investment. Costs would be similar to rehabilitation and are estimated at around $ 2.200 per hectare.

Modernization in all areas will require investments in the amount of about $ 3 billion and will provide an opportunity for additional irrigation on a total area of about 1180 thousand hectares. Despite the significant amount of need for funds, projects for the restoration and development of irrigation systems are investment attractive due to their short payback period.

In Strategy the calculations are given only for the modernization, restoration and expansion of the technical component of irrigation systems. However, a necessary condition for the long sustainable use of irrigation systems is not only the improvement of the productive functions of soils, but also the preservation and improvement of their ability to perform environmental, social functions and provide ecosystem services.

The irrigation is one of the most intensive and effective factors of anthropogenous loads on an environment as a whole and irrigated land in particular. Irrigation influences upon directivity of soil processes and evolution of soils, often bringing to development soil-degradation processes, this requires the study of changes in soil properties under the influence of irrigation to avoid soil degradation (Baliuk S., *et al,* 2017).

The results of these change can carry as positive (the improvement water supply, increasing of fertility, efficiency and etc.), so and negative character (salinization, appearance solonetzization, alkalinization of soils, contamination and others). Directivity, periodicity and alteration rate depend on the quality of irrigating waters, volume of water delivery, initial state of soils and degree of natural drain-ability of territory, technologies of irrigation, level of agriculture.

The soil cover of Ukraine is essentially featured:

a) diverse variety of soils (up to 1.000 kind of soil);

b) unique exceptionality of soil cover (more than 60 percent chernozem soil-formation types).

Ukraine is the fourth country in the world by total area of chernozem after Russia, USA and China. Per 100 residents of Ukraine accounts the 61 hectares of chernozem and per this index, Ukraine holds the 2nd place, next to Russian Federation (Bezugliy, M.D., *et al*, 2012); c) significant dissemination of poorly productive and degraded soils (~ 30%).

In Forest-steppe and Steppe zones of Ukraine is disposed 98% irrigated lands (*table 1*). The soil cover of the irrigated lands is extremely complex.

Table 1

Distribution of irrigated lands in Ukraine by natural areas

Zone, subzone	Irrigated land, % of total area of irrigation
Polissya	1.0
Forest Steppe	13.6
Step Northern	31.2
Step Southern	30.4
Steppe Dry	23.0
Carpathian mountain region	0.5
Mountain region of Crimea	0.3

Practically all types of the soils of the Ukraine are represented in its structure, but chernozem and dark-chestnut soils predominate (*table 2*).

Table 2

Irrigated soils of Ukraine

Soil		Area, thousands ha
In the national classification	In the WRB classification	
soddy-podzolic soils	albeluvisols umbric	7.9
light grey forest soils	albeluvisols umbric	40.2
dark grey podzolized soils	phaeozems albic	26.0
podzolic chernozems	chernozems albic	50.0
typical chernozems	chernozems chernic	230.0
ordinary chernozems	chernozems chernic	720.0
southern chernozems	chernozems chernic	566.0
meadow chernozems	phaeozems haplic	99.0
dark-chestnut soils	kastanozems haplic	384.6
chestnut solonetzic soils	kastanozems luvic	10.0
meadow-chestnut solonetzic soils	phaeozems sodic	54.7
chestnut solonetz	solonetz humic	5.5

The most common forms of the degradation of the irrigated soils are soil over compaction, crustification; erosion; swamping and under

flooding; pollution of soils with heavy metals, pesticides, radioactive nuclides; secondary salinization, solonetzization and alcalinization. They are developed after using for the irrigation waters of the not proper quality (suitable for determined limit and not suitable for the irrigation) and/or because of the low level of agriculture and insufficient resource investments - humus and nutritious elements losses.

Let us pause at such forms of irrigational degradation as salinization, solonetzization and alkalinization (Baliuk S. *et al*, 2016).

Secondary salinization is accumulation in the soil of water-soluble salts, a change of the salt composition to increasing in sodium concentration and contraction is relation Ca:Na. The degree of soils salinization is determined by the content of gross and/or toxic salts taking into account chemism of salinization (its type). There are approximately 100 thousand ha of secondary salinized soils (content of salts in the layer 0-100 cm) among the irrigated lands.

