INNOVATIVE LAND RECLAMATION TO ENSURE EFFECTIVE LAND MANAGEMENT

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Modern agriculture requires a variety of scientific and practical approaches to the rational, environmentally friendly and efficient use of land resources. One of these techniques is direct land reclamation, which involves a set of works that include organizational, economic and technical measures aimed at radical and rapid cultivation of unproductive soils, as well as their protection from degradation caused by excessive (unacceptable) anthropogenic load and non-compliance of scientifically sound recommendations on their modes of economic turnover.

Among the various reclamation measures aimed at improving the quality of agricultural land, chemical land reclamation occupies one of the leading positions in the system of intensive agriculture [1]. Thus, chemical ameliorants include various substances or their mixtures of natural or man-made origin such as gypsum, phosphogypsum, chalk, defecation mud and rocks containing more than 10% of calcium compounds, including calcium-iron-containing sludge, which is a waste of steel-wire production.

Reclamation measures in Ukraine have a certain territorial distribution, as acidic soil solution prevails in Polissya and Forest-Steppe, and alkaline one – in Steppe. Therefore, it affects the development and carrying out of agro-ameliorative measures, organizational, technological and project bases for its implementation.

According to the X round (2011–2015) of the agrochemical survey of agricultural lands, the area of lands in Ukraine with acidic soil solution is 3621 thousand hectares or 19.1% of the total area. As for the alkaline soil medium, the total land area is 4462.3 thousand hectares or 23.9% of all lands [2, p.20].

Evaluation of the effectiveness of innovations of agro-ameliorative measures is a multidimensional vector of improving the use of land resources and it is not possible to study it only from the standpoint of one or more indicators. For this priority in our study we followed the principles of methodology for determining the economic effectiveness of the innovation that is the direct basis for operating with specific indicators of its evaluation. In general, these indicators in the field of protection and rational use of soil resources are classified according to the method of calculation, the degree of synthesis, content and source data [3, p.100]. However, this study organically combines not only the issue of economic evaluation of innovations in land reclamation, but the emphasis is mainly shifted to the environmental efficiency of their implementation on irrigated lands, ie on lands where there is a high risk of salinization.

In Ukraine, more than 80% of land areas (over 24 million hectares) are characterized by such types of water regime of arable soils, which form the dominance of scarce (or periodically scarce) moisture. At the same time, irrigation can improve the efficiency of land use, but at the same time can cause unnecessary costs and, moreover, environmental damage. For example, low hydro-buffering under conditions of high infiltration capacity of soil-subsoil leads not only to unreasonably high losses of water masses of precipitation, but also to leaching of biogenic elements from the soil root-containing nutrient medium. Therefore, scientists suggest for irrigated agriculture to adhere to such a limit that the soil moisture is constantly maintained in the range closer to the lower limit of its availability than to the upper one [4, p.38-44].

In general, the negative (dangerous) consequences of agro-ameliorative measures can be obtained on any soil with a disturbed pH balance. Thus, studies of thermodynamics of soil processes show that continuous and excessive liming of acid soils often leads to the development of dangerous phenomena in modern soil formation, which can significantly worsen the ecological state not only of the soil but also the environment medium. It is characteristic that the intensification of negative effects on the ecological state of the soil environment occurs on low-buffer acid-base balance soils. At the same time it is noted the prolonging effect of influence of ameliorant on an agroecological state, in particular aftereffect of the phenomenon (effect) of overliming of acid soils can last till 2-3 and more years [5, p.44-45].

Therefore, in order to achieve a sustainable ecological balance together with the economic efficiency of land use, it is necessary to move to innovative agro-ameliorative measures, although we do not deny the possibility of using traditional or similar technologies, which usually provide higher rates of chemical reclamation. It depends on many factors and conditions, when specific decisions are made in this matter, but any of them must meet both the urgent need and compliance with scientifically sound requirements for their implementation, and the last one must be under mandatory supervision.

