Water conservation in the reclamation of saline irrigated lands of Uzbekistan

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Abstract. On the territory of Uzbekistan, almost half of the area of irrigated land is subject to salinization, for this reason up to 30 % or more of the crop yield is lost. With a shortage of water resources, which will deepen due to climate change, water-saving technologies must be used not only for irrigation but also for the reclamation of saline soils. The authors have developed a new approach to the regulation of the salt regime and soil reclamation. The conducted experiments have established that the use of the Biosolvent preparation almost doubles the efficiency of washing saline lands, due to the increased leaching of salts. To reduce salinity by 0.1% of the total amount of salts, the water-saving unit costs are 610 m3/ha. Calculation on the basis of field experimental data from 2016 (of established indicators of salt removal when using Biosolvent), shows a reduction of soil washing norm by 3000 m3/ha or by 38 %, at the transition of soils from "strong" degree of salinization to "non-saline". The study 2020 proved that the application of Biosolvent preparation for the melioration of highly saline gypsum soils, combined with their preliminary deep loosening, allows reducing soil salinity by 5 dS/m, due only to atmospheric precipitation.

1 Introduction

On the territory of Uzbekistan, almost half of the area of irrigated land is subject to salinization. Soil salinization is a serious problem of irrigated land degradation, due to which more than 30% of agricultural crops are lost. There is also a shortage of water resources in the republic, which will obviously deepen due to climate change.

The Government of Uzbekistan is taking measures to economically use water, including economic incentives for land users to apply water-saving irrigation technologies - basically drip irrigation. Water-saving technologies are as well necessary in the fight against soil salinization on irrigated arrays. For example, the cost of water for high-quality leaching of lands of medium salinity, spread over an area of about 1 million hectares, is 4000-6000 m3/ha, which in total will be more than 5 million m3 of water. Reduction of water costs during the non-growing period will allow for saving it in water reservoirs and using it during the growing period for agricultural production. In this regard, innovative approaches to the regulation of the salt regime and soil reclamation aimed at reducing water costs are

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actual. The productivity of irrigated lands also reduces the accumulation of gypsum in the form of layers located in the soil profile. These gypsum layers lead to compaction, reduced water and air permeability, deterioration of soil structure, and salt accumulation. In this case, there is a violation of the water and air regime of soils and a significant loss of yields of cultivated plants. One of the distribution zones of gypsum-bearing and highly saline (difficult-to-reclamation) lands is the South-Eastern part of the Hungry Steppe.

The study aims to find methods and technologies for improving the efficiency of saline land leaching, providing water savings.

Objectives to fulfil the goal:

1. Establish quantitative and qualitative indicators of gain leaching of salts and develop a technology for the use of the local preparation of Biosolvent based on physical modelling of the leaching process; (Biosolvent is the preparation of local production, developed at the Institute of Bioorganic Chemistry of the Academy of Sciences of Uzbekistan, as an analogue of the famous preparation Spersal).

2. To check in the field the technology of using Biosolvent for washing saline soils and clarify its effect on leaching capacity, indicators of soils leaching, quantitative indicators of water saving;

3. Check the hypothesis about the possibility of desalinization of highly saline and gypsum soils by precipitation (without irrigation water costs): due to deep loosening with soil treatment with Biosolvent and give practical recommendations.

The studies were carried out on saline lands of the Syrdarya region. Soils of the Mirzaabad district were used in laboratory experiments, and field experiments on leaching saline lands were carried out in Mirzaabad and Khavast districts (Figure 1). These two districts were chosen as related to the problematic, in terms of land reclamation, districts on the territory of the Syrdarya region.

So, in Mirzaabad district, for many years, the area of irrigated lands of medium and strong salinity is up to 60%, and in Khavast about 40%.

On the territory of the Khavast district, irrigated lands with unfavourable soil properties were developed in the 80s of the 20th century. Due to the lack of water, the impossibility of investing in ameliorative improvement, reduced productivity, long-term non-use, high salinity, they have become degraded.

As the practice of using the lands of the Syrdarya region of Uzbekistan shows, gypsum-bearing and highly saline soils located in the South-Eastern part are low-productive, and, from the moment of their development, require special melioration. Gypsum, located in the aeration zone and below, creates layers that are difficult to permeate, and even deep loosening of the soil does not always solve the problem [1]. In some studies of previous years, due to the failure of reclamation measures and the persistently low productivity of land, it was proposed to use the territory of this zone for animal husbandry purposes [2].

