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Methods for estimation of the ecological-melioration sustainability of agro landscapes

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Abstract: For quantitative and qualitative estimation of ecologic and ameliorative status of irrigated lands, a technique was developed for estimation of ecologic and ameliorative sustainability of agricultural landscapes which include the following: the type and the level of soil salinization, depth of occurrence, and mineralization of ground water which are habitat forming factors of a natural system. A technique was developed for estimation of ecologic and ameliorative sustainability of agricultural landscapes which allow determining the trend and intensity of hydro-geo-chemical processes in irrigated lands.

Key words: Ecology; Melioration; Agro landscape; Techno genic loading; Environment

1. Introduction

Preservation of the ecological-melioration functions of agro landscapes in the natural-ecological system in many respects depends on the level of anthropogenic loads which are subject matter of diagnosis of environmental changes. It lies in determination of the number of factors at which the natural-ecological systems don't come out of control, and which require that nature management efficiency criteria as an activity also should be substantially expanded as compared to the estimation criterion of the ameliorative condition of the irrigated land. Here with, at the heart of agro landscape management should be the environmentally balanced and sustainable land-use management, for the purposes of which the landscape melioration approach has gained wide-spread currency.

The landscape melioration approach includes estimation of the resource and the ecological-economic balance, and also of the ecological-melioration state of the territory. From the perspective of ecological balance of its development, such integrated indicators as chemical pollution, population health, life duration and ecological state are significant. Because of that, the ecological-melioration state of agro landscapes plays no less important role in the territory's economic development and ecological sustainability of the natural ecological system than its natural resources potential.

The needs for development of amelioration of lands are determined by the public needs for agricultural products. Amelioration of lands is the sector which actively uses natural resources and influences the ecological status of the territory. The goal of amelioration is to preserve and to improve the fertility of soils in the course of rational use of land, water and other resources, and environmental management.

Deaquation and irrigation results in both constant changes in natural processes which have different directions and in periodic variation of the anthropogenic ally or naturally dependent factors.

Hydro engineering types of amelioration provide for improvement of soils, have a feature of long-lasting action and create real prerequisites for sustainable agricultural production, procurement of the planned output yields and achievement of high economic results.

Along with the positive influence of such process over the results of agricultural production, transformation of natural conditions under the influence of amelioration quite often comes amid with a number of negative occurrences. Due to that, the ecological situation in a region worsens and the efficiency of the production on ameliorated lands declines.

At present, in the field of amelioration, there is no method for estimation of ecological and ameliorative state of irrigated lands which would take into account main habitat-forming factors of landscape systems, that is, the type and the degree of soil salinization, the depth of occurrence and mineralization of underground waters in natural systems.

Finding an optimal combination of lands in the structure of natural-ecological system is a complex task, and its solution should be based on the

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quantitative description of the interrelated natural processes and anthropogenic effects, and optimized with taking into account the social-economic and environmentally friendly (nature protection) indicators.

Such aggravation of ecological problems in the recent decade requires permanent estimation of ecological and ameliorative sustainment of agro landscapes.

In such way, any environmental impact should include ecological and economic appraisal of such impact.

2. Literature review

In national and foreign literature, the following issues are discussed: general agricultural ecology (Ottaviani and Pastore, 2003), agricultural and ecological estimations (Pacini et al., 2015), estimations of ecological and geochemical sustainability of agro landscapes (Bechini et al., 2011), the tolerance of soils to technogenic impacts (Fengyun et al., 2006; Maas, 1977), the features of amelioration of lands in different territories (Richards, 1954), estimations of the land-polluting factors (Leenaers et al., 1990), estimations of salinity of soils (Child, 1975), estimations of the quality of the ground water (Hoorn, 1958), the impact of salinized soils on agricultural plants (Hopcins, 1950), the role of forest-protecting belts, of hydro technical facilities and of other natural barriers in maintaining the stability of agricultural landscape (Barrett, Peles, 1994; Rakov et al., 2009), modeling dynamic processes in agro landscapes (Smits, 2000), optimization of impact on agro landscapes (Merante et al., 2015), and many other.

