ПЛОДОРОДИЕ ПОЧВ

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ENVIRONMENTAL ASSESSMENT EFFECTIVENESS OF RECLAMATION MEASURES

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*Abstract:*The article discusses the results of studies of a long post-reclamation period of meadow salt marshes of the piedmont plain of the Ili Alatau.

Based on the use of balance and statistical methods of analysis and control of research and forecasts, the features of the formation of water-salt and nutritional regimes of reclaimed soils have been studied, relationships have been developed between individual amelioration indicators and factors influencing the formation of reclamation regimes of soils. Scientifically grounded assessments of the ecological efficiency of agromeliorative measures for soil formation processes are given.At present, it is advisable to ensure the conduct of continuous engineering and reclamation monitoring, i.e. a system of regular observations, assessments and forecasts of the ecological state of reclaimed lands, which ensure optimal reclamation regimes and protection of the natural environment.

Key words: saline soils, humus, fertility of reclaimed soils, complex reclamation, ecology, level of ecological sustainability, fertility models.

INTRODUCTION

Ecological functions of soils are determined by their natural (natural fertility), that is, the presence of humus reserves, since humus is the basis of all water-physical and physico-chemical properties of soils, making the soil a powerful biological barrier that regulates the relationship between biological and geological cycles and the amount of runoff from the catchment area. Over the past 40 years, the content of humus in the soils of Kazakhstan has decreased by 25-30 %, while the total damage is estimated at $ 2.5 billion. In this regard, a dynamic assessment of the humus state of reclaimed soils that are ecologically unstable due to the constant influence of natural and anthropogenic influences is relevant.

Throughout the history of the soil science development, saline soils have been one of the main objects of research in many countries of the world. Firstly, this is due to the wide spread of saline soils in different regions of the Earth; secondly, due to the fact that salinity is one of the main genetic properties and meliorative features of soils in arid and semiarid regions and also a property that limits their fertility. Finally, thirdly, salinity is one of the main signs of the unfavorable ecological condition of the soils.

Saline soils are distributed on all continents; they are found in 100 countries of the world and practically in all natural zones, but dominate in the steppes, semi-deserts and deserts. At the same time, in various regions saline soils differ significantly in their properties, genesis and, consequently, in melioration methods, which causes differences in their development, rational use and salinity control [1].

Secondary salinization of irrigated lands brings enormous damage to agriculture. The main reason for this harmful phenomenon is the lack of an engineering collector-drainage network in conditions of weak natural groundwater outflow, which lead to secondary soil salinization and deterioration. Deterioration of the water-salt and nutrient status of soil leads to decrease in the productivity of irrigated land and falling of a part of irrigated arable land out of agricultural [2-4]. Today, despite the well-studied genesis of saline soils in the southeast of Kazakhstan, the issues of improving saline soils in the sasa belt of the Ili Alatau foothill plain require further development and generation of practical experience in its implementation.

OBJECTS AND METHODS

Experimental studies were carried out at the Teskensu (Kaz.Teskensu) village in the Enbekshikazakh district (43°32' N, 77°51' E) of the Almaty region of Kazakhstan (Figure 1).

The study area is situated between 601 m elevation from sea level.

Figure 1 - Location map of the study area

The climate type of study area is “Continental Climate” which can be described as low humidity, plenty of sunlight, a short but rather cold winter. The average annual air temperature is 12.3 °C, total rainfall is 275.7 mm. The average long-term sum of precipitation for a period with temperature above 10 °C is 198-245 mm [5].

The field experiment

Between 1985 and 1989, the field experiment established by S. Kaldybayev to ameliorate with alfalfa (*Medicago sativa* L.) cultivation soils in some parts of meadow Solonchaks[5-6] (Beketova et al., 2017; Yerteyeva et al., 2018). From 1989 until 2017, alternating leguminous plants (especially leguminous vegetable and alfaalfa) were grown integrated production without other amelioration methods in bio -ameliorated meadow Solonchaks. Other parts in meadow Solonchak is virgin land.