At present, increasing the productivity of irrigated lands, when creating agricultural and industrial clusters, is very important. At the same time, there is a shortage of water resources in the republic, therefore, in order to use saline lands, each land user must use water sparingly, both for irrigation and for reclamation of saline lands.

In this regard, innovative technologies for desalinization and soil improvement are very important for further effective use. In this article, there is a short information about former results of research on the application of salt leaching preparation. It also presents new research data from 2020 showing the possibility of a gradual reduction of salinization of gypsiferous, compacted, highly saline soils by atmospheric precipitation, using the preparation Biosolvent after deep soil loosening. The technology is proposed for use where traditional soil leaching with water supply to specially prepared checks is not possible due to lack of water or drainage.

Fig. 1. Location of the Syrdarya region in Uzbekistan and places where experiments were conducted.

2 Materials and methods

Studies of the effectiveness of the Biosolvent preparation to enhance the leaching of salts from the soil were carried out in the Mirzaabad district in 3 stages: Stage I - Experiments on physical modelling of the process of soil leaching in bulk soil columns (laboratory experiments); Stage II - Experience in washing the soil in vegetation vessels; Stage III - field studies of soil leaching.

I. Experiment-1. Leaching of saline soil (ECe = 6.92 dS/m) with the supply of a volume of solution (water) equivalent to 1000 m3/ha. Variant 1 - Biosolvent solution at a concentration of 2% (10 ml of the drug per 500 ml of water); Variant 2 - Biosolvent solution at a concentration of 10% (50 ml per 500 ml of water). Control, - soil leaching with distilled water. Experiment-2. the same, with the supply of a volume of solution (water) of 500 m3/ha. Soil salinity according to ECe=9.88 dS/m. Variants of soil leaching at a concentration of solutions 1: 500, 1:100 and 1:50. Control, - soil leaching with distilled water.

II. Leaching of saline soil (ECe from 6.0 to 10.0 dS/m) with a volume of water corresponding to 1500 m3/ha. Variant: tillage before leaching with a 10% Biosolvent solution; Control - ordinary soil leaching with river water.

III. Winter-spring leaching of saline soil (ECe up to 10 dS/m) by checks, 20x20 m in size, with a water supply of 2000 m3/ha. Variant: tillage before leaching with a 10% Biosolvent solution; Control - ordinary leaching of the soil with irrigation water.

The effect of salt leaching of the technology: loosening the soil, plus its treatment with a 10% solution of the Biosolvent preparation, was studied on very highly saline gypsum soil (ECe > 20 dS/m, gypsum > 30%) of the Beck cluster in the Khavast district. Variants of the experiment: Control - leaching the soil according by checks, with a net water supply rate of

2000 m3/ha; Variant 1 - soil desalinization under the influence of precipitation, without the cost of irrigation water.

In experiments I-III, the soils are light and medium loamy, homogeneous in terms of mechanical composition, and light loamy in the field of the Beck cluster, with interlayers of sands and sandy loams.

Evaluation of the efficiency of salt leaching in the variants of experiments with the use of the Biosolvent preparation was carried out on the basis of a comparison of the results of laboratory analyses of leaching water and soil. In leaching simulation experiments, volume, pH, EC were measured and the chemical composition of the feed solutions and filtered waters was determined. In addition, in all, without exception, conducted experiments, "before" and "after" leaching, we determined: pH, EC, TDS, and the ionic composition of the soil in the water extract.

3 Results and discussion

As a result of laboratory experiments on modelling the leaching of highly saline soils on columns, with testing of the Biosolvent preparation at a concentration of 0.5 to 10% (at a leaching rate of 500 to 1000 m3/ha and when the preparation is added directly to water), the following was established [3, 4]:

- According to the data analysis of filtrates, soil washing in bulk columns showed that the Biosolvent solution removes significantly more amount salts from highly saline soil than distilled water. The amount of removed salts increases with increasing concentration of the Biosolvent solution. The higher ion content in the filtrate is evidence of more efficient leaching of the soil from salts. A solution of the Biosolvent preparation, with a concentration of 2% and 10%, in comparison with distilled water, enhances the leaching of salts, respectively, by a dense residue by 1.2 times and 1.7 times, and by EC - by 1.3 and 4.1 times.