Leading scientists of agronomy, applied soil science and geology study the impact of natural factors on soil salinity in dependence from the relief, the depth of occurrence of ground water, and the lithological structure of the composition of soils.

Present-day science actively studies the field of hydro engineering modeling, because the analysis and forecasting of the variation of the level of occurrence of ground waters has a great significance. A method for forecasting of the variation of the level of occurrence of ground waters in natural conditions and in irrigated areas has been developed; a graphic technique is used for analysis and forecasting the natural conditions of ground waters and of the ground water level under the impact of hydro engineering facilities; there are methods for calculation of steady-state filtration and forecasts of the ground water dam in the areas of hydro engineering facilities and in irrigated territories; the methods for evaluation of useful groundwater supply are developed. A method for integral estimations has been developed, which reflects the quantitative assessment of the risk of under flood and risk scales, functions of benefits and losses which are the basis for ecologic and economic analysis in situations of decision-making in respect of use of under water conditions and irrigation rates. A method is used for modeling ground water levels with application of the hydro dynamic calculation formulas.

Partially different points of view on the estimation of ecologic and amelioration sustainability of agro landscapes are found in two thesis researches: improvement of ecologic sustainability of agro landscapes with the help of integrated irrigation (Cass, 1982; Feeds, 1978), and ecologic estimation of the physical state of salinized soils (Chhabra, 2005).

In her thesis, I. V. Belova suggested a model for forming environmentally sustainable and productive agricultural landscape (Belova, 2005). An adequate set of amelioration impacts was modeled, which provides for intensification of agricultural production and a sustainable functioning of the agricultural geologic system. The scientist suggested a technique for carrying out scenario research for evaluation of productivity and ecologic sustainability of agricultural landscape. In result of scenario research, an acceptable variant of development and allocation of amelioration measures and the scope of amelioration works are opted.

A. A. Starodubov brings up the concern of secondary salinization, pollution of soils under the anthropologic impact. In his thesis, the estimation of degradation and desertification of soils is discussed (Starodubov, 2010).

The use of the Pegov-Khomyakov model for estimation of the productivity of ameliorated agricultural landscape as an integral indicator of the state of the agricultural geo system should be mentioned separately. It uses the agricultural amelioration properties of soil (content, elements) and climatic parameters (temperature and humidity). The use thereof makes possible forecasts and estimations under the impact of anthropogenic or natural factors (Ivanov et al., 2013).

At the same time, there are no omnibus researches related to estimation of ecologic and amelioration sustainability of agrolandscapes.

3. Material studied, methods, techniques

The methods of ecological-melioration stability estimation of the agro landscapes were developed, which allow determination of the direction and intensity of hydro chemical processes in the irrigated lands on the basis of qualitative and quantitative integral criteria.

System analysis and generalizations in development of the methods for estimation of ecologic and amelioration state of irrigated lands in neighboring countries and beyond have shown that they are represented at the level of monitoring (Smits, 2000;) which require a flexible method for a multi-dimensional estimation which cover the habitat-forming factors of salinized irrigated lands.

As a first approximation we can use such generalized indicators as the coefficient of ecological stability or techno-natural and quasi-natural system stability by V.A. Baranov (Baranov, 2004) and the level of ecological-geo-chemical stability by M.A. Glazovskii (Glazovskii, 1997). At that, the coefficient of ecological sustainability (stability) (C_{es}), taking into account the structure of biotic and abiotic elements of the landscapes and their ecological significance, is determined according to the formula:

$$C_{es} = (1/F)(\sum_{i=1}^{n} f_i \cdot c_1 \cdot c_2),$$

where F - the area of natural and techno-natural systems (water drainage system); f_i - area of i -th land; C_1 - stability coefficient for the broad-leaved forests – 1.0; swamps, water flows and water reservoirs – 0.79; mixed forest – 0.63; meadows – 0.62; gardens, forest cultures, woodland belts – 0.43; coniferous forests – 0.38; arable lands averagely – 0.14; urbanized territories (inhabited localities, industrial areas and etc.) sharply reduce the ecological stability of the water drainage system, so for them the coefficient of stability is taken as the negative one and approximately equal to -1 (Aidarov, 2004); C_2 - coefficient that takes into account the geological-morphological relief stability, depends on the area of ravines, steep slopes, landslides, unfixed sands and etc., it changes from 1.0 for the stable relief up to 0.70 – for non-stable one.

