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Criteria for the evaluation of reclamation status of soils in the Mugan-Salyan massif

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Abstract

Thorough information about the reclamation status of soils based on complex studies carried out in the Mugan-Salyan massif are given in the article. Based on results of recent studies on the evaluation of reclamation status, soils were divided into 4-categories and the reasons behind each division and contemporary status were shown. Soils over Mugan-Salyan massif were evaluated with respect to all parameters and results were set up in a table. The evaluation allowed to prepare suggestions for farm owner on how to increase soil fertility.

Key words: *anthropogenic and natural factors, evaluating criteria, reclamation status, salinity, solonetz, subsoil waters*

INTRODUCTION

Recent decrease of soil fertility has been the reason for the reduction of agricultural plant productivity. The Mugan-Salyan massif is one of the ancient regions where irrigation was applied in agriculture and now 52.5% of the zone area is used for plant crops. The majority of the collector-drainage systems operating in the zone is unsatisfactory and their exploitation period comes to an end.

The reclamation status of soils changed because reclamation systems didn't work efficiently and soils were inappropriately used. Therefore, preparation and application of the evaluation criteria are of both scientific and practical importance. The improvement of the reclamation status of irrigated soils based on complex studies may be valid also for other similar zones.

STUDY OBJECT AND METHODS

All the soils of the Mugan-Salyan massif were taken as an object of this study. The methods used widely in determining salt quantity, mineralization of subsoil waters, structural parameters, humus content and other soil parameters were used in the study. For comparison, results of studies on the evaluation of reclamation status in Middle Asia and Azerbaijan were also used.

RESULTS AND DISCUSSION

The long-term studies showed that a category of the evaluation of reclamation status reflects the usefulness, character and type of management of increased fertility potential of soils used in agriculture. Considering reclamation parameters and the natural and anthropogenic factors, the soils were divided into 4 categories: good, satisfactory, risk of deterioration of the satisfactory status and unsatisfactory. Soil reclamation status is:

- Good when ground water depth is lower than permissible limit. Then, soil forming processes are stable or proceed in positive direction, there is no risk of subsoil water rising, of increasing salinity and formation of natric horizon and engineering and geological processes do not affect irrigation. In such conditions, if only initial parameters ensure soil fertility, the status of reclamation and agro-technical measures should be maintained.

- Satisfactory when ground water depth is at a permissible level in the vegetation period, soils are not salted, solonchak-like and soil forming processes are stable and there is no risk of subsoil waters rising. If the initial parameters ensure soil fertility, there is no engineering-geological processes to impede irrigation of the area larger than 10–15%. Then, the reclamation and agro-technical measures should be directed to abolish salinization and solonetzification and prophylactic measures should be undertaken.
- At a risk of deteriorating the satisfactory status when the depth of subsoil waters is lower than permissible during mean vegetation period, but it is variable and rises at a rate of 0.2–0.5 m·year^{-1} or when the depth of subsoil waters is at a permissible limit, the soils aren't salinized but deterioration of water-physical parameters is observed. When the secondary salinity appears and salinization or the formation of natric horizon is observed in soils, the initial parameters don't provide soil fertility and engineer-geological processes occupy an area smaller than 10–15% then the complex agro-reclamation countermeasures should be prepared for soils of this category.
- Unsatisfactory when the depth of subsoil waters is higher than permissible limit in a mean vegetation period and salinization and solonetzification changes from weak to intense in naturally saline soils. Then, the initial parameters don't influence soil fertility, engineer-geological processes develop intensively in the zone larger than 10–15%. In such a case, the reclamation measures should be directed to decrease mineralization and the depth of subsoil waters and to improve water-physical properties.

The reclamation status of soils is evaluated by engineer-geological parameters at the time when a category of both soil and hydro-geological parameters is 1 or 2 grades low, and special complex system of measures is required to remove unsatisfactory processes. Evaluation of soils by limiting parameters must be conducted while one of the parameters in the whole zone is in the lowest category. Therefore, soil evaluation must be conducted in different cases and all the features of the zone should be taken into account. Based on results of the complex studies conducted in meliorated soils of the Mugan-Salyan massif, their evaluation is given with special attention paid to the engineering-geological conditions shown in Table 1. The following parameters were adopted while determining the criterion of the reclamation state evaluation in the irrigated soils: the permissible level of ground water table is a criterion of the reclamation status of the irrigated soils. So, if the subsoil water depth is low, toxic salts don´t collect in the upper soil layers, soil water-physical properties depend on natural conditions and there are good water-salt, air and nutrient regimes for growing agricultural plants. The subsoil water depth limit under different soil-climate condition depends on drainage, granulometric structure, soil type and salinity, aeration zone, mineralization of subsoil waters, their chemical composition, evaporation, the quality of irrigation waters and a kind of field crops. When the table of subsoil waters is lower than 5 m in the considered zones, their mineralization, chemical composition and pH must be estimated.