On the basis of the National Scientific Center "Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky" scientists developed and and tested innovative soil reclamation technology in humid natural and climatic zones. As Yu.L. Tsapko notes, this technology is based on local soil reclamation in which reclamation is achieved not of the entire arable mass of soil (about 3000 t/ha), but only a small part of it (190-200 t/ha), as a result of which it allows saving money on soil cultivation and fertilization with ameliorants [6]. No less important is the fact that with this reclamation technology the yield of crop products remains at the level of the traditional method of applying ameliorants. A special place in innovative technology is given to the preparation of organo-mineral fertilizers.

Insufficient consideration of technologies, minimization of organic and suboptimal application of mineral fertilizers simultaneously with increasing anthropogenic load negatively affects the environmental safety of land use, causing, in particular, significant distortion of the capacity of soluble bases, variables and mobilization of nutrients in soils in Ukraine. According to scientists [7, p.39], the processes of acidification of the soil cover are observed in 15 regions and are manifested even in the agro-landscapes of the Steppe, and the intensity in increasing area of acid soils ranges from 1% to 14%.

In this context, the development of a mechanism for effective management of land degradation neutrality is relevant, ie the ability to ultimately achieve sustainable use of soil resources, in particular, due to the reasons for the violation of their acid-base balance. This is one of the key components of successful land management, as it requires solving one of the key challenges for the restoration and renaturalization of degraded and unproductive lands. [8, p.7]. We believe that the implementation of these targets is possible with the further development of innovative technologies for land reclamation, which will widely use not only improved technical methods of land application and cultivation, but also the wide application of various scientific and applied approaches to innovation in agrochemically valuable organo-mineral fertilizers on special recipes and ways of "know-how", which will include the variability of the combination of both traditional fertilizers and numerous types of waste from the mining and metallurgical complex and the chemical industry.

In addition, for high-quality preparation of fertilizers with reclamation effect, it is necessary to use beneficial microorganisms on which innovative EM-technology is based, which gave a significant impetus to further development of organic production and positively affects the reproduction of fertility of soils, which are naturally unproductive. The use of phytomelioration is no less important in regulating the reaction of the soil medium.

Given the ability of the soil to provide ecosystem services, they are better depending on the initial state and the natural supply with moisture, while irrigation impairs their importance. As a result of scientific research conducted by L.I. Vorotyntseva, it was determined that non-irrigated ordinary chernozems with good ecological and ameliorative state are characterized by a high level of ecosystem services, and irrigated ones with satisfactory and unsatisfactory state – medium and low [9]. Given that in the context of climate change and its subsequent aridization, the need for irrigated land will increase, and given the effects of irrigation and local water quality – the risk of deterioration of soil ecosystem services is high.

To improve the situation with the salinizing effect of irrigated water, it is necessary to apply ameliorants, but the application of phosphogypsum and raw gypsum have a number of disadvantages. Thus, even if they are used with the norms calculated taking into account the actual degree of salinity of the soil and at the same time the water quality, they did not completely eliminate the chemical and agrochemical degradation of soils [10]. Therefore, the study in the Northern Steppe was conducted with the analysis of options of agro-ameliorative measures on change of the content of carbonates, which is shown in Figure 1.