The stability of the natural and the techno-natural system is estimated according to the following scale (Golovanov et al., 2006):

C_{es} <0.33 – stability is very low; C_{es} = 0.34-0.50 – low; C_{es} = 0.51-0.66 – average; C_{es} = 0.67-1.00 – high.

For estimation of the ecological-melioration stability (C_{elds}) of agro landscapes we developed the dependence on the basis of methods of M.A. Glazovskii (Golovanov et al., 2006):

$$C_{elds} = (\sum_{i=1}^{n} f_i \cdot c_s \cdot c_m \cdot c_d),$$

where f_i - area of i -th elements of agro landscapes (the degree of salinization, depth level, and mineralization of ground waters) which are their parts, i.e. $f_i = F_i / F_0$, where F_i - area of i -th elements of agro landscapes, ha; F_0 - total area of agro landscapes; c_s - coefficient that takes into account the ecological significance of saline lands; c_d - coefficient that takes into account the ecological significance of the depth level of ground waters; C_m - coefficient that takes into account the ecological significance of the ground water mineralization. For implementation of such approach it is necessary to perform grouping of the irrigated lands taking into account the biological productivity, which substantially differ in terms of the effective fertility, i.e. it is possible to divide them into three categories with taking into account their qualitative state (Mustafaev, 2004):

- Easily accessible resources of natural systems (F_e) – high-productive (profitable) agro landscapes, which do not require complex hydro-melioration measures for regulation of the basic factors of soil and plant life in accordance with their evolutionary requirements;

- Averagely accessible resources of natural systems (F_a) – with accessible productivity, requiring hydro-melioration measures for regulation of the basic factors of soil and plant life in accordance with their evolutionary requirements;

- Heavily accessible resources of the natural systems (F_h) – low-productive (ineffective under irrigation), which require complex hydro-melioration measures for regulation of the basic factors of soil and plant life in accordance with their evolutionary requirements.

Depending from the level of economic-ecological efficiency of usage of the water-land resources it is possible to estimate the economic and ecological stability of the development, location of the productive forces and capacities of the natural-techno genic system of water-economic zones of the river basins or agro climatic zones corresponding to them:

$$F = F_e + F_a + F_h;$$

$$F_e / F + F_a / F + F_h / F = \alpha_e + \alpha_a + \alpha_h = 1,$$

where α_e, α_a, α_h – the share of participation of easily-, averagely- and heavily accessible resources of agro landscape systems.

At that, the coefficient of economic stability of the natural system of river basins depends on the area of irrigated lands (F_i) and their qualitative (α_i), ecological productivity of agro landscapes ($\overline{y}_i$) and qualitative state of the river waters ($\overline{C}_o = C_o / C_{add}$), i.e. it is a function $C_{es} = \int (F_i, \alpha_i, \overline{y}_i, \overline{C}_i)$.

For estimation of the total (generalized) effect of the above-mentioned factors of environmental pollution of agro landscapes and ecological-melioration of stability (C_{elds}) it is appropriate to use geometric mean values of their indices:

$$C_{elds} = \alpha_e \cdot C_h \cdot \overline{y}_e + \alpha_a \cdot C_h \cdot \overline{y}_a + \alpha_h \cdot C_h \cdot \overline{y}_h,$$

where $\overline{y}_e$, $\overline{y}_a$, $\overline{y}_h$ - productivity of easily-, averagely- and heavily accessible agro landscapes.

For estimation of the degree of environmental threat of agro landscape we developed a mathematical model which takes into account the tolerance of the natural system and has the following form: $C_{ed} = C_{es} [1 - \exp(- C_{elds}]$, where C_{ed} - the integral indicators of the ecological danger degree of agro landscapes; C_{es} - maximally possible ecological-melioration stability of landscapes.

For determination of the qualitative value of significance of the separate elements of agro landscapes, i.e. parameters c_s, c_m and c_d, the materials characterizing the dependence of the harvest of agricultural plants from the degree of soil salinization, the depth level of ground waters and their mineralization, i.e. $c_s = f(S, y)$, $c_m = f(C_d, y)$ and $c_d = f(\Delta, y)$, were used (Table 1).