- Increasing the concentration of Biosolvent during leaching contributes to greater leaching of divalent Ca and Mg cations. When leaching the soil with a 2% solution of the drug, the leaching of calcium ions was 3 times (magnesium - 1.6 times), more than in the control, and at 10% concentration of the drug, calcium 15 times (magnesium - 2.4 times) more.

- A higher leaching ability of the Biosolvent preparation in the form of a solution of 10% concentration, having an acidic environment (pH=1.9) was established and a technology was proposed for using the preparation of this concentration, by spraying method the soil.

3.2. It has been established that spraying saline soil (before supplying water for leaching) with a solution of the drug, in a ratio of 1:10 with water, increases the leaching of HCO3, SO "4, Ca, Mg ions and, respectively, by 52, 26, 49 and 15%. The removal of calcium and magnesium sulphates is also 40-50% higher than in the control (leaching with river water, without soil treatment with the preparation).

3.3 The results of field studies of leaching of saline soils using Biosolvent also showed that the preparation enhances the leaching of ions. Under the influence of leaching, the ionic composition of the soil changed as follows:

- the content of HCO3, when leached with Biosolvent - decreases (hor. 0-30 cm), or increases to a lesser extent, and in the control (after leaching with plain water), - slightly increases.

- chlorine ion is leached out very well: on the control in a layer of 0-70 cm, -17.7% of the initial content was taken out, and in the variant, with Biosolvent 59.6%, the difference between the variants was 41.9%.

- the influence of Biosolvent is also noticeable when comparing the leaching of sulphates, which in a layer of 0-70 cm was: 21.8% - in the control and 35.2% - in the variant with the preparation (difference -13.4%);
- leaching of calcium ions from a layer of 0-70 cm, in the control was -32.5%, and in the experiment - 60.5% (difference - 28%);
- the content of magnesium, in a layer of 0-70 cm, in the control decreased by 2.9%, and in the experiment, it increased by -74.7%, which can be explained by an increase in the dissolution of magnesium by Biosolvent;
- an increase in sodium ion leaching in the soil layer of 0-70 cm was also noted: in the control, its leaching amounted to -36.6%, and in the experiment with the preparation, - 56.3% (difference -19.7%).

An illustration of the differences in the leaching of individual ions in the control and when using Biosolvent is shown in Figure 2.

The results of the study of soil leaching with Biosolvent indicate an increase in the intensity of salt leaching (up to 42% for chlorine). This means that the use of the preparation allows you to save up to 40% of the volume of water for leaching. Based on previous studies by the authors [5], for medium saline medium loamy soils, the calculated leaching rate is 4000-5000 m3/ha. Therefore, water savings can be 2000 m3/ha.

It also follows from experience that when using the preparation for leaching the soil from salts, not only the total but also the unit water consumption is reduced. With conventional leaching, to reduce salinity (according to TDS) by 0.1%, the actual unit water consumption is 1190 m3/ha, and with leaching using Biosolvent - 583 m3/ha, that is, almost half as much.

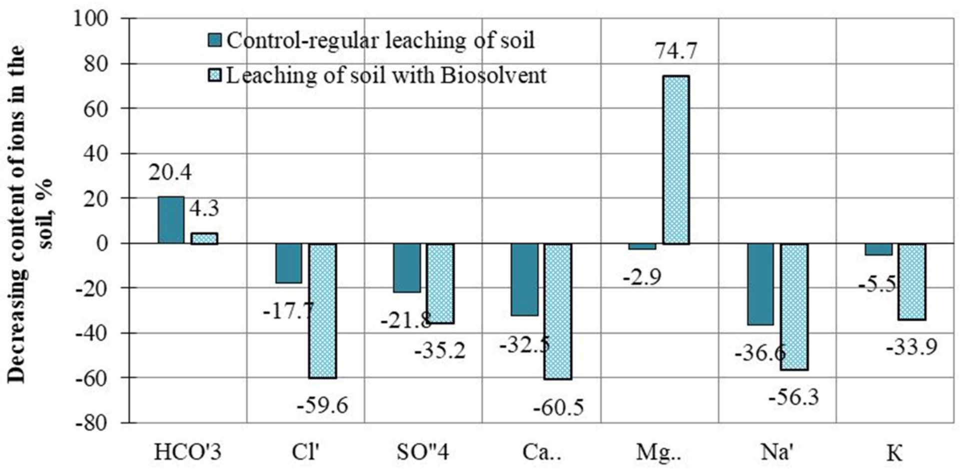

Fig. 2. Illustration of increasing ionic leaching during washing of soil with Biosolvent (0-70 cm). Based on 2016 field soil wash results, an average of 5 survey points, Mirzaabad.