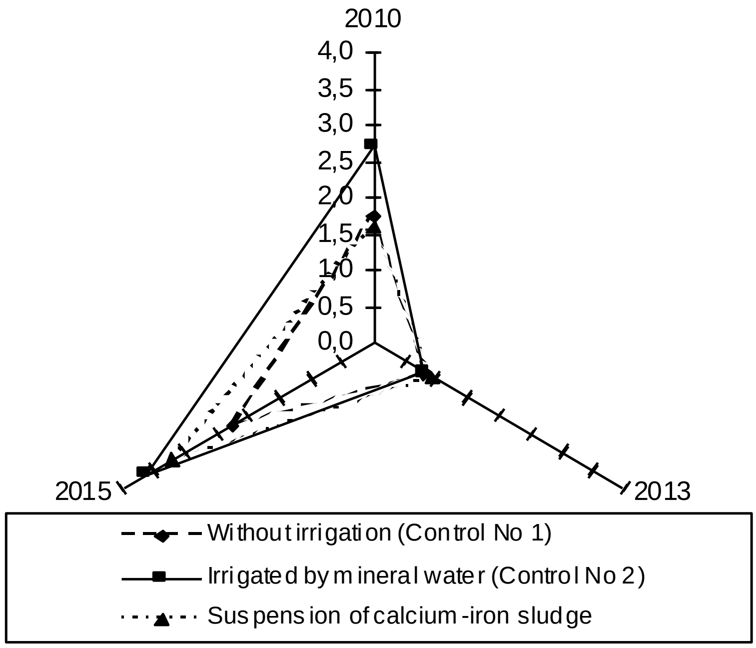

Figure 1. The average content of carbonates in the soil layer (up to 25 cm) according to the variants of experiments from agro-ameliorative measures during 2010–2015, %

In 2010, the initial content of carbonates in the soil layer to a depth of 25 cm with the variant of irrigation with mineralized water (control No. 2) significantly outweighed the value compared to control № 1 (without irrigation) and the application of calcium-iron sludge. However, in the future, as shown by soil sampling, the content of carbonates between the variants changed in favor of calcium-iron sludge, although in 2015 for the latter compared to control No. 2 their content lagged slightly, but differed sharply compared to control No. 1 (without irrigation). Therefore, it is obvious that the implementation of agro-ameliorative measures positively affected the dynamics of carbonate content in the soil, and the largest increase in the effect is observed with the application of calcium-iron sludge.

Therefore, according to L.I. Vorotyntseva an alternative to known for reducing salinity and soil pollution – ameliorants, is the use of local raw materials – calcium and iron-calcium sulfuric acid industrial waste [10]. The calculated conditional effect from soil desalination (to a depth of up to 25 cm) by types of ameliorants is given in Table 1.

Table 1. Conditional effect (income/expenses) of the change of carbonate content in the soil layer (up to 25 cm) according to the assessment of ameliorants of desalination action in 9-multicourse crop rotation depending on the variant of the experiment per 1 ha of area

Variant of experience	Ameliorant	Conditional effect on the volume of ameliorant (physical mass), t/ha	Conditional effect (income /expenses) at the cost of purchasing additional ameliorants, thousand UAH/ha	Conditional effect (income/expenses) on the purchase price and costs of applying ameliorants, thousand UAH/ha
Irrigated with mineral water (Control No. 2)	Phosphogypsum	24.2	8.2	9.3
	Calcium-iron sludge	24.5	5.2	8.0
	Chalk	15.3	7.8	8.5
	Gypsum	22.3	65.4	66.4
Suspension of calcium-iron sludge	Phosphogypsum	66.6	22.6	25.6
	Calcium-iron sludge	67.5	14.4	22.1
	Chalk	42.1	21.5	23.4
	Gypsum	61.4	180.0	182.7

The conditional effect was assessed on the basis of normative values of calcium content in terms of ameliorants, as well as in determining the absolute increase in carbonate mass in the soil by agro-ameliorative measures in comparison with the control variant No. 1 (without irrigation) during the entire crop rotation. Conditional effect, which is essentially ecological, as it improves the equilibrium reaction of the soil solution, the quality of its absorption complex due to the displacement of sodium and magnesium cations, while determining the value of this effect is based on both relative carbonate content in ameliorants and their market price with the cost of delivery and application.

In general, the application of calcium-iron sludge proves that the conditional effect from this agricultural measure significantly exceeds the variant on irrigation with mineralized water and its value is in a wide range depending on the assessed ameliorant. The assessment of the calcium-iron sludge shows that the conditional effect of soil desalination is higher both by irrigation with mineralized water – 24.5 t/ha, and by the application of calcium-iron sludge, which is 67.5 t/ha. It is clearly seen that the assessment of the conditional effect in the physical mass of the ameliorant for calcium-iron sludge is close to phosphogypsum and chalk, and most deviates from gypsum. And given the cost of these ameliorants, the difference between calcium-iron sludge and other ameliorants becomes even more significant.