Table 1. Evaluation was performed depending on subsoil water depth of irrigated soils and the proposed parameters

Categories of the reclamation status of irrigated soils	According to average value h_D of subsoil water level difference a vegetation period
Good	$QSS > h_D$
Satisfactory	$QSS = h_D$
Possible risk of aggravation of satisfactory status	$5 > QSS > h_D$
Unsatisfactory	$QSS < h_D$

Explanation: *QSS* – groundwater stage.
Source: own study.

Mean annual rate of ground water table change is the evaluation criterion. In drained areas the annual change is estimated till the ground water reaches 5.0 m depth under effective reclamation works. In areas where irrigation is carried out without drainage, the mean limit for vegetation is the difference between previous and current year.

Evaluation was performed depending on subsoil water depth of irrigated soils and the proposed parameters are given in Table 1.

The following criteria (soil parameters) are used to evaluate the reclamation status of irrigated soils:

- Aggregation structure of cultivated soil layer estimated by structure parameters of aggregates, that is by $C = C_o/C_1$ where: C_o is percent of fractions before irrigation and C_1 is percent of fractions at the time of irrigation (Tab. 2).
- Bulk density of tilled soil and underlying layer as a measure of compactness of genetic horizons. At the same time, the distribution of plant roots, changes in water-air, heat and filtration parameters were taken into consideration.

Table 2. Evaluation categories of soil and subsoil according to aggregation structure

Reclamation categories of irrigated soils	Parameter *C*	Direction of process
Good	$C > 1$	higher content of aggregates
Satisfactory	$C = 1$	changeable process
Unsatisfactory	$C < 1$	observed splintering

Explanation: *C* (structure of aggregate) is explained in text.
Source: own study.

The tilled layer depends on the amount of humus and soil agronomic parameters (Tab. 3). An optimum

Table 3. Evaluation categories according to changes in the soil and subsoil bulk density

Reclamation categories of irrigated soils	Soil-subsoil compactness $g \cdot cm^{-3}$		Process direction
	tilled layer 10–30 cm	under tillage layer	
Good	<1.20	1.20–1.30	stabilization or compactness
Satisfactory	1.20–1.30	1.30–1.40	unstable process
Possible risk of aggravation of satisfactory status	1.30–1.40	1.40–1.60	aggravation tendency
Unsatisfactory	>1.40	>1.60	the highest compactness

Source: own study.

quantity of humus in soil ensures its appropriate structure, improves water-air regime, soil physical and chemical properties (cation exchange, acidity, buffering). Humus is a source of plants nutrients (nitrogen, phosphorus, potassium and microelements) and contains physiologically active compounds (amino acids, enzymes etc.). Analyses of humus in soils is important in defining their contemporary status and in preparing methods for increasing soil fertility (Tab. 4).

Table 4. Evaluation categories of soils with respect to humus content

Reclamation categories of irrigated soils	Humus quantity %	Process direction
Good	>5	active humus formation
Satisfactory	5–3	directional process without stability
Possible risk of aggravation of satisfactory status	3–1	aggravation tendency
Unsatisfactory	<1	decrease of humus content

Source: own study.

Soil acidity (alkalinity) is defined by hydrogen ions activity in water solution. Agricultural plants are susceptible to pH, which may change in a limited range (Tab. 5). The status of irrigated soils is estimated according to pH parameters and this is especially important for desert and semi-desert soils of the Republic.

Table 5. Evaluation categories according to pH change

Reclamation categories of irrigated soils	soil pH value	Process direction
Satisfactory	6.0–6.6	low concentration of OH^- or stability
Good	6.6–7.2	Stability
Satisfactory	7.2–7.6	high concentration of OH^- or stability
Unsatisfactory	5.0–6.0 >7.6	meaningless, decrease of OH^- concentration is observed

Source: own study.

The amount of salt in water solution in the aeration zone (0–100 cm soil layer) and soil salinity are taken into consideration in the evaluation.

