Amelioration and Utilization of Alkali Soils of the Solonchak and Solonchak-Solonetz Types in the Region between the Rivers Danube and Tisza

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The alkali ("szik") soils occurring in Hungary's region between the rivers Danube and Tisza, except those lying close to the Tisza, contain large amounts of $CaCO_3$, and varying amounts of Na_2CO_3 and other salts of sodium, with here and there salt efflorescence. These are soils poor in humus and nitrogen and their adsorptive complex is dominated by Na^+. Such soils are classified as solonchak and solonchak-solonetz.

Most of such soils are to be found in low areas and, previous to their drainage about 1920, they used to be periodically flooded, partly by inundations of the Danube, partly by inland waters draining from higher areas.

Highly calcareous alkali soils containing varying amounts of Na-salts have developed on sites where, year after year, flood water have evaporated for thousands of years. The accumulation of Na-salts was particularly high on areas without natural drainage. It has been established that even water of the Danube, containing only small amounts of Na-salts, but plenty of $Ca(HCO_3)_2$ and generally considered to be excellent for irrigation purposes may cause alkalization when large amounts evaporate from the soil surface.

High water-tables contribute to the accumulation of Na-salts and alkalization of soils. The water-table, even in drained areas, is generally 1 to 1.5 m below the surface, but at some sites and periods it rises to within 40 cm, 30 cm or even closer to the surface.

Depth of the alkali-rich layer varies from 70 to 250 cm and, from the north towards the south, it becomes gradually deeper. There is sand and gravel below it down to a depth of 10 to 60 m, and this forms a natural drainage system which renders the leaching of these soils possible. For the time being these soils are covered with a natural sod, the composition of which depends on the properties and hydrological conditions of the soil. Since the establishment of drainage the leaching process is predominant, something clearly indicated by the change in composition of the vegetation.

The first requirement in reclaiming alkali soils in this region, the first thing to do is a thorough regulation of the hydrological conditions. Subsequent utilization of the soils can be done on two different bases, namely:

1. the quality of meadows and pastures will be improved by various processes, such as fertilizing, irrigation, weeding, etc. but without chemical and physical amelioration;

2. by carefully chosen chemical and physical methods the soil will be reclaimed and made suitable for growing field crops.

Table

Change of properties of solonchak soils resulting

Treatment	Depth cm.	$CaCO_3$ %	k_A	pH			
		1952		1952	1953	1955	1959
Ø	0—20	13.7	35	9.31	9.18	9.41	9.09
	20—30	21.9	34	9.51	9.32	9.58	9.28
	30—40	31.9	33	9.59	9.35	9.63	9.30
	40—50	—	32	9.54	—	—	9.30
	50—60	—	26	9.42	—	—	9.24
Gypsum 122 q/ha (= 72.8 q/ha $CaSO_4 \cdot 2\ H_2O$)	0—20	13.4	33	9.33	9.10	9.28	8.67
	20—30	21.4	34	9.62	9.32	9.52	9.20
	30—40	31.0	34	9.66	9.37	9.57	9.25
	40—50	—	30	9.62	—	—	9.29
	50—60	—	27	9.46	—	—	9.20
Gypsum 244 q/ha (= 145.6 q/ha $CaSO_4 \cdot 2\ H_2O$)	0—20	14.5	34	9.30	8.83	9.09	8.56
	20—30	23.0	35	9.63	9.33	9.50	9.14
	30—40	33.5	34	9.61	9.32	9.52	9.22
	40—50	—	31	9.55	—	—	9.18
	50—60	—	26	9.42	—	—	9.06
Gypsum 366 q/ha (= 218.4 q/ha $CaSO_4 \cdot 2\ H_2O$)	0—20	13.7	35	9.30	8.62	8.88	8.35
	20—30	21.0	34	9.57	9.30	9.40	8.91
	30—40	29.3	34	9.61	9.33	9.47	9.01
	40—50	—	31	9.58	—	—	9.09
	50—60	—	26	9.45	—	—	9.08
Gypsum 488 q/ha (= 291.2 q/ha $CaSO_4 \cdot 2\ H_2O$)	0—20	13.3	36	9.27	8.32	8.31	8.14
	20—30	18.2	35	9.57	9.22	9.30	8.72
	30—40	25.1	34	9.58	9.28	9.38	8.94
	40—50	—	31	9.60	—	—	8.95
	50—60	—	27	9.43	—	—	8.92

k_A = "sticky point" according to ARANY.