Table 1: Coefficient of relative ecological significance of separate elements of agro landscapes (Adaptive-landscape meliorations of the lands in Kazakhstan, 2012)

Elements of agro landscapes					
Soil Salinization Degree	c_s	Ground Waters			
		depth level	c_d	mineralization	c_m
Non-saline	1.00	<1.00	0.85	<1.00	1.00
				1.00-3.00	0.75
				3.00-5.00	0.50
				5.00-10.00	0.35
				<10.00	0.25
Low	0.85	1.00-2.00	1.00	<1.00	1.00
				1.00-3.00	0.85
				3.00-5.00	0.65
				5.00-10.00	0.55
				<10.00	0.35
Mild	0.65	2.00-3.00	1.00	<1.00	1.00
				1.00-3.00	0.95
				3.00-5.00	0.75
				5.00-10.00	0.65
				<10.00	0.40
High	0.35	3.00-5.00	1.00	<1.00	1.00
				1.00-3.00	0.97
				3.00-5.00	0.85
				5.00-10.00	0.75
				<10.00	0.70
		<5.00	1.00	<1.00	1.00
				1.00-3.00	1.00
				3.00-5.00	0.95
				5.00-10.00	0.93
				<10.00	0.90

Generally, the product of the significance coefficient c_d and c_m can be designated as a coefficient of hydro chemical significance of agro land scapes c_{hch}, i.e. $c_{hch} = c_d \cdot c_m$.

However, it can be used when the area of deposition depth of ground waters and mineralization will be equal, but as in the nature such hydro-chemical conditions state is not found, then it will be the most reliable to represent it in the following form: $c_{hch} = c_d \cdot f_d + c_m \cdot f_m$, where f_d - relative area of agro landscapes on the level of deposition depth of ground waters; f_m - relative area of agro landscapes on mineralization of ground waters.

4. Results of study

For carrying out a demonstrative calculation, the materials of the melioration cadaster, prepared by hydro geologic-melioration expedition of the Committee for Water Resources of the Ministry of Agriculture of Kazakhstan Republic (Tables 2-4), including the soil salting degree, depth of ground water deposition and their mineralization, were used.

Table 2: Dynamics of the melioration state of the irrigated agro landscapes of Zhambylsk region (ths. ha)

Soil Salinization Degree	Years					
	1960	1970	1980	1990	2000	2010
Non-saline	181.0	160.9	180.7	170.0	115.8	133.4
Sub-saline	63.8	36.9	46.3	41.4	31.5	66.8
Averagely-saline	16.0	11.5	18.0	14.9	9.2	17.3
Heavily-saline	14.2	15.7	19.5	18.7	4.4	9.0
Total	275.0	225.0	264.5	245.0	160.9	226.3

Table 3: Dynamics of the melioration state of the irrigated agro landscapes of Zhambylsk region (ths. ha)

Depth of ground water level (GWL)	Years					
	1960	1970	1980	1990	2000	2010

GWL > 5.0 m	184.0	155.3	176.3	158.3	101.9	147.8
GWL - 3.0-5.0 m	55.5	40.3	52.2	48.9	24.7	46.8
GWL - 2.0-3.0 m	129.2	132.4	229.3	257.3	240.0	242.3
GWL < 2.0 m	10.4	9.3	9.8	15.0	5.3	14.5
Total	275.0	225.0	264.5	245.0	160.9	226.3

Table 4: Dynamics of the hydro chemical regime of irrigated agro landscapes of Zhambylsk region (ths. ha)

Mineralization of GW	Years					
	1960	1970	1980	1990	2000	2010
1	2	3	4	5	6	7
C_d > 3.0 g/l	19.0	13.3	18.5	18.9	10.9	11.0
C_d =2.0-3.0 g/l	53.4	44.8	59.0	50.7	34.6	32.2
C_d =1.0-2.0 g/l	100.9	80.8	98.6	93.6	61.0	59.0
C_d <1.0 g/l	101.7	111.0	88.4	81.8	54.4	50.6
Totally	275.0	225.0	264.5	245.0	160.9	152.8

Based on this information support in respect of hydro chemical soil state and using the methodological support for estimation of the ecological-melioration stability of agro landscapes, we carried out a prediction calculation for determination of the ecological significance of separate elements of agro landscapes (Table 5) and ecological-melioration stability of water-economic Kazakhstan basins (Table 6).