One reason of low productivity of agricultural plants in the irrigated soils of the Azerbaijan Republic is soils solonetzification. Solonetzification is related to dispersion, swelling, variable quantity of aggregates, density and other peculiarities of agricultural soils. Solonetzification is determined by percent quantity of exchangeable sodium, magnesium and calcium in the soil (Tab. 6).

Table 6. Evaluation category in relation to salinity

Reclamation categories of irrigated soils	Salinity	Process direction
Good	not saline	salinity doesn´t occur
Satisfactory	weakly saline	stable or weak salinity
Possible risk of aggravation of satisfactory status	not or weakly saline	permanent accumulation of salts
Unsatisfactory	mean, high and very high salinity	intensive accumulation of salts

Source: own study.

The exchangeable cations (Ca, Mg, Na) and solonetzification were determined in soil within this study and results were used in evaluation. Reclamation status of irrigated soils depends on solonetzification and on the rock origin of 0–100 cm soil layer in the aeration zone (Tab. 7).

Table 7. Evaluation category in relation to solonetzification

Reclamation categories of irrigated soils	Salinity	Process direction
Good	salinity	solonetzification doesn't occur
Satisfactory	weak salinity	stable or not solonetzificated
Possible risk of aggravation of satisfactory status	unsalinized or salinized	accumulation of Na and Ca release
Unsatisfactory	mean, strongly solonet-zificated and saline	intensive accumulation of Na and Mg and release of Ca

Source: own study.

Research of the contemporary state of the collector-drainage system – the main factor in evaluating the soils status and in defining criteria – is one of the important problems for increasing its efficiency. The study showed that appropriate design of the collector-drainage networks is one of the main problems in the improvement of the soil status and its satisfactory utilisation. As we know, removal of salts from soils by leaching is necessary to obtain high productivity of agricultural plants. It is not necessary to get crop from any plant without irrigation in soils of the study area. Therefore, a study on the contemporary state of both irrigation and drainage networks and preparation of a set of adequate measures is one of the urgent problems for their improvement. Clearing of the irrigation canals is one of the main problems in the economical exploitation of water and in the provision of water in a volume intended by the project. The areas of irrigated soils have been enlarged as a result of establishment of some oil irrigation canals in the research zones and building new ones.

Beginning from 1930, some scientists, eg. KOSTYAKOV [1960], ZAKHAROV [1936], SHOSHIN [1937] and others, were of the opinion that building the parallel drainage network was important, otherwise the irrigated soils will be subjected to salinity. Building of the collector-drainage networks in large areas expanded in the republic in 1960–1970. The problems with defining water quantity required to purify saline soils, finding the distances between drains built in soils of various granulometric structure were solved in the same period [ABDUYEV 1977; ALIMOV 2002; BABAYEV 1984; VOLOBUYEV 1965].

The studies carried out till 1970 showed that 7–15 000 $m^3 \cdot h^{-1}$ and 1–3 years period were required to purify light and medium grain size soils from salts. Though conduction of these works proceeded slowly in 1980–1990, the leaching works weren't conducted later. At present, the new relations were created in soil irrigation system management. They have passed from general to the privative management system. Therefore, proper utilization of available drainage and irrigation systems is considered one of the main problems for obtaining high productivity and increasing soil fertility.

From among 50 covered drains observed for comparative purposes in the Mugan-Salyan massif within the studies carried out in 2000–2012, 15 (30%) were satisfactory and 35 (70%) were unsatisfactory. Twenty open drains (40% out of 50) were satisfactory but 30 (60%) of them were unsatisfactory. From among 40 collectors, 25 (62.5%) were satisfactory and 15 (37.5%) – unsatisfactory. Analyses of the actual status of the collector-drainage systems showed the system incapable of providing natural flow of subsoil waters near the surface and near critical depth of subsoil waters in the zone. Salt spots in these same zones, low plant yield, their low height and decrease of productivity can serve as an evidence. In general, clearing and maintenance of drains available in Mugan-Salyan massif have not been performed or have been conducted badly (with the exception of some drains). It is obvious that the status of covered drains operating in the study zones isn't satisfactory. Therefore, an area of soils salted to a different degree is larger there than in other regions. For the purpose of revealing ecological changes that had occurred in soils of this zones and their effect on soils reclamation status, both our and international studies on this issue were reviewed. We know that when agro-technical and reclamation measures system are not correctly implemented during intensive utilization of soils, the fertility of soils and plant productivity may be markedly reduced. Therefore, physical, chemical and water properties of soils as well as the status of available collector-drainage and irrigation systems and water mineralization should be defined. Changes in soils and environment resulting from natural and anthropogenic impact have recently been shown in some papers. They showed not only the destruction of soils, reduction of their productivity and washing out the upper fertile soil layer by atmospheric fallout but gave also scientific bases for reclamation measures to prevent from such phenomena [MADJAYSKY *et al*. 2003].

