World Applied Sciences Journal 29 (1): 110-116, 2014
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2014.29.01.13832

Methodological Bases of Agricultural Landscapes Technogenic Disturbances Assessment

Zh. S. Mustafayev, A.T. Kozykeeva and Zh.E. Eskermesov

Department of Melioration and Agronomy,
Faculty of Water Resources, Environment and Construction,
Taraz State University Named after M.Kh. Dulaty, Taraz, Kazakhstan

Abstract: The proposed system and selected integral criteria for evaluating the level of agricultural landscapes anthropogenic loads and environmental reclamation sustainability on the basis of the basin principle to support a set of priority actions for the development of the environmental regulation system to use water and land resources on the maximum permissible level.

Key words: Nature · A system · Natural technogenic system · Stability · A model · Evaluation · Ecology · Land reclamation · Basin · Agricultural landscape and landscape

INTRODUCTION

Anthropogenic loads on the catchment basin is an immediate cause of anthropogenic changes in the landscapes condition, it is reflected in the agricultural landscapes environmental- reclamation condition indicators changes, associated with the changes in the water bodies hydrological and hydro-geochemical regimes. To form a holistic understanding of anthropogenic impact on the agricultural landscapes and, in particular, the analysis of the spatial distribution of the anthropogenic loads level and assessment of environmental and reclamation sustainability there is required a multidisciplinary approach based on the basin principle of environmental regulation of agricultural landscapes systems anthropogenic loads. As the experience of the use of natural resources in the river basin, there is a close relationship between the loads on the reservoir territory and those indicators that define agricultural landscapes ecological - reclamation condition.

The aim of the research is the complex assessment of the level of agricultural landscapes technogenic loads and environmental reclamation sustainability, as the elements of natural and anthropogenic object, on the basin principle.

MATERIALS AND METHODS

Initial data for studies was the information of the public institution of South Kazakhstan hydro-geological reclamation expedition of the Republic of Kazakhstan Ministry of Agriculture controlling the irrigated lands reclamation condition in the lower reaches of the Syrdarya River Basin (Table 1-3).

Agricultural Landscapes Technogenic Disturbances and Stability Complex Assessment Modeling: The development basis of landscapes sustainability assessment methodology are the ideas and methods of geo-systematic approach allowing to describe, organize and understand the totality of natural processes taking into consideration the particular economic activity. Thus the economic activity aims at ensuring of renewable natural resources reproduction and, first of all, natural soil fertility preservation, biodiversity and biota productivity, which are the basis of the natural landscapes existence and sustainable and cost-effective agricultural landscapes creation.

Currently heterogeneous indicators equivalent matching methods are used to assess the design decisions technical level in reclamation science [1, 2]. Therefore, to assess the level of agricultural landscapes

Corresponding Author: Zh. S. Mustafayev, Department of Melioration and Agronomy, Faculty of Water Resources, Environment and Construction, Taraz State University Named after M.Kh. Dulaty, Taraz, Kazakhstan.

Table 1: Dynamics of the irrigated agricultural landscapes reclamation condition in the lower reaches of the Syrdarya River Basin

		Years					
Extent of the soil salinization	Indicators	1960	1970	1980	1990	2000	2010
Not saline	Thousands	66.4	60.5	52.3	36.6	32.2	18.1
	%	26.3	23.9	20.6	14.3	12.5	11.6
Slightly saline	Thousands	50.9	51.1	54.2	60.2	65.1	41.9
	%	20.1	20.2	21.3	23.5	25.3	26.2
Medium saline	Thousands	28.5	41.4	43.9	61.9	61.8	41.4
	%	11.3	16.3	17.3	24.1	24.0	25.9
Strongly saline	Thousands	106.6	100.3	103.8	97.7	98.7	58.6
	%	42.3	39.6	40.8	38.1	38.2	36.6
Total	Thousands	252.4	253.3	254.2	256.4	257.8	160.0

Table 2: Dynamics of the hydro-geological regime of the irrigated agricultural landscapes in the lower reaches of the Syrdarya River Basin