In the key areas (under the alfalfa sowing and in the control plot for determining the Seasonal Accumulation of Salts (SAS) at a 200 m interdrain area) soil samples were taken every 20 cm to a depth of 1 m and the following was performed and determined:

1 The aqueous extract analysis -by the K.Gedroits method [7].

2 Granulometric composition - by pipetting method [7].

3 CO_2-carbonates -by volumetric method [7].

4 Total absorbed bases – by P. Grabarov method [8].

5 Totalnitrogen - byKjeldahl [8].

6 Gross phosphorus - by K. Ginzburg, G. Shchegolova[8].

7 Hydrolyzed nitrogen - by I. Turin [7].

8 Nitrates in aqueous extract from fresh soil samples -by Grandval-Liazhu and by ion-selective method [8].

9 Labile phosphorus and exchange potassium -by B. Machigin in the modification of B. Grabarov [8].

10 Bulk weight -by using cutting cylinder [7].

11 Specific weight -by V. Faintsimmer (for saline potting soils) [7].

12 Total porosity -by calculating bulk and specific weight data [7].

13 Minimumwatercapacity [7].

14 Water permeability -by flooding the natural soil using cutting cylinders [7].

15 The degree and types of soil salinization -by anionic and cationic composition [7].

16 Toxic salts -by calculation according to the methodological recommendations of N. Bazilevich and N. Pankova [1].

Accounting for the alfalfa harvest was carried out on a key site (in three replications) of 4´4 meters in size with the drying of the green mass to an air-dry state.

The field, stationary and laboratory-analytical methods were used for research.

RESULTS AND DISCUSSION

Observations of soil formation processes showed that prior to reclamation activities (1985), the initial humus content in the 0-20 cm layer was ~ 2.5 %. After major washing of saline soil (1985-1986) and subsequent 3-year cultivation of alfalfa (1986-1989), there was a slight increase in the amount of humus in most experiment points (which was 2.88%).

As a result of a long post-melioration period (2016), the humus state of the studied soils shows little signs of improvement. So in the composition of humus there was a change in the soluble part of humus, and the ratio of groups of humic and fulvic acids can be stated about some improvement in the composition of humus - it is equal to one. The humus content increased from 2.88 % to 3.08 % (0-20 cm), organic carbon increased from 1.19 % to 1.98 %, and the ratio of humic acid to fulvic acids in the 0-40 cm layer increased from 1.0-1.03 to 1.04-1.18. Comparative assessment of changes in the relative content of humus in the soils of the agricultural landscape before reclamation and after reclamation was carried out using the "soil index" method (Aidarov I. P., 2004, 2009) [9].The basis of the definition, which is based on the definition of humus reserves and composition (humic and fulvate), reserves of the main elements of mineral nutrition (nitrogen, phosphorus, potassium) and acid-base indicators (pH and hydrolytic acidity), according to the formula:

where S is an integral indicator for assessing the level of soil fertility, points;

$$S = \frac{\rho\left(G_{gn} + 0.2G_{fk}\right)}{600} + 8.5\sqrt[3]{NPR \cdot \varphi} + 5.1\exp\left[-\frac{\left|(N_g - 1)\right|}{\beta}\right], (3),$$

G_{gn}, G_{fk}andfulvate humus reserves, % or t / ha;

N, P, K - the presence of food elements (nitrogen, phosphorus, potassium), as a percentage of their maximum content in the soil;

φ-coefficient that characterizes the efficiency of fertilizers depending on the pH;

N_g-hydrolytic acidity, mg-EQ/100 g of soil;

p-coefficient, ha / t;

β-coefficient, mg-EQ/100 g of soil.

The calculations are presented in the following table №1.