Secondary solonetzization is accumulation of sodium and potassium in the soil absorbing complex, which gives to soils unfavorable physical properties. Secondary solonetzization is the most common degradation process on the irrigated lands. The area of the irrigated solonetzic soils is approximately 700-800 thousand ha.

Alkalinization is increasing of the alkalinity of soil solution and the formation of soda, which occurs under the effect of secondary solonetzization, ground and irrigating waters, reducing of sulfates or other reasons. The regions of the Ukraine, where there is a danger of the formation of soda, are geographically separated. The greatest danger exists in the regions of the cultivation of rice in Kherson region and in the Crimea over the area more than 60 thousand ha.

Basic complex characteristic of irrigated land, which determines the possibility, technological features and prospects for their further use, is ecological and agroameliorative soil condition (measured by hydrogeological, soil - ameliorative, ecological - toxicological and agronomic criteria).

Generally, in Ukraine about 20% of the total irrigated lands have good ecological and agroameliorative condition, satisfactory - about 65% and not satisfactory - about 15%. Areas with not satisfactory condition are lands which are used unsuitable for irrigation water, soils strongly or medium saline and / or solonetzic and waterlogged. By satisfactory conditions are the lands, which have a low level of salinity and solonetzicity, are irrigated limited suitability for irrigation waters and are in automorphic - hydromorphic conditions. In all other cases, ecological and agroameliorative soil condition is defined as good.

Control of the fertility of the irrigated lands, directed to the formation of the models of steady, ecologically safe and economically effective agriculture is required. At present time, the main sources of information on the current condition of irrigated soils in Ukraine include the following:

a) Large-scale soil assessment data,

b) Land registry ('land cadastre'),

c) Data from the agrochemical records ('passporting') of agricultural lands,

d) agro-ecological monitoring data,

e) Research data of scientific and educational institutions and

f) Data of the national environmental monitoring system.

Thus obtained information is of narrow-departmental nature, obtained by different methods and non-correlated observation programs. These disadvantages are strong constraints against consistent usage of materials for evaluation and forecast of changes of soil cover in order to manage it.

An urgent necessity has risen to Monitoring of irrigated soils aimed at systematic control over their condition, as well as early detection of negative changes, and elaboration of measures for upgrading environmental and productive values for the modernization, restoration and expansion irrigated systems. Necessary is to assess the suitability for irrigation for previously no irrigated soils. But, unfortunately, investments for Monitoring aren’t provided for in the Strategy.

Monitoring soils as a natural object should include an assessment of the health of natural ecosystems under conditions of irrigation. The development of strategies for controlling water and salt regimes of irrigated lands requires the knowledge of the scale and trends of natural processes of salt accumulation under different hydrogeological and hydrochemical conditions that existed in soils before irrigation started (Averianov S.F., 1978).

The aim of monitoring is to produce a spatial assessment of the character and degree of soil degradation processes on formerly and currently irrigated non- irrigated and adjacent lands as well as the impact of these processes on soil fertility parameters agrophysical, agrochemical, physicochemical and toxicological), crop yields and the quality of produce. A need for such monitoring is associated with an interaction between ecology and economy.

The former studies bio-abiotic interactions, while the latter involves the management of such interactions (Aidarov I.P., 2012; Aidaro I.P.,

Zavalin A.A., 2015). The degradation of natural ecosystems leads to a reduction in their environmental and agricultural role in climate change, the condition of water and soil resources and public health.

A necessary condition for highly effective, environmentally safe of irrigated land usage is implementing the complex of measures to manage the fertility of irrigated land, improve their agro-ecological condition and level of use. This complex must constantly adapt to the variability of natural and anthropogenic factors in order to obtain the highest possible profit subject to the requirements of resource conservation, soil protection and maintain of natural processes balance both within agro-ameliorative landscapes and in the biosphere as a whole.

In order to overcome the crisis situation across ameliorated land of Ukraine, we proposed to: withdraw (with the National Land-Use Cadastre) certain acreage of arable fields being in poor environmental-reclamation status; implement a complex reconstruction of relevant systems; introduce innovative agro-farming options in order to avoid deterioration of key soil-functions. Under current economic conditions, returning to traditional technology of overall chemical soil-reclamation is inexpedient due to its high cost. Instead, we propose a set of novel alternative approaches to solving the problems of sodic soils' amelioration, but with compulsory shift to employ resource-saving technologies. It is highly necessary to return the strategy of deep plantage plowing; whose effectiveness and aftereffects' duration are very significant factors.

