Reclamation of Sodic Soils in Rumania

C. V. OPREA, GH. SANDU, E. STEPANESCU and I. VLAS

Institutul Agronomic, Timisoara and I.C.A.R., Bucharest, Rumania

Sodic soils which commonly occur in the Socialist Republic of Rumania, are represented by the following genetic types: solonchak-solonetz, solonetz-solonchak, crusty solonetz, saline solonetz, structureless (alkali) solonetz, and shallow-, medium- and deep-columnar solonetzes. Differing from salt province to salt province, the genesis of sodic soils is largely determined by hydrogeological, lithological, soil, climatic, geochemical and other factors. Therefore the reclamation of these soils has to be differentiated according to their salt regime.

The development of sodic soils for Rumanian agriculture proceeds along these main lines:

1. improvement of sodic soils to be taken under meadow and pasture;
2. improvement of sodic soils by minimum reclamation;
3. improvement of sodic soils by rice growing;
4. drastic improvement of sodic soils by a complex approach and
5. the prevention of secondary alkalinization of drained and irrigated areas of soda-saline soils.

Improvement of sodic soils under meadow and pasture

Most of the sodic soils in the Socialist Republic of Rumania are now under pastures and meadows with inferior low-yielding plant communities. Thus, on the alkali solonetz of the Western Plain, natural plant communities are represented by *Festuca pseudovina, Statice Gmelini, Poa bulbosa* var. *vivipara, Artemisia monogina* var. *salina, Puccinellia distans, Nostoc comune* and *Matricaria chamomilla.*

The crops yield from 6 to 9 centners of green mass per hectare. On the Rumanian Plain, SERBANESCU [14] singles out the following plant communities depending on salinity: *Salicornia herbacea, Suaeda maritima, Salsola soda, Bassia hirsuta* and *Obione pedunculata* — on badly saline soils; *Aster tripolium, Crypsis aculeata, Crypsis schoenoides, Petrosimonia triandra, Champhorosma monospelioca* — on slightly saline soils; *Bassia sedoides, Artemisia maritima* and *Atriplex littoralis* — on moderately saline soils.

In the western part of the Rumanian Plain (OPREA et al. [7]) on a medium-columnar solonetz, a network of shallow ditches was laid out for surface water discharge. This was accompanied by the application of phosphogypsum (5 tons per hectare), ammonium-sulphate (200—250 kg per hectare) and sheep manure. Owing to these measures, the yield of green matter reached 80—100 centners per hectare, while the percentage share of legumes, especially *Trifolium repens*, in plant communities grew from 10—15 to 25—35.

The best results on an alkali solonetz on the Western Plain were gained by *Puccinellia distans* and applying 20 tons of phosphogypsum and 200 kilograms of ammonium-sulphate per hectare (VLAS and OPREA [16]) (Table 1).

Table 1

Yields of Atropis (Puccinellia distans) on an alkali solonetz in Socodor locality average for three years (1962—1964)

Reclamative agents and fertilisers	Yields, centn./ha periods		
	1st	2nd	3rd
1. Control	5.80	8.19	5.99
2. Phosphogypsum, 20 to/ha + ammonium sulfate, 200 kg/ha	44.82	51.49	25.35
3. Liquid manure, 20 to/ha + ammonium sulfate, 200 kg/ha	30.62	32.96	21.21
4. Phosphogypsum, 20 to/ha + liquid manure, 20 to/ha + ammonium sulfate, 200 kg/ha	37.92	41.95	20.02
5. Phosphogypsum, 10 to/ha + liquid manure, 10 to/ha + manure, 40 to/ha + ammonium sulfate, 200 kg/ha	18.87	42.46	23.79
LSD-5%	29.56	22.63	13.63

Leaning upon detailed ecological and floristic studies, SERBANESCU [14] proposed improving pastures of the Rumanian Plain by sowing the following crops: *Puccinellia distans, Aster tripolium, Agropyrum repens, Alopecurus, pratensis, Lotus corniculatus.* The most soda-resistant of the cereals on sodic soils of the Rumanian Plain are the following crops: *Agropyrum elongatum, Agropyrum tenerum, Melilotus albus,* in combination with *Agropyrum cristatum. Bromus inermis* is medium salt-resistant and *Dactylis glomerata* poorly salt-resistant (POP et al. [9]).

Improvement of sodic soils by minimum reclamation

The most effective development of sodic soils is obtained through the application of reclamative agents, chemicals and phytotechnics.

On a shallow- and medium-columnar solonetz on the Western Plain, it is possible to considerably increase the yield of grasses in a grass rotation system (OPREA et. al. [7]) by ploughing up natural pastures, applying fertilizers and sowing plants capable of surviving high concentrations of soda (sudan-grass, sorghum, *Puccinellia*, vetch-oats mixture, etc.).