However, it should be noted that at physical weight – the conditional effect was greater than with two agro-ameliorative measures for calcium-iron sludge, where after valuation the same effect became the opposite, and now calcium-iron sludge has the lowest value, which indicates more moderate economic costs compared to other types of ameliorants in case of their possible use for desalination of soil in the studied conditions. That is, the lower value of the conditional effect on calcium-iron sludge is considered not only as the revenue side, but mainly indicates the saved reclamation resource for the implementation of these two agronomic techniques in relation to the control value according to experiment No. 1 (without irrigation). Thus, the data in Table 1 show that the saved costs (income) on irrigation with mineralized water (control No. 2) compared with control No.1 (without irrigation) with ameliorant – calcium-iron sludge, is 8 thousand UAH/ha, when for gypsum – 66.4 thousand UAH/ha, and in the experiment with the application of calcium-iron sludge increase to 22.1 and 182.7 thousand UAH/ha, respectively. Therefore, the conditional effect from desalination of the soil is in a wide cost range, estimated by the cost method to restore the carbonate content specifically at soil depth up to 25 cm, depending on the choice of ameliorant.

Innovations require not only agro-ameliorative measures in agricultural production, but equally important are scientific and methodological techniques (approaches) that allow a more objective analysis to identify these changes, to give a fuller description of them. Therefore, we calculated the proportion of the conditional effect from improving the reclamation of soils with impaired alkaline reaction, taking into account the modeling of the probability of changes in crop yields and overall crop productivity by the Monte Carlo method, which is covered in detail in the scientific publication [11].

To determine the yield of crops according to the obtained moments of their distribution in time and space dynamics, as a similar experiment had four repetitions during 9 years, ie the entire crop rotation. According to the results of simulation modeling, the most probable scenario was identified, which corresponds to the subsequently calculated and adopted for the economic justification of agro-ameliorative measures the value of the average yield of crops that entered the crop rotation. This is confirmed by the statistical significance of fluctuations in the random value of yield according to the distribution quantile and the significance of the statistical estimate of the normal distribution in 95% of cases.

Only after confirming the normal distribution of the analyzed yield and the ability to achieve the most probable value, we calculated the difference between the conditional effect from land reclamation in terms of its share to the overall environmental and economic effect. The ecological effect continued to include the results according to the survey of the soil to a depth of 25 cm, which is shown in detail in Figure 2.