Such complexes of measures include the main elements:

a) Rehabilitation and modernization of irrigation systems, taking into account their environmental and reclamation condition;

b) Conversion of irrigated agriculture on the adaptive-landscape environmentally safe (compensatory) agriculture systems;

c) Rational structure of sowing areas and crop rotation oriented on market economy with the obligatory inclusion in crop rotation the perennial legume grasses;

d) Restoration of works with chemical reclamation of irrigated land and irrigation water, on the fundamentally new provisions;

e) Usage of internally soil reserves of calcium salts (soil self-reclamation) through the reclamation plantage plowing on the area about 500 thousands of hectares;

f) a complex of engineering, agro-ameliorative and preventive measures nominated the composition of which for each region should take into account the occurrence causes and the development features of flooding processes;

g) Soil replenishment with organic matter by plant residues, organic fertilizers, crop rotation with perennial legume grasses;

h) Effective application of fertilizers.

Agro-technological approaches will ensure harmonious relationship between man-caused stress on soil and natural earth-potential, in compliance with soils varieties, needs of regions and the whole country, as well as goals of sustainable development thereof. The following measures are also required: acquisition substantial, trustworthy, reliable, accurate and timely information on status of soils; updating the materials on status of soil resources in Ukraine, using digital mapping and GIS-technologies; creating a National Soil-Information Center as a unified source of information on soils of Ukraine.

Thus obtained results will serve as a State-owned tool which would subsequently facilitate the use and protection of soil resources all over the country. Now major investment to Ukraine's irrigation system will be needed to let the sector fulfill its economic potential. Analysis above showed that investment along priority irrigation systems would require more than $ 3 billion, taking into account a range of measures to prevent and reduce soil degradation.

A comprehensive financing plan for the complex of measures to manage the fertility of irrigated land, improve their agro-ecological condition and level of use could include:

a) Self-funding of agricultural enterprises and associated organizations,

b) The state budget of Ukraine and local budgets at all levels,

c) Nature conservation funds at all levels,

d) Bank loans and finance lease,

e) Domestic and foreign investments and international technical support and other

f) Non-budget funds in accordance with current legislation. Investments can come from global and regional funds, common investment institutions, international financial and credit institutions and government loans from developed countries.

CONCLUSIONS

In the structure of land resources of Ukraine (one of the most agriculturally developed countries) there are significant disproportions, the deepening of which can be a threat to the environment and living environment, as well as the effectiveness of economic activity, sustainable development of the national economy.

The country is needed in change to adjust to the new market economy, rehabilitated of the irrigation sector, and improve efficiency of irrigated land. Irrigation and drainage strategy of Ukraine until 2030 can to ensure sustainable ecologically balanced development of agriculture in Ukraine by modernization, rehabilitation and expansion of irrigation systems.

A necessary condition for the sustainable use of irrigation systems is not only the improvement of the irrigation system specifications and productive functions of soils, but also the preservation and improvement of their ability to perform environmental, social functions and provide ecosystem services.

The soil cover of Ukrainian irrigated land is featured a significant dissemination of poorly productive and degraded soils: 100 thousand ha of secondary salinized soils, 700-800 thousand ha of irrigated secondary solonetzic, 60 thousand ha with alkalinization.

Monitoring of the irrigated soils fertility, directed to the formation of the models of steady, ecologically safe and economically effective agriculture is required. The authors developed the complex of measures to manage the fertility, improve their agro-ecological condition and level of use irrigated land.

Analysis showed that investment along priority irrigation systems would require more than $ 3 billion, taking into account a range of measures to prevent and reduce soil degradation.

Financing of solutions to the problem of protection of soils and increasing their fertility are proposed to be implemented at the expense of State and local budgets, innovation and investment projects, entrepreneur and private business entities and other sources allowed by the legislation.

Bearing in mind the limited financial resources in the country and considering an amount of expenses to implement these goals, the economy-experts think it important to be guided by criterion of obtaining a maximum ecological effect.

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