Table 5: Determination of the significance of separate elements of agro landscapes of Zhambylsk region

Soil Salinization Degree	Indicators	Years					
		1960	1970	1980	1990	2000	2010
1	2	3	4	5	6	7	8
Non-saline	f_d	0.669	0.690	0.667	0.645	0.718	0.653
	c_d	1.00	1.00	1.00	1.00	1.00	1.00
	$c_d \cdot f_d$	0.669	0.690	0.667	0.645	0.718	0.653
	f_m	0.069	0.059	0.070	0.077	0.068	0.072
	c_m	0.95	0.95	0.95	0.95	0.95	0.95
	$c_m \cdot f_m$	0.066	0.056	0.067	0.073	0.065	0.068
	c_{hch}	0.734	0.746	0.733	0.718	0.782	0.721
Sub-saline	f_d	0.202	0.179	0.197	0.200	0.173	0.207
	c_d	0.85	0.85	0.85	0.85	0.85	0.85
	$c_d \cdot f_d$	0.172	0.152	0.167	0.170	0.147	0.176
	f_m	0.194	0.199	0.223	0.207	0.215	0.211
	c_m	0.85	0.85	0.85	0.85	0.85	0.85
	$c_m \cdot f_m$	0.165	0.169	0.189	0.176	0.183	0.179
	c_{hch}	0.337	0.321	0.356	0.346	0.330	0.355
Averagely-saline	f_d	0.087	0.089	0.099	0.082	0.071	0.076
	c_d	0.75	0.75	0.75	0.75	0.75	0.75
	$c_d \cdot f_d$	0.065	0.067	0.074	0.062	0.053	0.057
	f_m	0.367	0.359	0.373	0.382	0.379	0.386
	c_m	0.75	0.75	0.75	0.75	0.75	0.75
	$c_m \cdot f_m$	0.275	0.269	0.280	0.287	0.284	0.290
	c_{hch}	0.340	0.336	0.354	0.349	0.337	0.347

Heavily-saline	f_d	0.042	0.042	0.037	0.077	0.038	0.064
	c_d	0.35	0.35	0.35	0.35	0.35	0.35
	$c_d \cdot f_d$	0.015	0.015	0.013	0.027	0.013	0.022
	f_m	0.370	0.383	0.334	0.334	0.338	0.331
	c_m	0.85	0.85	0.85	0.85	0.85	0.85
	$c_m \cdot f_m$	0.314	0.325	0.284	0.284	0.287	0.281
	c_{hch}	0.329	0.340	0.297	0.311	0.300	0.303

Table 6: Ecological-melioration stability of Kazakhstan agro landscapes

Soil Salinization Degree	Indicators	Years					
		1960	1970	1980	1990	2000	2010
1	2	3	4	5	6	7	8
Non-saline	f_i	0.658	0.715	0.683	0.698	0.720	0.589
	c_s	1.00	1.00	1.00	1.00	1.00	1.00
	$f_i \cdot c_s$	0.658	0.715	0.683	0.698	0.720	0.589
	c_{hch}	0.734	0.746	0.733	0.718	0.782	0.721
	C_{esi}	1.392	1.461	1.416	1.416	1.502	1.310
Sub-saline	f_i	0.232	0.164	0.175	0.169	0.196	0.295
	c_s	0.85	0.85	0.85	0.85	0.85	0.85
	$f_i \cdot c_s$	0.197	0.139	0.149	0.144	0.167	0.251
	c_{hch}	0.337	0.321	0.356	0.346	0.330	0.355
	C_{esi}	0.534	0.460	0.505	0.486	0.497	0.606
Averagely-saline	f_i	0.058	0.051	0.068	0.061	0.057	0.076
	c_s	0.65	0.65	0.65	0.65	0.65	0.65
	$f_i \cdot c_s$	0.038	0.033	0.044	0.040	0.037	0.049
	c_{hch}	0.340	0.336	0.354	0.349	0.337	0.347
	C_{esi}	0.378	0.369	0.398	0.389	0.374	0.396
Heavily-saline	f_i	0.052	0.070	0.074	0.072	0.027	0.040
	c_s	0.35	0.35	0.35	0.35	0.35	0.35
	$f_i \cdot c_s$	0.018	0.025	0.026	0.025	0.009	0.014
	c_{hch}	0.329	0.340	0.297	0.311	0.300	0.303
	C_{esi}	0.347	0.365	0.323	0.336	0.309	0.317
C_{elds}		0.662	0.663	0.660	0.657	0.670	0.657
C_{ed}		0.461	0.461	0.459	0.458	0.464	0.458