To clarify the values (volumes) of possible water savings during leaching with the use of Biosolvent, indicators of soil leaching were determined, based on actual data on soil desalinization by conventional leaching and with Biosolvent in field conditions. The calculations were carried out according to the formula of V.R. Volobuev:

$$MLE = 10000\ \alpha\ \lg (Sin/Sadd)$$

where:
MLE – leaching rate, m3/ha;

Sin – salt content in the soil layer in need of washing, in% of the soil mass;

Sadd – permissible salt content in this layer, in% of the soil mass;

α – soil leaching coefficient, established according to the data of pilot production flushing.

The required leaching rates for highly saline soils, in the considered leaching options, are calculated using the same formula and the soil leaching coefficient indices established experimentally.

The determination of indicators of leaching of salt based on the actual data in the variants of field experiments, as well as the leaching rates calculated from them, which are necessary for highly saline soils, are shown in Table 1.

The data in Table 1 show that when using Biosolvent, the intensity of salt leaching (by dense residue) increases. At the same time, the indicator of leaching, used in the formula of V.R. Volobuev, decreases by 2.3 times. This, accordingly, bring a reduction in the leaching norm. According to the calculation given in Table 1, complete desalination of highly saline soils can be achieved: with normal leaching, the volume of water (necessary net leaching rate) is 8549 m3/ha, and with the use of the preparation, 5298 m3/ha will be required or 38% less.

3.4 Deep loosening of gypsum and saline soils in a layer of 0-70 cm, carried out in the area of the Bek cluster in the Khavast district, made it possible to reduce the volumetric mass of the soil by about 25%: from 1.55-1.65 g/cm3 to 1.18 -1.36 g/cm3 (Figure 3) [7, 8]. This potentially contributes to an increase in cotton yields up to 50%. In accordance with domestic criteria (The method of soil bonitet of Goskomzem of Uzbekistan, 1981), with a volumetric weight of 1.4 g/cm3, yield losses are 10-15%; at 1.5 g/cm3 - 20-30%; at 1.6 g/cm3 - 30-50%, and at >1.6 g/cm3 40-60%.

Table 1. Indicators of soil salinity by TDS (%) and calculated leaching rates for highly saline soils in the variants field experiments (for layer 0-70 cm (on data 2016).

S initial before leaching, % by mass	Sfinal, % by mass	Differences (Sinitial-Sfinal)	Sinitial/ Sfinal	Lg Sinitial/ Sfinal	Soil leaching, coefficient, α	Ratio: αC/ αB	Calculated norm of leaching soils, m3/ha	Differences (C-B)	
								m3/ha	%%
Control (C)									
0,812	0,644	0,168	1,26	0,10	1,99		8549		
Biosolvent (B)									
0,842	0,499	0,343	1,69	0,23	0,88	2,3	5298	3251	38

In accordance with the previously proposed technologies for the development of lands with gypsum and saline soils, after deep loosening, it is recommended to carry out their capital leaching by the norm of 10000 m3/ha, against the background of well-functioning permanent drainage, enhanced by temporary drains (up to 1 m). Simultaneously with deep loosening of the soil, it is recommended to introduce at least 20 t/ha of lignin or manure (which acidifies the soil and enriches it with organic matter) as ameliorants. Currently, this technology cannot be applied for a number of reasons, including:

- Deficit of water resources;
- Lack of chemical ameliorants, including manure and lignin;
- Unavailability of descending water flows during leaching, due to the unsatisfactory state of field drainage, as well as the consistently close location of groundwater from the surface of 1.5-2.5 m.