Table № 1 - Assessment of changes in soil fertility

Indicators	Humus content,%			Elements of mineral nutrition			Hydrolyte acid, mg-EQ/100	Coefficients			The level of soil fertility, S	
	$G_{гн}$	$G_{фк}$	G	N	P	K	$H_г$	ρ, ha/t	β, mg-EQ/ 100	ф	mark	%
Before reclamation, (original-1985)	0,10	0,10	2,50	1,50	0,35	1,46	1,5	6,4	4	0,3	5,15	0,0

The rest of the table 1

	0,153	0,130	3,08	0,68	0,88	0,69	1	6,4	4	0,6	5,81	13
Post-melior-period (2016)	0,153	0,130	3,08	0,68	0,88	0,69	1	6,4	4	0,6	5,81	13

As can be seen from table 1, the level of soil fertility in the dynamics of 2016 has improved slightly, the growth to the original was only 13%, which is only due to the return of part of the biomass, i.e. the total fertility of the soil is low. The increase in humus content due to increasing the productivity of agricultural crops is not significant, i.e. the expanded reproduction of humus reserves, and as a result, the growth of soil fertility without the use of fertilizers is limited [10].

As shown by numerous studies, in the arid zone, the main role in the formation of soil fertility belongs to mobile nutrition elements (NPK) ~40%, the PH of the soil solution ~33%, and the humus content ~27 %. In the Russian Federation, the corresponding Method for calculating the soil fertility index is used to assess soil fertility (the order of the Ministry of agriculture of the Russian Federation dated January 11, 2013) № 5.

According to this method, the assessment of soil fertility is carried out on the basis of specific indicators of its fertility status, as the average value of the sum of the ratios of the actual four agrochemical indicators to their optimal values.When calculating using this method, the following agrochemical parameters are taken into account:soil acidity (pH, units); humus content (%); content of mobile forms of phosphorus (P_2O_5 mg/kg of soil); content of exchange potassium (K_2O mg/kg of soil).

The acidity index for alkaline soils is calculated as the ratio of the optimal value of the indicator to the actual, for acidic soils - the actual to the optimal [11].

The fertility index for a specific type of soil is calculated for alkaline soils using the formula (4), for acidic soils using the formula (5):

$$K=\left(\frac{\text{humus f.}}{\text{humus opt}}+\frac{P_2O_5f.}{P_2O_5opt.}+\frac{K_2O\ f.}{K_2O\ opt.}+\frac{pH_{(KCl)}opt.}{pH_{(KCl)}f}+\frac{pH(H2O)}{pH(H2O)}\right):4,\ (4)$$

$$K=\left(\frac{\text{humus}f.}{\text{humus opt}}+\frac{P_2O_5f.}{P_2O_5opt.}+\frac{K_2Of.}{K_2Oopt.}+\frac{pH_{(KCl)}opt.}{pH_{(KCl)}f}+\frac{pH(KCl).}{pH(KCl)}\right):4,\ (5)$$

where: - soil fertility index for each soil type;

(humus), (pH), (P_2O_5), (K_2O) - agrochemical indicators;

f - actual values of agrochemical indicators;

opt-optimal values of agrochemical indicators;

$pH_{(H2O)}$ - for alkaline soils;

$pH_{(KCl)}$ - for acidic soils.

The integral indicator of soil fertility is calculated using the formula:

$$K_i=\frac{K_{пп.1}\ x\ S_1+K_{пп.2}\ x\ S_2+\ldots+K_{пп.n}\ x\ S_n}{S_j},\ (6)$$

where K_1 the indicator of soil fertility;

K_{pp1}, K_{pp2},.... K_{ppn} - fertility index for each type of soil;

$S_1, S_2,\ldots S_n$ - sown area of agricultural crops occupied by each type of soil, ha;

S_j- total sown area of agricultural crops, ha.