As it is can be seen from Tables 5-6, the prediction calculation of ecological-melioration stability of the irrigated lands of Zhambylsk region showed that it was relatively low, as in the result of violation of the natural geological water and chemical substance circulation, deep changes of hydro chemical region regime took place, as in these regions the coefficient C_{elds} = 0.657-670, i.e. the ecological-melioration stability of the irrigated lands, is relatively low.

In many respects this owes to reclamation of saline lands, i.e. in result of leaching saline lands their soil-melioration state didn't improve, on the contrary, they even contributed to worsening of the soil-melioration state of the earlier existed highly productive irrigated lands of the region.

As a result, agro landscape systems which are unsafe and dangerous in terms of ecology appeared in Zhambylsk region, which require the full reconstruction of the water economic systems of the region.

5. Discussion

The issue of an integrated assessment of ecologic and amelioration sustainability of agricultural landscape at the present stage is still not paid a due attention to. While the very justification of the economic feasibility and of ecologic reliability is a necessary precondition for correction of the state of irrigated land in the-time scale.

The impact of human economic activity on ground waters leads to the necessity to consider complex computational models, and because of that analytical methods of computation are used, methods of mathematic modeling. Express methods and models for forecasting the estimation of soil salinization for the purposes of ecologic monitoring are being developed. A number of researches in the field of environmental regulation of irrigation have been undertaken on the basis of modeling the state of soil fertility. There is a method determining the extent of restrictions on irrigation rates depending on physical mechanical parameters of soils and on agricultural technologies.

In such way, as of today, the scientific challenge of estimation of ecologic irrigation sustainability of agricultural landscape and of the environmental of amelioration measures still remains under discussions and scientific researches, and because no single approach has been opted. That is why there is a need and practicability of use and development of existing evaluation methods, and of development of new methods.

6. Conclusions

In such way, the developed method of estimation of ecologic amelioration sustainability of agro landscapes in the conditions of anthropogenic activities allow to forecast the dynamics and trends of natural processes, the degree of the sustainability and the stability thereof, which allows to monitor the state of irrigated lands at the space-time scale. Herewith, main functions of the agricultural landscape – the systematicity, the ability to create, and efficiency, which provide for sustainable and stable functioning of the natural system – are the most important elements determining the particulars of differentiation of crop farming in accordance with the hierarchy of landscapes, which may be used in all geographic zones, as the instrument making it possible to forecast the role of habitat-forming factors of ecologic and amelioration state of irrigated lands.

At present, there is a need for creation of a new fundamental scientific field with relevant set of methods and approaches in the domain of agro landscapes, for forecasting of the processes of moisture and salt transfer, of water regime, air and heat conditions, which allows, along with the estimation of the state, to forecast the further evolution of the sustainability of agro landscapes.

Further researches will be aimed at creation of a software package for estimation of the ecologic amelioration sustainability of agro landscapes on the basis of modeling the method of salinization of soils and ground waters. The software package will allow automating the processes of input data processing and of carrying out necessary computations, and of generation of electronic maps. The result will be a model and forecast of augmentation of agricultural landscape's natural resources' potential for improvement of the state of agricultural lands by way of enhancement of the environmental sustainability and productivity with the help of a set of amelioration measures. The suggestions will be aimed at multifaceted ameliorations which include carrying out drainage, agricultural engineering and land clearing amelioration operations.