Several experiments dealing with the reclamation and utilization of "szik" soils have been conducted for over a decade in the region between the Danube and Tisza, primarily in the part adjacent to the Danube. Major results of these experiments are as follows:

1. *Utilization as grassland*

Results achieved in this way are dealt with in an other report. However, it should be mentioned that on the average of 10 years HERKE has obtained the following hay yields (q/ha):

	Ø	N_{71}	N_{142}	N_{213}
a) on non-irrigated land	8.17	22.94	35.11	42.75
b) on irrigated land	25.03	41.36	53.18	61.87

Note: The subscripts in the headings refer to N applied in terms of kg/ha.

1.

from various doses of gypsum without irrigation

Total salts %				Exchangeable Na^+ me./100 g.				Na^+ percentage of "S" value			
1952	1953	1955	1959	1952	1953	1955	1959	1952	1953	1955	1959
0.34	0.18	0.20	0.13	11.9	11.3	8.7	8.7	70	67	51	51
0.53	0.20	0.20	0.17	14.7	12.0	9.9	10.6	115	94	77	83
0.67	0.24	0.20	0.17	12.9	9.4	8.5	8.5	140	102	92	92
0.62	—	—	0.14	10.4	—	—	6.3	135	—	—	82
0.48	—	—	0.08	6.9	—	—	4.2	119	—	—	72
0.35	0.18	0.12	0.07	11.9	8.6	7.0	5.2	70	51	41	31
0.62	0.19	0.18	0.14	14.7	10.8	9.1	9.5	115	84	71	74
0.69	0.21	0.18	0.15	12.9	9.6	7.6	8.6	140	104	82	93
0.54	—	—	0.13	10.4	—	—	6.7	135	—	—	87
0.40	—	—	0.07	6.9	—	—	4.2	119	—	—	72
0.34	0.16	0.09	0.05	11.9	6.8	4.7	3.7	70	40	28	22
0.59	0.19	0.16	0.10	14.7	10.8	8.1	7.8	115	84	63	61
0.66	0.20	0.13	0.10	12.9	9.6	7.7	6.6	140	102	84	72
0.71	—	—	0.07	10.4	—	—	4.7	135	—	—	61
0.44	—	—	0.05	6.9	—	—	3.4	119	—	—	58
0.33	0.16	0.11	0.03	11.9	5.9	3.9	3.1	70	35	23	18
0.60	0.18	0.15	0.07	14.7	10.5	7.1	5.8	115	82	55	45
0.74	0.19	0.16	0.07	12.9	9.0	7.0	5.2	140	98	76	56
9.60	—	—	0.07	10.4	—	—	4.2	135	—	—	54
0.41	—	—	0.04	6.9	—	—	3.0	119	—	—	52
0.29	0.19	0.15	0.03	11.9	4.5	1.4	1.8	70	27	8	11
0.57	0.19	0.17	0.07	14.7	10.3	6.5	3.5	115	82	51	27
0.66	0.19	0.16	0.09	12.9	9.4	6.3	5.0	140	102	68	54
0.66	—	—	0.08	10.4	—	—	4.1	135	—	—	53
0.44	—	—	0.06	6.9	—	—	3.1	119	—	—	53

2. *Utilization by field crops grown after chemical and physical amelioration*

Solonchak and solonchak-solonetz soils can be used for growing field crops only after a thorough reclamation of their extremely bad chemical and physical properties. For this purpose several reclaiming materials have been tested in our experiments, namely: mineral gypsum, sulphuric acid, hydrochloric acid, exposed and roasted alunite, lignite dust unfit for use as fuel, ferrosulphate (an industrial by-product), gypsum sludge from sulphuric acid and alumina factories. All of them have proved to be suitable ameliorating materials, both in experiments and in actual farm practice. However, only lignite dust and gypsum or their combination are being used, as they are the ones available.