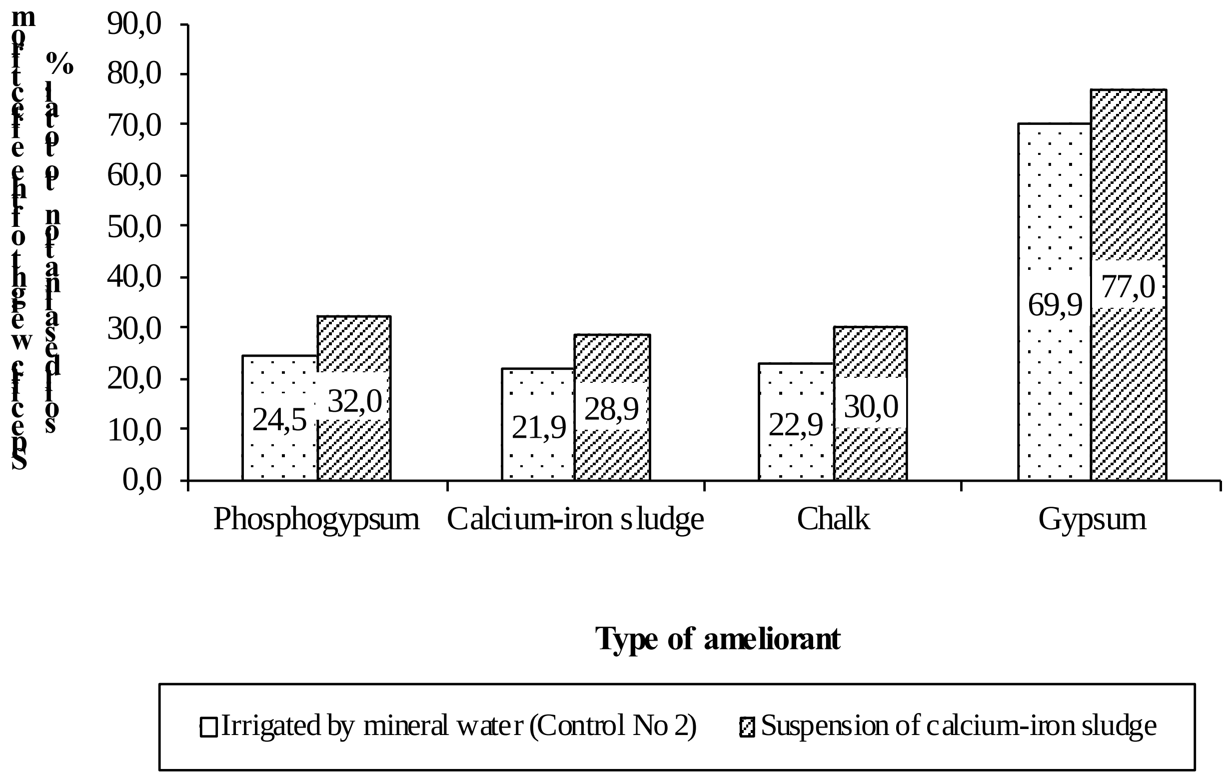

Figure 2. Specific weight of the conditional effect from soil desalination to a depth of 25 cm estimated by different ameliorants to the total value of the ecological and economic effect compared to the control No. 1 (without irrigation) with a high probability of crop yield

As shown in Figure 2, the most specific weight of the conditional effect from soil desalination (up to 25 cm deep) is characteristic of the assessment of gypsum, and the least of calcium-iron sludge. Given the positive changes in the ecological condition of soils based on irrigation with mineralized water (control No. 2) compared to the experiment without irrigation (control No. 1), however, the application of calcium-iron sludge adds a better nature of growth, as its share continues to increase, which indicates not only the quantitative but also the structural shift in the overall effect of the application of this agro-ameliorative measure. An additional increase in specific weight of the conditional effect in the overall environmental and economic effect between the application of calcium-iron sludge and control No. 2 for all ameliorants is about 7%. And the approximation is caused not so much by the physical parameters of ameliorants as their cost component due to differences in the cost of their use.

Thus, the conditional reclamation effect according to experiment No. 2 (irrigation with mineralized water) reaches the saved costs (income) estimated by calcium-iron sludge in 21.9%, and by gypsum – 69.9%, according to the experiment with calcium-iron sludge this value is respectively 28.9 and 77%. Evaluation by other ameliorants shows insignificant differences compared to calcium-iron sludge in terms of the studied agro-ameliorative measures.

The results of profitability (unprofitableness) of agro-ameliorative measures in comparison with the control No. 1 (without irrigation), which are evaluated by different types of ameliorants of desalination action are shown in Figure 3.