Due to the fact that in our case, estimated the fertility of the reclaimed saline soils, we recommended to additionally include in the above formulas (5,6) ratio of valid values of salinity to its real rate (in%) (in this case we give a formula for the studied type of alkaline soils), i.e.:

Calculations of the dynamics of the soil fertility level using our corrected formula (7) are presented in the following

$$K_{pp} = \left(\frac{humus f.}{humus\ opt} + \frac{P_2O_5 f.}{P_2O_5 opt.} + \frac{K_2O f.}{K_2O opt.} + \frac{pH_{H_2O} opt.}{pH_{H_2O} f} + \frac{notesalting.}{fact\ salting}\right) : 5, (7)$$

table №2. As shown by analytical calculations (table 2), if the initial (natural) level of soil fertility before reclamation (1985) was not satisfactory, then after capital washing of saline soils and application of mineral fertilizers (in addition, P_2O_5 - 270 kg/ha was added before sowing), the level of fertility in relation to the original increased by 19%, and amounted to only 33% (1986) of the optimal level, i.e. it became satisfactory. After three years of cultivation of alfalfa on washed soils (1989), the level of fertility decreased sharply and reached the optimal level of -2 %, due to seasonal salinization of the soil and removal of nutrients by the crop, i.e. it became unsatisfactory. In postmilitary period (2016) had a slight increase in the level of fertility, levels of fertility to the source increased by 19% and amounted to 35% of the optimal level (the level match in 1986, after major flushing), i.e., is satisfactory, which is due only to the accumulation of plant residues in soil (table 2). Thus, it can be stated that during the post-melioration period, there was a simple reproduction of fertility, which is due to the extensive nature of agricultural production) [12].

The ecological significance of reclaimed land is determined by the formula:

where K $_{(after)}$, K $_{(before)}$ coefficients of the ecological significance of the land be-

$$K_{after} = K_{before} \frac{(c+g)_{before} y_{after}}{(c+g)_{after} y_{before}}, (8),$$

fore and after land reclamation;

$(C+g)_{before}$, $(c+g)_{after}$ - the sum of surface runoff and water exchange with ground water before and after land reclamation, mm;

U_{before} and U_{after} - crop yields before and after the reclamation of land, kg/ha.

Taking into account the fact that the studied landscape was used as a low-productive pasture before reclamation (K_{before}=0.3), then after capital washing of saline soils, introduction of the optimal reclamation mode of irrigation of washed soils, the agrolandscape can be used for high-performance fodder crop rotations. The calculated coefficient of environmental significance can be K_{after}=1.2 i.e. an increase of 4 times.

To assess the environmental sustainability of reclaimed agro-landscapes (agrocenoses) is used the coefficient of ecological stability of the natural environment, which is determined depending on patterns of usage and relative ecological importance of different agricultural land subject to geological and morphological conditions of the terrain:

$$K_{ust} = \frac{\sum_1^n f_1 K_1 K_2}{F}, (9),$$

where K_{ust} is the coefficient of ecological stability of the agricultural landscape, in fractions of one;

F_1-area of biotic and abiotic elements, %;

K_1-coefficient that characterizes the ecological significance of individual biotic and abiotic elements (0.19 for pastures and hayfields);

K_2-coefficient of geological and morphological stability of the terrain [K_2 = 0.7 for unstable terrain (Sands, slopes, landslides) and K_2 = 1.0 for stable terrain];

F - the total area of the array.

The significant levels of environmental sustainability of the agricultural landscape used in the assessment practice before and after the complex of reclamation measures of the systems are shown in the following table №3.

Table № 3 -Scale of the degree of stability of agricultural landscapes

K_{ust}	degreeofstability
≤ 0,33	unstable
0,34…0,50	lowresistance
0,51…0,66	medium-stable
0,67…1,00	stable

In accordance with the carried out expert evaluation of the coefficient of ecological stability ameliorated agrobiocenosis after reclamation amounted to K_{ust}=0,51<0,66; and belongs to the category of "medium-stable", because of the constant impact of a number of factors of influence (close occurrence of mineralized groundwater, the presence of pressure feed, saline profile of soils, significant evaporation of moisture against a high temperature regime, etc.), as a result, it is necessary to constantly maintain the optimal soil reclamation regime through the use of environmentally sound agromeliorative measures.