In the course of our investigations the following methods have been studied:

a) Chemical amelioration without irrigation.

b) Chemical amelioration along with sprinkling irrigation with and without subsoiling,

c) Chemical amelioration along with rice growing

With each treatment various combinations of manuring and of crops were studied.

Table 2.

Yields obtained on solonchak soils reclaimed with various amounts of gypsum without irrigation

Treatment	Mangel-wurzel (roots)	Wheat (grain)			Rye (grain)			Sweet clover (green)
	Yield kg./100 m²							
	1953	1954	1957	1958	1959	1960	1961	1963
Ø	19.99	0	0	1.17	10.16	2.83	2.67	24.49
72.8 q/ha $CaSO_4 \cdot 2\ H_2O$	161.60	5.83	2.83	3.66	21.32	14.16	10.17	26.16
145.6 „ „	151.61	6.16	4.83	4.33	28.49	19.82	14.50	73.30
218.4 „ „	128.28	4.33	3.66	4.16	24.82	21.16	16.17	80.80
291.2 „ „	106.62	3.50	1.67	3.00	28.99	21.99	11.50	88.62
S. D. (5% point)	27.15	1.46	1.33	1.48	2.73	2.50	2.00	23.66

a) *Chemical amelioration and utilization of solonchak and solonchak-solonetz soils without irrigation.* — Comparative experiments have been carried out with reclaiming materials of various doses mixed into the upper 0 to 20 cm layer of the soil. The amounts required were worked out on the basis of an index number obtained by the method HERKE developed for this purpose. The index number is computed from the exchangeable Na^+ and soda contents of the soil.

The process of melioration in the case of dry farming (i.e. without irrigation) is presented with the results of an experiment with gypsum (Table 1.).

The data of Table 1 reveal the fact that only the 0 to 20 cm layer, into which the gypsum was worked, has been significantly improved. Total salts, pH, and exchangeable Na^+ have decreased considerably in the lower

Table

Change of properties of solonchak-solonetz soils resulting from the application

Treat me nt	Depth cm.	$CaCO_3$ %	k_A	pH		
		1959. VIII.		1959. VIII.	1962. X.	
					without subsoiling	with subsoiling
Ø	0—10	5.1	34	8.38	8.74	8.69
	10—20	12.4	38	9.09	9.01	9.01
	20—40	25.3	33	9.25	9.35	9.36
	40—60	38.8	25	9.25	9.41	9.40
Lignite dust 1738 q/ha (= 191 q/ha $CaSO_4 \cdot 2\ H_2O$)	0—10	5.1	33	8.35	7.68	7.79
	10—20	11.8	40	9.07	8.12	8.08
	20—40	24.1	33	9.33	9.05	8.54
	40—60	33.7	26	9.25	9.34	9.31
Gypsum dust 347 q/ha (= 191 q/ha $CaSO_4 \cdot 2\ H_2O$)	0—10	4.8	35	8.45	7.54	7.58
	10—20	12.3	39	9.08	8.22	8.00
	20—40	20.5	34	9.31	9.09	9.01
	40—60	31.8	26	9.25	9.25	9.20

layers, but the percentages of Na^+ equivalent reveal that here the soil has remained alkaline. As a consequence, soils reclaimed in this way will have only a shallow layer with good tilth. In the cultivated topsoil the rate of improvement was considerable even in the first year, while at lower levels it took place only after some years owing to the slow dissolving and percolation of gypsum under the influence of the natural rainfall (500 to 600 mm per annum). The subsoil has kept on improving, though at a slower rate, after the first three years.

Total salts in the control plots broken up, and planted with field crops, without chemical amelioration, have decreased considerably. This is because the upper 80 cm layer of the experimental plot is a medium heavy sandy loam with a highly permeable sand beneath; when the upper level is cultivated an appreciable leaching probably takes place as a result of natural precipitation.

Similar improvement was achieved with lignite dust if used in equivalent amounts to the active agent of gypsum dust. Main active agents of lignite dust are: gypsum, ferrosulphate and sulphur. In soils with alkaline reaction lignite dust has an additional beneficial effect due to its organic matter content (about 35 per cent), though the nature of its action has not yet been clarified. The extensive use of lignite dust is hampered by its low content of active agent and consequently the great amounts required. In our latest experiments lignite dust applied in combination with gypsum gave very good results.