		Years					
Ground water level depth (GWL)	Indicators	1960	1970	1980	1990	2000	2010
GWL > 5.0 M	Thousands	124.2	113.3	99.4	62.3	64.7	21.1
	%	49.2	44.7	39.1	24.3	25.1	13.2
GWL -3.0-5.0 M	Thousands	43.3	45.9	44.7	50.9	53.1	39.5
	%	17.2	18.1	17.6	19.9	20.6	24.7
GWL -2.0-3.0 M	Thousands	56.3	40.1	54.4	50.7	54.6	37.0
	%	22.3	15.8	21.4	19.8	21.2	23.1
GWL < 2.0 M	Thousands	28.6	54.4	55.7	92.5	85.4	62.4
	%	11.3	21.4	21.9	36.4	33.1	39.0
Total	Thousands	252.4	253.3	254.2	256.4	257.8	160.0

Table 3: Dynamics of the hydro-geochemical regime of the irrigated agricultural landscapes in the lower reaches of the Syrdarya River Basin

		Years					
Ground water mineralization	Indicators	1960	1970	1980	1990	2000	2010
Cg> 3.0 g/l	Thousands	155.8	161.3	168.7	187.1	194.8	93.1
	%	46.9	48.5	50.7	56.3	58.6	58.2
Cg=2.0-3.0 g/l	Thousands	62.2	64.9	67.6	69.9	76.3	37.0
	%	18.7	19.5	20.3	21.0	22.9	23.1
Cg=1.0-2.0 g/l	Thousands	55.6	53.3	50.2	39.4	35.2	19.8
	%	16.7	16.0	15.1	11.8	10.6	12.4
Cg <1.0 g/l	Thousands	58.9	53.1	46.0	36.1	26.3	10.1
	%	17.7	16.0	13.9	10.9	7.9	6.3
Total	Thousands	332.5	332.6	332.5	332.5	332.6	160.0

technogenic disturbances, one can use the indicators characterizing the ratio of the use of natural resources and changes in their components in the environmental management system [3]:

- At agro-technical territory development: $K_f = F_i / F$, where F_i- the area of the mastered territory, ha; F- the area of the natural and semi-natural ecosystems, ha;
- At agricultural lands reclamation: $K_o = (O_p^a - O_p^e) / O_p^e$, where ?q? - actual irrigating norm or specific water intake, m^3/ha; O_p^a- soil and ecological admissible irrigation norm, providing an optimum ratio of heat and moisture in definite natural climatic zones, m^3/ha;
- at the use of water resources: $K_b = (Q_b - Q_c - Q_p) / Q$, where Q_b- river basin water resources at disposal, km^3 or m^3/s; Q_c- sanitary release, providing ecological sustainability in the lower reaches of the river basins, km^3 or m^3/s; Q_p- water intake volume for the need of industrial enterprises and agricultural organizations, km^3 or m^3/s;

- At the assessment of changes in hydro-chemical water regime: $K_c = (C_i - C_e)/C$, where C_e- natural mineralization of river water before anthropogenic human activity, g/l; C_i- river water mineralization, in the process of anthropogenic human activity, g/l.
- When dumping returnable waters into the water source: $K_d = (Q_{dp}/Q_d)$, where *Qdp*- collector- drainage and sewage water, km^3 or m^3/s.
- At the assessment of the irrigated lands hydro-chemical regime: $K_s = F_s/F_i$, where F_s- the area of unproductive saline lands, ha.

The indicator of the natural resources usage rate, gives, to a certain degree, the opportunity to determine the level of change in the natural system, then the approximate values of the coefficient characterizing the level of agricultural landscapes disturbances is possible to determine by the formula:

$$K_t = \sum_{i=1}^{n} K_i / n,$$

where *n*- quantity of natural system components, adopted for determining the level of natural systems technogenic disturbances.