CONCLUSION

An assessment of the dynamics of humus content in reclaimed soils of the massif over the period under review (30 years) showed a slight increase.Since there was only a simple reproduction of the humus state of the soil (ΔG=0.5%), due only to the return of part of the biomass.The increase in humus content due to increasing the productivity of agricultural crops is not significant, i.e. the expanded reproduction of humus reserves, and as a result, the growth of soil fertility without the use of fertilizers is limited. Not a significant increase in the "soil index" indicator as a result of land reclamation activities (washing, sowing, irrigation) indicates the need to develop an additional set of measures to improve soil formation processes. The problem of extended reproduction of soil fertility should be solved exclusively from the standpoint of optimizing the water-physical, physical-chemical, agrochemical properties of the soil and regulating the biological cycle, and this is possible only when using complex reclamation. They should ensure that the disturbed balance of organic matter and chemical elements in the soil is restored to the required level.

Artificially created ecosystems (agrocenoses) are highly productive, but low - and medium - stable ecological systems that require constant purposeful influence for their maintenance, without which they cannot exist. In this regard, it is necessary to conduct continuous soil-reclamation monitoring of agrocenoses, i.e. a system of regular observations, assessments and forecasts of the quality of reclaimed soils, the quality and quantity of irrigation, drainage and ground water, as well as the technical condition of hydro-reclamation systems.

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ТҮЙІН

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МЕЛИОРАТИВТІК ШАРАЛАРДЫҢ ТИІМДІЛІГІН ЭКОЛОГИЯЛЫҚ ТҰРҒЫДАН БАҒАЛАУ

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Мақалада Іле Алатауы тау алды жазығының шалғынды сортаңдарын ұзақ мерзімді мелиорациялаудан кейінгі нәтижелері келтірілген.

Тепе-теңдік, статистикалық талдау әдістері және зерттеулер мен болжамдарды бақылауды қолдану негізінде мелиорацияланған топырақтардың су-тұз және қоректік құбылымдарының қалыптасу ерекшеліктері зерттелді, топырақтың мелиоративтік құбылымдарының қалыптасуына әсер ететін жекелеген мелиоративтік көрсеткіштер мен факторлар арасындағы тәуелділік анықталды. Топырақ түзілу процестеріне агромелиорациялық шаралардың экологиялық тиімділігіне ғылыми негізделген баға берілді. Қазіргі уақытта тұрақты инженерлік-мелиоративтік мониторинг жүргізуді қамту орынды, яғни оңтайлы мелиоративтік құбылымдарды және табиғи ортаны қорғауды қамтамасыз ететін тұрақты бақылау жүйелері, мелиорацияланған жерлердің экологиялық жағдайларын бағалау және болжау қажет.

Түйінді сөздер: тұзданған топырақтар, гумус, мелиорацияланған топырақтардың құнарлылығы, кешенді мелиорация, экология, экологиялық тұрақтылық деңгейі, құнарлылық модельдері.

РЕЗЮМЕ

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ЭКОЛОГИЧЕСКАЯ ОЦЕНКА ЭФФЕКТИВНОСТИ МЕЛИОРАТИВНЫХ МЕРОПРИЯТИЙ

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В статье представлены результаты исследований длительного постмелиоративного периода луговых солончаков предгорной равнины Илийского Алатау.

На основе применения балансовых и статистических методов анализа и контроля исследований и прогнозов изучены особенности формирования водно-солевого и питательного режимов мелиорированных почв, разработаны зависимости между отдельными мелиоративными показателями и факторами, влияющими на формирование мелиоративных режимов почв. Даны научно-обоснованные оценки экологической эффективности агромелиоративных мероприятий на процессы почвообразования.

В настоящее время целесообразно обеспечить проведение постоянного инженерно-мелиоративного мониторинга, т.е. системы регулярных наблюдений, оценок и прогнозов экологического состояния мелиорированных земель, обеспечивающих оптимальные мелиоративные режимы и охрану природной среды.

Ключевые слова: засоленные почвы, гумус, плодородие мелиорированных почв, комплексная мелиорация, экология, уровень экологической устойчивости, модели плодородия.