The progress of improvement is manifested not only in change of soil properties but also in the growth of plants and in the yields (Table 2.).

The above data reveal that, in the years subsequent to amelioration, yields did not increase in proportion to the amount of gypsum applied or to the apparent soil improvement; on the contrary, yields decreased. KÓNYA has suggested that the repressive effect of $CaSO_4$ on nitrification may be the cause. According to recent experiments this decrease can be prevented by

3.

of lignite dust, gypsum dust and subsoiling along with sprinkler irrigation

Total salts %			Exchangeable Na^+ me./100 g.			Na^+ percentage of "S" value
1959. VIII.	1962. X.		1959. VIII.	1962. X.		1959. VIII.
	without subsoiling	with subsoiling		without subsoiling	with subsoiling	
0.08	0.13	0.11	4.23	5.22	4.00	35.2
0.20	0.17	0.15	9.21	7.65	7.10	82.2
0.20	0.20	0.18	8.71	10.03	9.10	104.9
0.13	0.15	0.14	5.77	6.93	6.17	111.0
0.08	0.10	0.10	4.37	1.82	2.07	38.7
0.18	0.12	0.11	10.18	3.23	3.18	90.9
0.18	0.19	0.18	9.64	6.92	6.88	110.8
0.13	0.15	0.15	6.14	5.52	6.18	113.7
0.08	0.16	0.12	4.22	0.56	0.58	41.4
0.19	0.20	0.15	9.93	2.42	1.27	90.3
0.19	0.20	0.17	9.48	6.72	5.63	107.7
0.12	0.15	0.13	5.55	5.08	4.13	106.7

Table 4.

Yields obtained on solonchak-solonetz soils reclaimed with lignite dust, gypsum dust and subsoiling along with sprinkler irrigation (1962—1963)

Treatment	Wheat grain crop		Mangel-wurzel root crop		Sunflower grain crop		Red clover hay crop		Sweet clover hay crop	
	q./ha.	%	q./ha.	%	q./ha.	%	q./ha.	%	q./ha.	%
⌀	6.5	100	206	100	6.5	100	28.8	100	20.0	100
Subsoiled	6.9	106	220	107	7.7	118	35.2	122	24.4	122
Lignite dust.....	14.7	226	490	238	16.1	248	53.5	186	22.0	110
Lignite + subsoiling	18.4	283	640	311	18.0	277	69.5	241	36.3	181
Gypsum dust.....	12.7	195	424	206	18.0	277	56.3	195	24.4	122
Gypsum + subsoiling	16.5	254	537	261	19.9	306	69.2	240	25.7	128
SD_5%	2.9	45	123	60	3.4	52	8.9	31	8.9	44

an adequate dose of nitrogen fertilizer. Experimental results of 1959—1963, when doses as low as 35 kg/ha. of nitrogen were applied, seem to support this suggestion.

Chemical reclamation of alkali soils for production of field crops without irrigation is not profitable.

Table

Change of properties of solonchak-solonetz soils resulting from the application

Treatment	Depth cm.	$CaCO_3$ %	k_A	pH			
		1954. IV.		1954. IV.	1954. X.	1955. XII.	1956. X.
⌀	0—10	9.5	36	8.88	8.90	8.56	8.61
	10—20	9.3	37	8.98	8.93	9.08	8.89
	20—30	17.1	34	9.30	9.37	9.43	9.36
	30—40	26.5	31	9.48	9.47	9.57	9.48
	40—50	40.8	26	9.25	9.60	9.52	9.59
	50—60	41.9	21	9.20	0.30	9.53	9.49
Gypsum sludge 400 q/ha (= 200 q/ha $CaSO_4 \cdot 2\ H_2O$)	0—10	11.7	36	8.97	7.98	7.95	7.90
	10—20	12.4	34	9.13	8.37	8.37	8.31
	20—30	22.6	31	9.37	9.25	8.82	9.07
	30—40	29.6	28	9.52	9.52	9.05	9.22
	40—50	40.8	25	9.50	9.45	9.25	9.22
	50—60	32.4	23	9.45	9.47	9.15	9.17
Lignite dust 800 q/ha (= 160 q/ha $CaSO_4 \cdot 2\ H_2O$)	0—10	8.0	37	9.07	8.53	8.26	8.05
	10—20	9.2	34	8.86	9.00	8.90	8.65
	20—30	15.5	31	9.33	9.52	9.45	9.42
	30—40	22.6	29	9.30	9.52	9.50	9.50
	40—50	28.4	25	9.30	9.57	9.57	9.57
	50—60	29.6	22	9.30	9.50	9.55	9.50