To assess the level of the natural system technogenic disturbances, one can use the composite index *ktd*, determined by the formula [4]:

$$K_{td} = 1 - \sqrt{\prod_{i=1_i}^{n} K_i^i}$$

where $K_i^i = \exp(-K_i)$ - relative values of the level of natural object technogenic disturbances [5].

To assess the system dynamics, characterizing its stability, it is sufficient to use the indicator k_c, that takes into account the structure of biotic and abiotic components of landscapes, their ecological importance [6, 7]:

$$K_c = \sum_{1}^{n} f \cdot k_1 \cdot k_2,$$

Where *f* - areas of biotic and abiotic components, that are part of the landscape, as the proportion of the total system area; *k*1 - relative ecological importance of a separate element; *k*2 - the coefficient of geological and morphological relief stability.

To assess the environmental and reclamation stability (K_{esi}) of agricultural landscapes we have developed the formula, having the following form [8]:

$$K_{esr} = (\sum_{i=1}^{n} f_i \cdot k_s \cdot k_a \cdot k_g),$$

Where *fi* - area of the *i*-s elements of agricultural landscapes (salinity, depth and ground water mineralization), входящих в ее состав, that is $f_i = F_i / F_o$, here *Fi* - area of the *i*-s elements of agricultural landscapes, ha; *Fo* - the total area of agricultural landscapes; *ks* - the coefficient taking into account the ecological importance of saline lands; *km* - the coefficient taking into account the ecological importance of groundwater depth; *kg* - the coefficient taking into account the ecological importance of groundwater mineralization.

To assess the degree of agricultural landscapes environmental risk, we have developed a mathematical model that takes into account the natural system tolerance and has the following form: $K_{eh} = ?_{es}[1 - \exp(-K_{esr}]$, where *Keh*- integral exponent of environmental landscapes hazard degree; *Kes*- the highest possible environmental and reclamation landscapes sustainability.

To quantify the significance of agricultural landscapes separate elements, i.e. the parameters *ks*, *km* и *km* there were used the materials describing the dependence of the yield of crops from the soil salinity, groundwater level and their mineralization, i.e. $k_s = f(S,Y), k_m = f(C_g, Y)$, and $k_g = f(\Delta, Y)$ (Table 4) [8].

In general, the product of the significance coefficient *kg* and *km* may be defined as the agricultural landscapes hydro-geochemical significance coefficient *khc*, i.e. *khc* = *kg*. *Km*.

However, it can be used when the groundwater depth area and salinity are the same, but because such hydro-geochemical conditions do not occur in nature, it would be authentically represented in the following way: $k_{hc} = k_g \cdot f_g + k_m \cdot f_m$, where *fg* - agricultural landscapes relative area in the groundwater depth level; *fm* - agricultural landscapes relative area in the groundwater salinity.

Thus, while justifying landscapes structure (composition and proportions of various biotic elements) one must take into account, on the one hand, the requirements for the landscapes ecological stability and minimization of the economic activity negative impact on biodiversity, soil, biological and water resources on the other hand – the need for agricultural or other types of production.

Table 4: The coefficient of relative ecological importance of agricultural landscapes separate elements [8]

Agricultural landscapes elements					
		Ground waters			
Extent of the soil salinization	k_s	Depth	k_s	Mineralization	k_m
Not 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
Slightly	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
Medium	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
Strongly	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

RESULTS AND DISCUSSION

To evaluate the assessment of local ecosystems components technogenic disturbances in the lower reaches of the Syrdarya River Basin, based on the data on agricultural landscapes soil and environmental and land-reclamation condition there was made an expected calculation, characterizing the technogenic disturbances degree (Table 5).

Table 5: *Kf*- territory development index; *F* - agricultural landscape total area; F_{opi}- irrigated lands area; K_o- irrigated massifs water resources usage index; O_p^a - water intake gross; O_p^e - ecological irrigation norm; *Kc*- water quality index of the water source; *Ci*- water salinity before development; *Ce*- water salinity after development; K_s- unproductive land development index; *Fs*- area of unproductive (medium – and strongly saline) soils.