In consequence of the anthropogenic effects, more and more information about the soil degradation process in the Republic were given in detail in some studies. Vernadsky expressed the opinion about important ecological role of soils in his studies. Dokuchayev touched upon some scientific-theoretical problems of soil ecology while describing natural zones and soil forming factors. Sibirtsev gave superiority to ecological principles in his classification of soils. He considered important to utilise information about natural condition that formed definite characteristics of soils including morphological, physical and chemical properties, relief and climate. The problems associated with subjecting soils to technogenic effects in some places and assimilation of the zone to agriculturally required level acquired a special significance during the study on changes occurring in soil and in soil ecology.

VOLOBUYEV [1965] showed in his studies that a correlation between soil and its environment, their mutual relationships become an ecological issue. An optimum condition corresponding to stable productivity of the main agricultural plants is revealed while determining the ecological changes. It is necessary to take into account that environmental protection should be the primary issue in the zone influenced by the constructions (collector-drainage and irrigation systems, water stores, etc.) and in the neighbouring areas. One of the main problems is to rationally use water resources and to protect them from pollution with the purpose of reducing water deficiency. Hydro-technical installations widely use river waters often polluted by industrial waste waters which are harmful for aquatic biota. At the same time hydro-technical installations over the rivers change water regime, decrease water flow, increase turbidity and sedimentation of debris and negatively affect bottom-feeding fish and those migrating to their spawning grounds. That's why the design of the system of countermeasures and its implementation should not disturb ecological effects in the soils impact zone, should conform to the available rules of irrigation, and protect waters from pollution while performing any reclamation works [MUSTAFAYEV 2007; MUSTAFAEV 2009; MUSTAFAYEV 2010].

The areas under crop plants must be taken as a control object monitored 2–3 times in a vegetation period depending on plant physiology. Soil loss due to rain, wind and water (irrigation) erosion should be checked in the study areas and the amount of mineral matter, soil acidity and alkalinity, salinity and solonetzification, pollution with heavy metals should be determined. The problems of ecological importance arise when the rules of appropriate land reclamation are not fulfilled. Neglecting the ecological characteristics of the zones in soil reclamation was the reason of its negative impact on nature conservation in the Republic.

This is the reason of disturbed equilibrium, salinization of thousand hectares, erosion and landslides, pollution of soils surface, etc. Unplanned use of the irrigation systems of low quality, waste waters from industrial objects and rising the Caspian Sea level seriously influenced the areas of good soil and enhanced ecological tension in the environment of the Republic. Therefore, in any reclaimed area, the future actions aimed to not inflict environmental damage and disturb the balance should be based on scientific and theoretical grounds.

Generally, stable desalting of the salted soils can be achieved by means of agro-technical and complex reclamation measures. The measures should include: conducting daily leaching at the end of autumn and in winter months, smoothing of micro-relief, fallow tillage in autumn till the rainfall season, early spring (in March) irrigations, next irrigations in amounts not less than 60% of the field water capacity of 0–150 cm soil layer in the vegetation period. Soil surface must be loosened after irrigation and organic and mineral fertilizers should be applied.

Increase of soil fertility and productivity can be achieved by these measures in the research zone. The technical parameters are projected correctly, water constructions are fulfilled to a necessary level and soil water-salt regime is regulated depending on three parameters (irrigation water, drainage flow and general evaporation) and their ratios in the reclamation networks, whose exploitation is satisfactory [MUSTAFAYEV 2012].

Effective leaching irrigation recommended over regions and plant irrigation regimes must be applied, including the increase of irrigation norms by 10–30%. Irrigation and daily leaching should be conducted with reference to water needs of agricultural plants.

As we know, drainage should ensure the regulation of the water-salt balance in zones subjected to salinization. Natural and man-made factors affect the salt regime of waters. The former include the input and output of ground waters, rainfall, evaporation, plant transpiration, and surface and underground flows from the neighbouring areas. Water capacity of drainage and irrigation system is a man-made factor. Combination of these factors shape the ground water regime. Possibility of regulation of the natural factors is practically clear to us. That´s why a regulation of the salt regime in drained area should be ensured at the expense of artificial factors, i.e. irrigation and drainage flow.