b) *Chemical amelioration and utilization of solonchak and solonchak-solonetz soils in combination with subsoiling and sprinkler irrigation.* — In order to accelerate and intensify the rate of leaching and to develop a deeper tilth on saline, sodic alkali soils, as well as to secure a better water supply for the crop plants, we have been conducting experiments in recent years in which chemical amelioration is combined with subsoiling (i.e. subsoil loosening) and sprinkler irrigation. By subsoiling to a depth of 60 cm, the strongly compacted "B" horizon, which is an obstacle both to leaching and to penetration of roots, was broken up. As chemicals, lignite dust and gypsum dust were applied. In 1960 and 1961 sweet clover was grown for green manure, and from 1962 on various crop plants were grown in rotation. In 1960 $2 \times 30 = 60$ mm, in 1961 $3 \times 25 = 75$ mm, in 1962 $12 \times 30 = 360$ mm and in 1963 $6 \times 30 = 180$ mm water was applied by sprinkler. Because of the low infiltration capacity of the soil more water could not be applied at a time.

The resulting changes in soil properties are shown in Table 3.

As revealed by these data, sprinkler irrigation, because of the small amounts of water applied at a time did not cause significant changes in the soil. Irrigation provides a better supply of water for the plants, and increases yields (Table 4.). 44 kg/ha P_2O_5 and 65 kg/ha N were given to the experimental plots in both years.

According to the average of two years data, sprinkler irrigation produced satisfactory yields, and subsoiling considerably increased the yield of all crop plants studied.

5.

of lignite dust and gypsum sludge to land for rice growing

Total salts %				Exchangeable Na^+ me./100 g.				Na^+ percentage of "S" value			
1954. IV.	1954. X.	1955. XII.	1956. X.	1954. IV.	1954. X.	1955. XII.	1956. X.	1954. IV.	1954. X.	1955. XII.	1956. X.
0.14	0.14	0.07	0.09	7.6	4.3	3.5	3.3	64	36	29	28
0.18	0.13	0.11	0.10	7.1	6.6	6.6	4.5	57	53	53	36
0.25	0.17	0.14	0.12	11.1	8.4	8.7	6.7	105	80	82	64
0.36	0.16	0.14	0.11	9.9	8.4	8.5	6.1	106	90	91	62
0.33	0.16	0.14	0.09	8.2	—	7.8	5.1	108	—	103	67
0.23	0.14	0.12	0.08	5.2	—	5.4	4.3	98	—	102	62
0.14	0.14	0.08	0.11	6.5	2.8	1.2	1.1	66	24	12	12
0.18	0.14	0.08	0.08	7.9	2.2	2.9	1.9	78	21	30	19
0.32	0.14	0.08	0.06	10.4	7.0	3.8	3.6	125	85	46	43
0.33	0.13	0.07	0.05	8.3	6.1	4.5	3.6	117	86	63	46
0.24	0.12	0.05	0.05	7.1	5.2	3.4	2.7	109	94	62	49
0.15	0.11	0.04	0.02	3.8	—	2.9	2.1	63	—	63	47
0.18	0.14	0.10	0.07	8.8	4.1	3.0	3.2	66	31	26	24
0.18	0.16	0.13	0.13	7.7	7.0	5.2	4.6	56	51	38	34
0.32	0.19	0.15	0.13	9.8	9.8	7.3	6.5	97	96	72	64
0.35	0.20	0.15	0.14	9.3	8.8	7.6	6.4	115	109	94	80
0.23	0.19	0.13	0.11	8.0	7.2	5.7	5.3	140	126	100	93
0.20	0.17	0.11	0.09	6.3	—	4.7	3.4	126	—	95	68