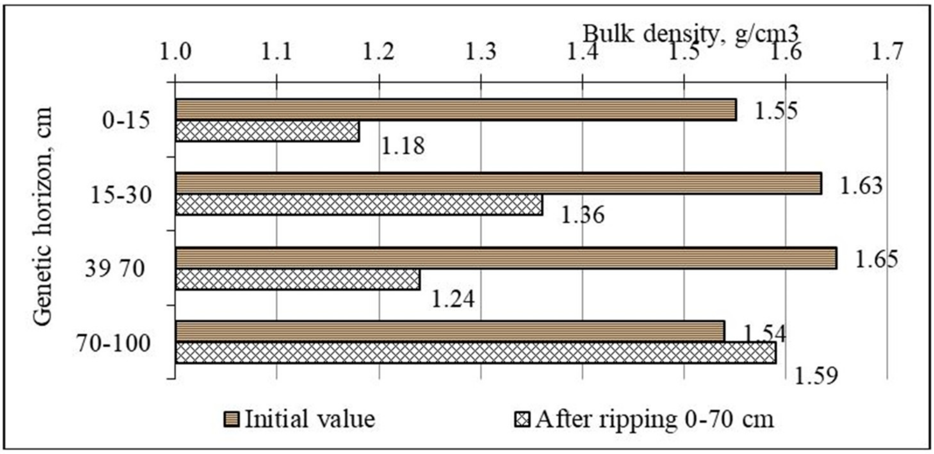

Fig. 3. Change in soil bulk density after ripping according to soil transect data in the Bek Cluster, 2019 [7].

Under these conditions, even in the presence of water, it is impossible to organize high-quality soil desalinization, since at GWL=2 m, the capacity of soil saturation with water during leaching, according to calculations for medium loams, is 2100 m3/ha. If you do not provide a sufficient outflow of leaching water and do not supply an additional (salt-displacing) volume of water and do not provide its downward flow, then leaching the soil from salts will not be successful.

The above results of increasing the efficiency of leaching, due to the use of the organic preparation Biosolvent, seem to us to be a modern solution, an alternative to the introduction of organic additives (manure, lignin).

Experimental washing of the soil in 2020, with traditional technology (by cells), after loosening soil, with a water supply of 2000 m3/ha, carried out in the Bek cluster, showed the low efficiency of this soil's desalinization by leaching, even despite the use of the Biosolvent ameliorant (table 2). The salts in the 0-70 cm layer dissolved and slightly moved down (Figure 4a). It is likely that the layer of water poured into the checks during leaching compacts the loosened soil to its original state [1]. At the same time, the water is poorly filtered down, and, accordingly, the displacement of salts is reduced.

In this experiment, Variant 1 was also laid - soil desalinization under the influence of precipitation, without the cost of irrigation water. The combination of loosening the soil with spraying it with Biosolvent made it possible to reduce soil salinity by the beginning of the growing season to a depth of up to 70 cm, with the most pronounced effect in the 0-30 cm layer (Figure 4b, Figure 5).

Table 2 shows that in the upper 0-30 cm soil layer in the variant of desalination by precipitation, soil salinity decreased by 4.7 dS/m.

Thus, the possibility of desalination of loosening soil processed with Biosolvent by atmospheric precipitation has been experimentally proven. This technology does not require the cost of irrigation water and labour for preparation before and after leaching, delivery, and filling of water, etc.

Table 2. Comparison of soil salinity by experimental variants at observation points in the 0-30 cm layer (experimental washing of the soil in 2020)

Option of experience	Observation points code	Soil salinity by ECe, dS/m			
		04 March	05 June	Changes	Average for the variant
Leaching by checks at the norm of 2000 m3/ha, when spraying the soil with the preparation, before pouring water	1-1	13,26	10,94	2,3	5,0
	1-2	15,40	13,00	2,4	
	2-3	21,81	11,63	10,2	
Soil desalinization by precipitation (190 mm) on the background of ripping and spraying the soil with the preparation	1-2	16,65	12,42	4,2	4,7
	1-3	12,04	10,36	1,7	
	2-1	20,69	15,44	5,3	
	2-2	20,6	17,63	3,0	
	2-3	22,96	13,65	9,3	