As can be seen from Table 5, disregarding the laws of nature and natural processes in the 20th century led to the discrepancy of the productive forces development nature to the nature protection relation ones in the lower reaches of the Syrdarya River Basin, where the coefficient characterizing the technogenic disturbances level as a result of agricultural lands reclamation, that is *Ktd* reaches up to 0.547.

The analysis of agricultural landscapes soil-ecological condition in Kazakhstan river basins revealed the following level of technogenic loads on the environmental system [8]:

- The optimum technogenic impact on the environmental system $K_{mm} \le 0.30$ - is the result of the total display of complex, long or relatively short processes with the natural and anthropogenic components, providing favourable agricultural landscape ecological condition or slowing down the deterioration process.
- Satisfactory technogenic impact on the environmental system ($K_{km} = 0.3 - 0.65$) – system unstable functioning as a result of total display of complex, long or relatively short processes with the natural and anthropogenic components, that leads to agricultural landscapes dynamic and ecological balance disturbances.

Table 5: Assessment of technogenically disturbed agricultural landscapes in the lower reaches of the Syrdarya River Basin

Indicators	Years					
	1960	1970	1980	1990	2000	2010
1	2	3	4	5	6	7
Kyzylorda oblast						
Parameters of agricultural landscapes components						
Arable lands area, thousand	13151.5					
Irrigation massifs areas(F_i), thousand	220.0	200.0	250.4	251.0	147.8	164.1
Ecological irrigation norm, (O_p^e) , mm	776.0					
Irrigation water mineralization, g/l	0.700	0.980	1.740	1.390	1.400	1.500
Saline lands area (F_s), thousand	135.1	141.7	147.7	159.6	160.5	100.0
Actual irrigation norm (O_p^α) mm	3820	4510	3620	3720	3280	1269
Indicators of technogenic loads on agricultural landscapes						
$K_f = F_i / F$	0.017	0.015	0.019	0.019	0.011	0.012
$K_o = (O_p^a - O_p^e)/O_p^e$	3.322	4.812	3.665	3.794	3.227	0.635
$K_c = (C_i - C_e)/C_e$	0.400	0.960	2.480	1.780	1.800	1.900
$K_s = F_s / F_i$	1.530	1.130	0.670	0.630	1.080	0.510
$K_f^i = \exp(-K_f)$	0.983	0.985	0.981	0.981	0.989	0.988
$K_o^i = \exp(-K_o)$	0.036	0.008	0.025	0.022	0.040	0.530
$K_c^i = \exp(-K_c)$	0.670	0.382	0.840	0.169	0.165	0.149
$K_s^i = \exp(-K_s)$	0.216	0.323	0.512	0.532	0.339	0.600
K_{td}	0.410	0.449	0.232	0.574	0.481	0.248

- Intense technogenic impact on the environmental system ($K_{km} \geq 0.65$) - is the result of the total display of complex, long or relatively short processes with the natural and anthropogenic components, characterized by the significant changes in agricultural landscapes and the general deterioration of the human environment.

The analysis of the assessment results of the agricultural landscapes technogenic disturbances level in the lower Syrdarya River Basin showed the level of technogenic impact on the environmental system is on the satisfactory level that requires adjustment of technogenic loads during agricultural lands reclamation.

Thus, the perspective of possible changes in agricultural landscapes natural processes, while maintaining the existing system of land tenure and agricultural reclamation activities is the specific well-reasoned information about future. Contents and the actual degree of such information is determined to many years of farming systems experience, the results of theoretical and industrial research and methods of possible changes in natural processes developed on the basis of their evaluation.

On the basis of information provision on the soil hydro-geochemical condition (Table 1-3) and using the methodological support for the assessment of agricultural landscapes environmental and reclamation sustainability, there was made an estimated calculation of the definition of the agricultural landscapes individual elements ecological significance (Table 6) and environmental - reclamation sustainability in the lower reaches of the Syrdarya River Basin (Table 7).