c) *Chemical amelioration and utilization of solonchak-solonetz soils for rice growing.* — The question of utilization of solonchak and solonchak-solonetz soils for rice production has been studied since 1954, along with attempts to bring about their amelioration. It has been established that on such soils — because of the high degree of alkalinity — chemical amelioration is an indispensable prerequisite to successful rice growing. Applications of reclaiming materials for rice production are considerably smaller than for other field crops. Rice can grow satisfactorily in soil with good structure to a depth of 10 to 12 cm. In soils of coarse texture constant flooding will bring about considerable leaching and improvement, so chemical amelioration of the top 10 to 12 cm layer may be sufficient. Finer textured alkali soils, however, have to be reclaimed to at least a depth of 20 cm, not so much for the sake of rice, but for the sake of the field crops which are to follow it.

The improvement achieved in alkali soils of coarse texture by chemical amelioration and flooding is shown in Table 5.

Leaching and improvement caused by flood water alone was considerable, as shown by the data. Gypsum sludge was more efficient than lignite dust, because of the higher active agent content of the dosages applied. It may be noted that, because of the increasing permeability of the soil, the water requirement for rice increased year by year, corresponding to the rate of soil improvement.

In course of these experiments the following rice yields were obtained (Table 6.).

Table 6.

Rice yields obtained on solonchak-solonetz soils

Treatment	Rice yield q/ha			
	1954	1955	1956	1957
∅	1.97	7.15	11.57	22.84
Gypsum sludge	32.40	12.60	22.00	sweet clover
Lignite dust.....	48.60	28.00	28.00	sweet clover

The data show rice yields on unreclaimed soil was not satisfactory in the first three years, but increased year by year. Though the reclaiming effect of lignite dust was lower than that of gypsum sludge, yields with lignite dust were higher. This may be due to its stimulating effect on plant development.

In heavy alkali soils the combined practices of chemical amelioration and subsoiling appeared to be the best.

d) *Manuring of reclaimed solonchak-solonetz soils.* — As alkali soils of this type are very poor in organic matter and nutrients, particularly in nitrogen, but often in phosphorus as well, manuring is indispensable. The potassium supply is usually medium or good.

For the methods described in items 1 to 3 manuring experiments were also conducted. The results show that organic manuring is neccessary partly to provide nutrients, but partly also to improve the physical properties of soil. If no farmyard manure is available, green manure may successfully be applied.

Application of N-fertilizer is essential and greatly increases the yield of all crops except legumes. Phosphorus used alone has a significant yield increasing effect only in the case of legumes. Generally the joint application of N and P fertilizers has proved to be the best. Potassium has no yield increasing effect. Effects of fertilizers are greatly enhanced by irrigation.

Results of experiments with joint application of fertilizers and irrigation, described (under item 3.), are shown in Table 7. Results indicate the first class importance of manuring in reclaimed alkali soils.

Table 7.

Fertilizing of solonchak-solonetz soils reclaimed with lignite dust + gypsum dust and leached (for 3+2 years) while growing rice (1961—1963)

Treatment	Rice grain crop		Wheat grain crop		Maize ear crop		Mangel-wurzel root crop		Red clover hay crop	
	q/ha	%	q/ha	%	q/ha	%	q/ha	%	q/ha	%
0	20.8	100	11.9	100	22.6	100	292	100	79.8	100
P_{90}	23.1	111	14.3	120	26.2	116	372	128	120.1	150
N_{125}	32.0	154	21.7	182	48.2	213	605	207	111.0	139
$P_{90}N_{125}$	34.1	164	28.2	236	46.7	207	713	244	110.0	138
S. D. (5% point)	2.4	12	3.5	29	10.2	45	53	18	11.6	14

The treatment subscripts refer to the "effective agent kg/ha".

Summarizing the results of our investigations it may be stated that saline, basic, calcareous alkali soils (i.e. solonchak and solonchak-solonetz soils) can be permanently reclaimed and made suitable for growing field crops with the use of proper chemical materials. In order to obtain a quicker and better result and to obtain efficient crop production, irrigation, subsoiling, and manuring (with organic manure and fertilizers) should be implemented.