Sometimes, as a result of leaching, ground water level is not stable, it may rise even higher than the critical depth. Ground water with high mineral content accumulates on soil surface at the expense of transpiration and evaporation of water raised by capillaries in the drained areas. The next irrigations repeat this process. These problems were taken into account in the evaluation of the reclamation status. The results of studies carried out in systems similar in the preparation and evaluation of the reclamation status to that in the research zone were comparatively used in both Middle Asia and Azerbaijan (Tab. 8).

As seen in Table 8, according to the drainage of soils in the research zones, subsoil water depth and its mineralization, total evaporation, soils salinity, the ratio of drainage waters to the input waters, plants

Table 8. Evaluating criteria of the ecological and reclamation status of soils in the Mugan-Salyan massif

Parameters	Reclamation status of soils				
	absolutely unsatisfactory	unsatisfactory	relatively suitable	satisfactory	good
Draining rate, $m^3 \cdot day^{-1} \cdot ha^{-1}$	<5				>20
Ground water depth, m before vegetation during vegetation at the end of vegetation	 <0.5 <1.0 <1.5	 0.5–1.0 1.0–1.5 1.5–2.0	 1.0–1.3 1.3–1.8 2.0–2.5	 1.3–1.5 1.8–2.5 2.5–3.0	 1.5–2.0 2.5–3.0 2.5–3.0
Mineralization of subsoil waters (dry residue), $g \cdot l^{-1}$	>20	15–20	0–15	3–10	<3
Ratio of drainage to input water	>1	1.0	0.8–1.0	0.6–0.8	<0.6
Ratio of total evaporation to input water	>0.15	0.15–0.20	0.20–0.25	0.25–0.35	<0.35
Salinity according to chlorine in the upper 100 cm layer, %	>0.1	0.1–0.05	0.02–0.05	0.015–0.02	<0.015
Soil salinity limits and salinity expressed in dry residue, %	saline S_0+2.9	strongly salinized S_0+(2.95–1.15)	salinized to an average degree S_0+(1.15–0.45)	salinized to a weak degree S_0+(0.45–0.15)	unsalinized, harmfulness limit S_0 and less
Main plants For cotton plant: – productivity, $kg \cdot ha^{-1}$ – relative productivity, %	 0 0	 300–1000 10–40	 1000–1800 40–70	 1800–2500 70–100	 ≥2500 100
For grain plant: – productivity, $kg \cdot ha^{-1}$ – relative productivity, %	 0 0	 500–1500 20–50	 1500–2000 50–80	 2000–2800 80–100	 ≥2800 100

Explanation: S_0 – non saline soils.
Source: own study.

productivity etc., the status of irrigated soils was evaluated as good, satisfactory and absolutely satisfactory.

The complex system of reclamation measures was prepared to improve the ecological status of irrigated soils in the same zones concerning the criteria described above.

CONCLUSIONS

The studies showed that the amount of salts is lower than or equal to permissible limit in places where collector-drainage systems are good and satisfactory. In areas where drainage and irrigation systems are unsatisfactory and absolutely satisfactory the amount of salts is larger than permissible limit and plant productivity is very low there. That's why the amount of salts should be decreased by soil reclamation in places where salt content exceeds 0.50%. To ensure the rationality of the drainage networks available in the research zones, it is necessary to define the corresponding drainage parameters, mutual settlement of the constructions with the irrigation network, exploitation rules, etc. by studying technical level and reclamation efficiency of the drainage installations.

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Kryteria oceny stanu melioracji gleb w masywie Mugan-Salyan

STRESZCZENIE

Słowa kluczowe: *czynniki naturalne i antropogeniczne, kryteria oceny, sołonczaki, stan melioracji, wody gruntowe, zasolenie*

W artykule przedstawiono gruntowną analizę stanu melioracji gleb wykonaną na podstawie kompleksowych badań prowadzonych w masywie Mugan-Salyan. Wykorzystując oceny stanu melioracji, gleby podzielono na cztery kategorie, podając przyczyny takiej kategoryzacji i przedstawiając aktualny stan gleb. Gleby masywu oceniono, uwzględniając wszystkie parametry, a wyniki zestawiono w tabeli. Dokonana ocena umożliwiła sformułowanie sugestii dla właściciele gospodarstw rolnych dotyczące możliwości zwiększenia żyzności gleb.