As it is seen from Tables 6-7, an estimated calculation of the irrigated lands ecological and reclamation sustainability in the lower reaches of the Syrdarya River Basin showed that it is relatively low, as a result of the natural geological water cycle and chemicals disturbances, the profound changes in hydro-geochemical regime of the region took place, as these regions coefficient K_{esr}= 0.545-604, i.e. the irrigated lands ecological and reclamation sustainability is relatively low.

This is largely due to the saline lands development, i.e. as a result of the saline lands flushing their soil - reclamation condition didn't improve, but they have contributed to the deterioration of the soil- reclamation condition of the former highly productive irrigated lands in the region.

Table 6: Determination of the significance ofagricultural landscapes individual elements in the lower reaches of the Syrdarya River Basin

Extent of the soil salinization	Indicators	Years 1960	1970	1980	1990	2000	2010
1	2	3	4	5	6	7	8
		Kyzylorda oblast					
Not saline	*fg*	0.492	0.447	0.391	0.243	0.251	0.132
	kg	1.00	1.00	1.00	1.00	1.00	1.00
	kg. fg	0.492	0.447	0.391	0.243	0.251	0.132
	fm	0.469	0.485	0.507	0.563	0.586	0.582
	km	0.95	0.95	0.95	0.95	0.95	0.95
	km. fm	0.445	0.461	0.482	0.535	0.557	0.553
	khc	0.937	0.908	0.873	0.778	0.808	0.685
Slightly saline	*fg*	0.172	0.181	0.176	0.199	0.206	0.247
	kg	0.85	0.85	0.85	0.85	0.85	0.85
	kg. fg	0.146	0.154	0.150	0.169	0.175	0.210
	fm	0.187	0.195	0.203	0.210	0.229	0.231
	km	0.85	0.85	0.85	0.85	0.85	0.85
	km.fm	0.159	0.166	0.173	0.179	0.195	0.196
	khc	0.305	0.320	0.323	0.389	0.424	0.406
Medium saline	*fk*	0.223	0.158	0.214	0.198	0.212	0.231
	kg	0.75	0.75	0.75	0.75	0.75	0.75
	kg,fg	0.167	0.119	0.161	0.149	0.159	0.173
	fm	0.167	0.160	0.151	0.118	0.106	0.124
	km	0.75	0.75	0.75	0.75	0.75	0.75
	km.fm	0.125	0.120	0.113	0.089	0.080	0.093
	khc	0.292	0.239	0.274	0.238	0.239	0.266
Strongly saline	*fg*	0.113	0.214	0.219	0.364	0.331	0.390
	kg	0.35	0.35	0.35	0.35	0.35	0.35
	kg.fg	0.040	0.075	0.077	0.127	0.248	0.137
	fm	0.177	0.160	0.139	0.109	0.079	0.063
	km	0.85	0.85	0.85	0.85	0.85	0.85
	km.fm	0.150	0.136	0.118	0.093	0.067	0.053
	khc	0.190	0.211	0.195	0.220	0.315	0.190

Table 7: Agricultural landscapes ecological and reclamation sustainability in the lower reaches of the Syrdarya River Basin

Extent of the soil salinization	Indicators	Years 1960	1970	1980	1990	2000	2010
1	2	3	4	5	6	7	8
Not saline	*fi*	0.263	0.239	0.206	0.143	0.125	0.116
	ks	1.00	1.00	1.00	1.00	1.00	1.00
	fi,ks	0.263	0.239	0.206	0.143	0.125	0.116
	k_{esi}	0.937	0.908	0.873	0.778	0.808	0.685
	kesi	1.200	1.147	1.079	0.921	0.933	0.801
Slightly saline	*fi*	0.201	0.202	0.213	0.235	0.253	0.262
	ks	0.85	0.85	0.85	0.85	0.85	0.85
	fi.ks	0.171	0.172	0.181	0.200	0.215	0.223
	khc	0.305	0.320	0.323	0.389	0.424	0.406
	kesi	0.476	0.492	0.504	0.589	0.639	0.629