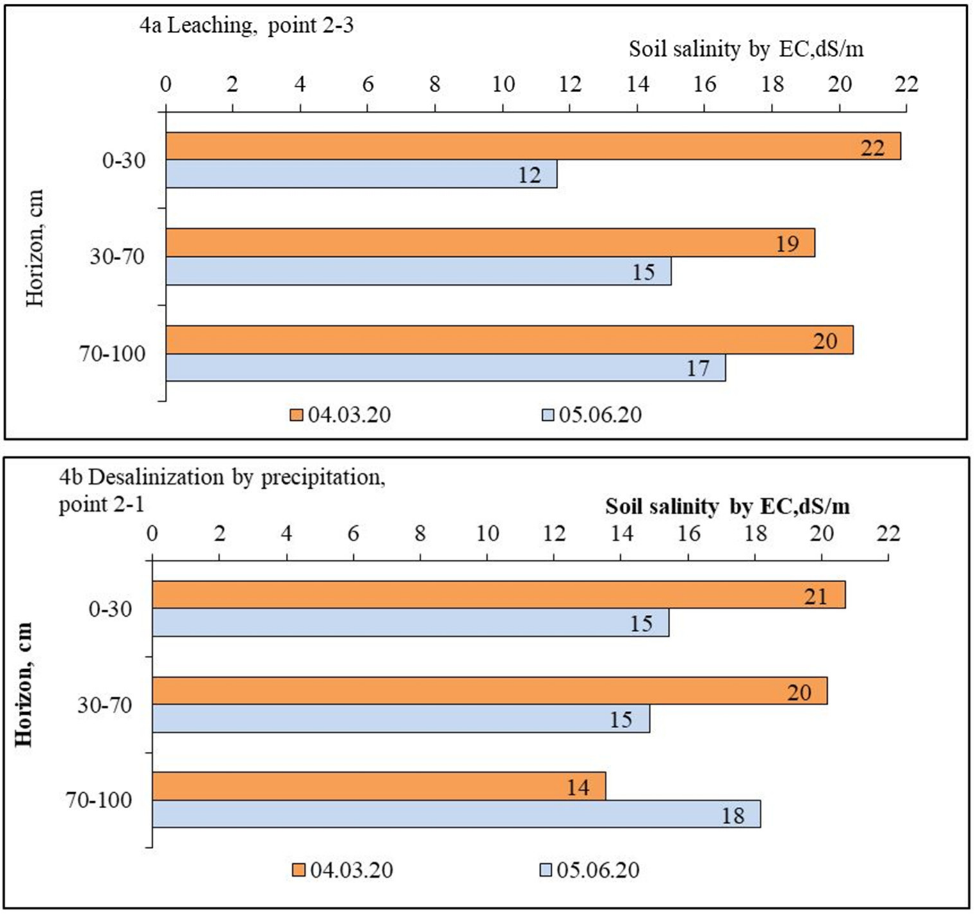

Fig. 4. Illustration of the possibility of desalinization of the upper layer of highly saline soils by precipitation (2020).

4 Conclusions

Strengthening of salts leaching from saline soil with the use of local preparation Biosolvent created on the basis of polymaleic acid was established. The technology of Biosolvent application for leaching, by spraying the soil in checks, before the water supply, has been experimentally verified. Indicators have been established: preparation consumption - 10 liters per 1 hectare, concentration - 10 %, pH = 1,9. Leaching with preparation almost doubles the output of salts from the soil and saves up to 40% of irrigation water (2000 m3/ha, with a medium degree of soil salinity).

Recommendations for desalinization of highly saline soils along the whole profile (and compacted, in separate layers, or entirely), were prepared during their development: in the mid-eighties of the 20th century. According to these recommendations, for the reclamation of such soils, it is necessary to supply large volumes of water by tact: dissolving salts and creating flows displacing salts on the background of powerful, well-working permanent drainage, reinforced by temporary drains. At present time it is technically impossible and economically unprofitable, as there are not enough water volumes, ground waters are steadily located at the depth of 2.0-2.5 m (in some zones about 1.0-1.5 m), and field drainage is worn out and cannot provide intensive drainage of leaching water.

The variant of technology for the development/rehabilitation of hardly meliorated (saline and gypsiferous) lands under water resources deficit is developed. The technology includes deep loosening and soil treatment with a 10 % solution of Biosolvent, at 10 l/ha, with further soil desalinization by precipitation. Such technology is most effective at close groundwater tables, and, hydraulically based, on the gradual movement of salts downwards, by drops and streams of water in the soil, formed by precipitation. This creates a more environmentally friendly effect of water on the soil than washing with a layer of water in checks when both soil and salts are dissolved in water. (With a small supply of water to the checks, salts only dissolve and are not sufficiently washed out to down, but the soil will be compacted in this area). So, in some conditions, the use of rainfall is a method possible for the desalinization of soils. As it is desalinized, it is recommended to use these lands for sowing salt-tolerant crops, including fodder crops.

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