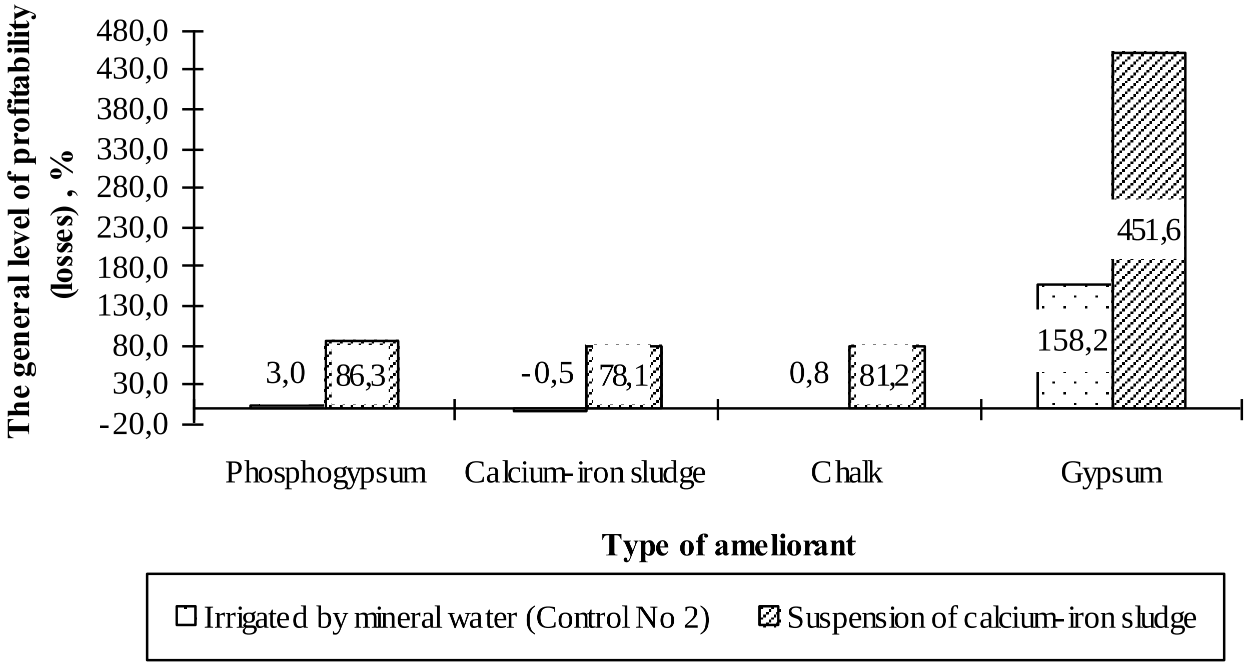

Figure 3. The level of profitability (unprofitableness) of agro-ameliorative measures assessed by the obtained ecological and economic effect compared to the control No. 1 (without irrigation) in terms of types of ameliorants with a high probability of crop yield,%

Calculations show that irrigation with mineralized water is quite expensive, and therefore, depending on the assessment of the ameliorant, its profitability is low for phosphogypsum 3%, and for chalk is 0.8%. In addition, according to calcium-iron sludge, this agricultural measure is worse than in the control No. 1, and the value of the indicator is -0.5%. The high level of this agro-ameliorative measure is achieved only by assessing the reclamation effect of gypsum, but forms an overly optimistic scenario, as there is a significant alternative choice of different ameliorants, and therefore can not indicate extremely high profitability of the measure, as the economic component remains unchanged. In the case of using calcium-iron sludge, the level of profitability is achieved by all evaluation variants of ameliorants and is significant compared to the control No. 2, and also differs positively from the control No.1. In general, the level of profitability of the use of calcium-iron sludge is 78.1% compared to control No. 1 (without irrigation), while at control No. 2 the value is negative (-0.5%). The use in the assessment of other ameliorants proves a similar environmental and economic effect, except for the variant with gypsum. For the latter, the large share is shifted to the conditional effect of desalination and / or salinization, which is caused mainly by the high cost of the ameliorant and the cost of its application, rather than significant savings due to calcium-containing compounds in its composition.

According to the results of research, innovations in land reclamation are very important for managing their sustainability of reproduction, increasing productivity and economic value. It was found that irrigation with mineralized water is an environmentally effective reclamation measure, but its economic efficiency is insufficient, as it was influenced by the quality of irrigated water. However, it is revealed that the ecological and economic efficiency of the application of calcium-iron sludge is not only the highest in comparison with lands without irrigation, but also significantly differs from the experiment of irrigation with mineralized water.

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