Table 7: Continue

		Years					
Extent of the soil salinization	Indicators	1960	1970	1980	1990	2000	2010
1	2	3	4	5	6	7	8
Medium saline	*fi*	0.113	0.163	0.173	0.241	0.240	0.259
	ks	0.65	0.65	0.65	0.65	0.65	0.65
	fi.ks	0.073	0.106	0.112	0.157	0.156	0.168
	khc	0.292	0.239	0.274	0.238	0.239	0.266
	kesi	0.365	0.345	0.386	0.395	0.395	0.434
Strongly saline	*fi*	0.423	0.396	0.408	0.381	0.382	0.366
	ks	0.35	0.35	0.35	0.35	0.35	0.35
	fi.ks	0.148	0.138	0.191	0.133	0.134	0.128
	khc	0.190	0.211	0.195	0.220	0.315	0.190
	kesi	0.338	0.349	0.386	0.353	0.449	0.318
kesr	0.595	0.583	0.589	0.565	0.604	0.545	
keh	0.426	0.420	0.423	0.410	0.430	0.399	

As a result there appeared agricultural landscape systems in the lower reaches of the Syrdarya River Basin, which are unsafe and dangerous, from an environmental point of view, requiring a complete reconstruction of water systems in the region.

Thus, the assessment of agricultural 1andscapes ecological and reclamation sustainability in terms of anthropogenic activity reflects natural processes dynamics and direction, the degree of strength and stability that allows developing agriculture and land reclamation adaptive- landscape system projects. At the same time, agricultural 1andscape basic functions - consistency, creativity and efficiency, providing natural system solid and stable functioning, are the essential elements that define differentiation features of agriculture in accordance with the landscapes hierarchy. This necessitates consideration, on the one hand, of natural landscapes, consisting of a number of interrelated and interdependent components (atmosphere, biota, soil, surface water and groundwater), on the other hand – of economic activity, including reclamation and learning the complex of the above mentioned environmental components and their changes in the anthropogenic activities process. The natural environmental features should be also assessed by the properties, which are system -forming factors and their numerical values are integral criteria, reflecting the condition of the landscape individual components and considering the economic activity impact.

Thus, the proposed system and the selection of the agricultural landscapes environmental sustainability evaluating criteria are the methodological basis for the substantiation of the complex of priority actions to develop a system of environmental regulation of the maximum permissible level of water and land resources in the human anthropogenic activity.

REFERENCES

1. Mustafayev, Zh. S., 2004. Methodological and Environmental Principles of Agricultural Lands Reclamation - Taraz, pp: 306.
2. Khachaturyan, Kh. V., 1988. Applied Methods for Assessing Chernozems. Water and Salt, Heat and Nutrient Regimes. Irrigation and Water Management, Irrigation and Irrigation Systems Series (general data). M.: CBSTR USSR Minvodkhoz, 3: 56.
3. Mustafayev, Zh. S. And A.D. Ryabtsev, 2009. Mathematical Model of Agro landscapes Settlement Monitoring, Taraz, pp: 136.
4. Shchedrin, V.N. and D.S. Guzykin, 1993. Environmental and Economic Aspects of Reclamation Grounds. Reclamation and Water Management, M, 2: 9-11.
5. Janie, K., 1990. Average Values, M, Statistics, pp: 532.
6. Agroecology - Moscow: Kolos, 2000 pp: 536.
7. Glazovsky, M.A.,k 1997. Methodological Bases of Assessment of Soils Environmental and Geochemical Stability to Anthropogenic, Impacts, M. pp: 236.
8. Mustafayev, Zh. S., A.D. Ryabtsev and G.A. Adilbektegi, 2007. Methodological Basis of Landscapes Stability Assessment, Taraz, pp: 218.
9. Mustafayev, Zh. S., A.T. Kozykeeva, K. Zh. Mustafayev, 2013. World Applied Sciences Journal, 26(9): 1160-1167.