The great irrigation scheme now being developed in the region between the rivers Danube and Tisza, has given careful consideration to the results of our investigations and our findings will be used extensively in the project.

Мелиорация и использование засоленных почв типа солончаков и солончаков-солонцов в междуречье Дуная и Тиссы

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Резюме

Засоленные почвы типа солончаков и солончаков-солонцов в Венгрии располагаются в первую очередь на территории, лежащей между реками Дунай и Тисса. Эти почвы содержат в больших или меньших количествах соду и другие соли натрия, а также большое количество карбоната кальция. Гумусом они бедны и их почвенно-поглощающий комплекс насыщен натрием. Причиной развития этих почв является отчасти испарение накопившихся поверхностных вод, отчасти капиллярное поднятие засоленных грунтовых вод. Под засоленным горизонтом, толщиной в 0,7—2,5 м, характеризующимся плохой структурой, на глубине 10—60 м находится слой песка и гравия, который создает естественную дренажную систему и этим самым возможность выщелачивания (промывания) этих почв.

В настоящее время эти почвы находятся под залежью и использование их под полевые культуры будет возможным лишь после коренного улучшения их крайне неблагоприятных химических и физических свойств.

Одним из способов, разработанных в целях лучшего использования этих почв, является повышение урожайности естественных выпасов (Puccinellia limosa, Agrostis alba) путем внесения удобрений а, где возможно, и орошением.

Другой метод, коренного улучшения, при котором производится подъем пласта за которым следует химическая мелиорация и посев полевых культур или трав. В качестве химических средств мелиорации используются гипс, или лигнитный порошок, или же смесь обоих веществ. В результате химической мелиорации химические и физические свойства почвы изменяются пропорционально дозам внесенных мелиорирующих веществ. Степень улучшения почвы наибольшая в первые два-три года, но процесс улучшения продолжатся, — хотя и медленнее — и после этого срока.

Для коренного улучшения почвы требуются очень большие дозы мелиорирующих веществ, поэтому, как правило, химической мелиорации подвергается только сравнительно тонкий (20—25 см) верхний слой почвы. В результате этого на таких площадях возможность выращивания полевых культур без орошения сильно ограничена и нерентабельна. Ряд опытов доказал, что наиболее быстрым и основательным методом улучшения таких почв является химическая мелиорация в сочетании с орошением, после которых и использование этих почв становится рентабельным. На территориях где проведено регулирование рек уже одно только орошение может вызвать значительное улучшение. Степень улучшения зависит от степени выщелоченности почвы, а также от количества и качества оросительной воды. Орошение повышает и эффективность химической мелиорации, т. е. весь профиль засоленных почв с более легким механическим составом можно в совершенстве промыть и изменить.

Из-за большой массы воды, используемой при затоплении риса наибольшее выщелачивание и улучшение почвы наблюдается при выращивании риса на почвах, подвергнутых химической мелиорации. На таких участках после 3—5 лет возделывания риса можно с успехом выращивать большинство полевых культур в условиях орошения. Выщелачивание можно усилить землеванием.

В течение ряда лет нами изучалась возможность комплексного использования дождевания, химической мелиорации и землевания. Хотя используемое при этом методе количество воды значительно меньше, чем при затоплении, — и следовательно и процесс улучшения почвы идет медленнее и менее интенсивно, оказывается, что растения и таким образом можно обеспечить необходимым для них количеством воды, то есть получить высокие и устойчивые урожаи. В этих опытах землевание в сочетании с глубоким рыхлением (60 см) почвы повысило урожайность всех участвовавших в опыте культур на 20—50%.

Ввиду того, что засоленные почвы весьма бедны питательными веществами, особенно азотом, для обеспечения соответствующего уровня урожайности наряду с химической и механической мелиорацией почвы неизбежно внесение удобрений. Наиболее важными являются азотные удобрения. Урожайность большинства полевых культур внесением одних азотных минеральных удобрений можно повысить вдвое. Урожайность бобовых культур же можно повысить внесением в первую очередь минеральных удобрений, содержащих фосфор.

При осуществлении грандиозного проекта орошения междуречья Дуная и Тиссы, происходящего в настоящее время, учтены и результаты наших опытов и будут созданы условия для их широкого внедрения в производство.