References

Aidarov, I. P. Prospects of the development of complex meliorations in Russia. 2004. Moscow, Russia: Nauka.

Baranov, V.A. Agroecology: Methods, Technology, Economy. 2004. Moscow, Russia: Nauka.

Barrett, G., Peles, J. Optimizing habitat fragmentation: an agrolandscape perspective. Elsevier Landscape and Urban Planning, 1994, 28 (1), 99-105.

Bechini, L., Castoldi, N., Stein, A. Sensitivity to information upscaling of agro-ecological assessments: Application to soil organic carbon management. Agricultural Systems, 2011, 104 (6), 480-490.

Belova, I. V. Environmental sustainability of agricultural landscapes by complex melioration. 2005. Moscow, Russia: Nauka.

Cass, A. Soil pore structural stability and irrigation water quality. Soil Science Society of America Journal, 1982, 46, 517-530.

Chhabra, R. Classification of salt-affected soils. Arid Land Research and Management, 2005, 19 (1), 61-79.

Child, S. W. Model of soil salinity effects on crop growth. Soil Science Society of America Journal, 1975, 39, 617-622.

Feeds, R. A. Simulation of field water use and crop yield. Simulation Monographs. 1978. Wageningen, Netherlands: Pudos.

Fengyun, M., Xinrong, Li., Jingguang, Z., Aixia, Li. Yingyong shenglai xuebao. Chinese Journal of Applied Ecology, 2006, 17 (5), 789-795.

Glazovskii, M. A. Methodological bases of estimation of ecological-geochemical soil stability to technogenic effects. 1997. Moscow, Russia: Nauka.

Golovanov, A. I., Sukharev, Y. I., Shabanov, V. V. Complex territorial arrangement – further stage of land melioration. Melioration and Water Economy, 2006, 23, 25-31.

Hoorn, J.W. Results of ground water level experimental field with arable crops on clay soil. Netherlands Journal of Agricultural Science, 1958, 6, 85-94.

Hopcins, H. T. Growth and nutrient accumulation as controlled by oxygen supply to plant roots. Plant Physiology, 1950, 25, 64-81.

Ivanov, D. A., Tyulin, V. A., Karaseva, O. V., Rublyuk M. V. Features of studying of dynamic processes in agrolandscape. Russian Agricultural Sciences, 2013, 39 (3), 254-267.

Leenaers, H., Qkx, J., Boumough, P. Comparison of spatial prediction methods for mapping floodplain soil pollution. 1990. Catena.

Maas, E. V. Crop salt tolerance current assessment. Journal of the Irrigation and Drainage Division, 1977, 103, 115-134.

Merante, P., Van Passel, S., Pacini C. Using agro-environmental models to design a sustainable benchmark for the sustainable value method. Agricultural Systems, 2015, 136, 1-13.

Mustafaev, Zh. S. Methodological and ecological principles of melioration of the agricultural lands. 2004. Taraz, Kazakhstan: Asaba.

Mustafaev, Zh. S., Ryabtsev, A. D. Adaptive-landscape meliorations of the lands in Kazakhstan. 2012. Taraz, Kazakhstan: Oktam.

Ottaviani, Li., Pastore, Ji. A multidimensional approach to understanding agro-ecosystems. Agricultural Systems, 2003, 76 (1), 207-225.

Pacini, G. C., Merante, P., Lazzerini, G., Van Passel, S. Increasing the cost-effectiveness of EU agri-environment policy measures through evaluation of farm and field-level environmental and economic performance. Agricultural Systems, 2015, 136, 70-78.

Rakov, A. Yu., Tsygankov, A. S., Sirota, M. A. Agrolandscape role of herbaceous communities, windbreaks, hydraulic structures, and other natural barriers. Russian Agricultural Sciences, 2009, 35 (2), 100-102.

Richards, L. A. Diagnosis and improvement of saline and alkali soils. Agriculture Handbook, 1954, 60, 143-160.

Smits, S. J. Modelling Irrigation Water Distribuion in a GIS Environment. 2000. Wageningen, Netherlands: Wageningen Academic Publishers

Starodubov, A. A. Environmental assessment of the physical condition of saline soils. 2010. Astrakhan, Russia: Logos.

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