Thus, on a shallow-columnar solonetz located at an experimental centre (OPREA et al. [8]), sudan-grass yielded 90.83—267.50 centners of green matter per hectare as a result of a number of measures: open ditches for surface water discharge, chiselling virgin soil to a depth of 20 cm, and the application of 5—10 tons of phosphogypsum and 200—250 kilograms of ammonium

Table 2

Yields of sorghum grain as a result of partial loosening of soil and other measures

Treatment	Yields, centn./ha			3 years' average	%
	1965	1966	1968		
1. Control	11.80	11.90	6.60	10.10	100
2. 20 to/ha of phosphogypsum + 200 kg/ha of $(NH_4)_2SO_4$	12.40	15.10	13.30	13.60	134
3. Drainage ditches, spacing 2 m, + 20 to/ha of phosphogypsum + 200 kg/ha of $(NH_4)_2SO_4$	14.30	17.30	16.30	15.90	157
4. Drainage ditches, spacing 1 m, + 20 to/ha of phosphogypsum + 200 kg/ha of $(NH_4)_2SO_4$	15.00	17.40	19.90	17.40	172
5. Drainage ditches, spacing 2 m	11.10	15.60	15.90	14.20	140
6. Drainage ditches, spacing 1 m	8.70	14.50	10.30	12.30	121
1 + 2 No drainage ditches	12.1	13.5	10.0	11.9	100
3 + 5 Drainage ditches, spacing 2 m	12.7	16.5	16.1	15.1	125
4 + 6 Drainage ditches, spacing 1 m	11.9	16.0	15.1	14.9	125
LSD — relative to control				1.4	11
LSD — relative to interaction				6.2	52
1 + 5 + 6 No phosphogypsum or fertilisers	10.5	14.0	10.9	12.2	100
2 + 3 + 4 Phosphogypsum and fertilisers	13.9	16.6	16.5	15.6	127
LSD — relative to control				0.18	2
LSD — relative to interaction				7.16	98

sulphate per hectare. Another method of raising the fertility of a sodic soil is to loosen it deep in rows and thus improve its water and salt regime. The above measures led to considerable changes in the water and salt regimes of an alkali solonetz in the area of Socodor (SANDU et al. [11]). (Deep loosening in rows was done by digging ditches with an interaxial spacing of 1 and 2 metres. The ditches 0.3 m wide and 0.6 m deep were dug by hand in autumn time).

The soils of the test plots subjected to partial deep loosening in rows (ditches being interspaced at 2 m), on applying 20 tons of phosphogypsum and 200 kilograms of ammonium sulphate per hectare, were high in moisture content. The highest in moisture (over 42 per cent) throughout the vegetation period were the soils subjected to deep loosening which occurred closest to the ditches. The farther the soil from the ditches the lower was the moisture content. This technique coupled with gypsuming and the application of fertilizers led to a sharp decrease in the exchangeable-sodium content in the soils.

The best results were recorded near the ditches (Fig. 1). At a depth of 20 cm, exchangeable-sodium content made up 8.97 per cent of the total

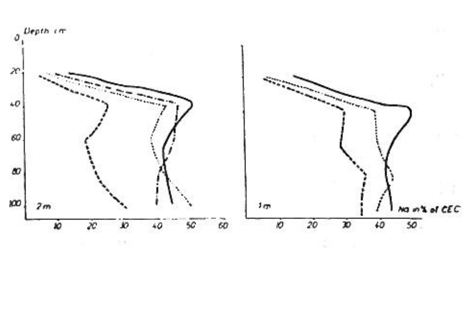

Fig. 1

Changes in exchangeable sodium content in soil (per cent of exchange capacity) as a results of deep loosening of soil, digging of ditches spaced at 1 m and 2 m, resp, and the application of phosphogypsum and fertilizers

Table 3

Sudan grass yields (green mass of first and second cuttings) on a shallow- and medium-columnar solonetz in Socodor locality (average data for 3 years)

Treatment	Yields		Yields increase	Significance
	centn./ha	%		
1. Control	125.06	100	—	—
2. 2.5 to/ha of sulfur + N_{96} + $P_2O_{5\,54}$	178.80	142	53.74	+++
3. 30 to/ha of phosphogypsum + N_{96} + $P_2O_{5\,54}$	204.26	163	79.20	+++
4. 1.25 to/ha of sulfur + 15 to/ha of phosphogypsum + N_{96} + $P_2O_{5\,54}$	197.33	158	72.27	+++
5. Lignite powder, 30 to/ha, + N_{96} + $P_2O_{5\,54}$	153.15	124	28.07	++
6. Lignite powder, 10 to/ha, + N_{96} + $P_2O_{5\,54}$	184.13	149	59.07	+++
LSD — 5%	191.70	36		
LSD — 1%	271.90	48		
LSD — 0.1%	341.13	67		

Note: In treatments 2 to 6, 40 to/ha of manure.

exchange capacity as against 18.83 per cent on control plots. By partial deep loosening in rows, gypsuming and applying fertilizers, an increase in sorghum grain yields of 5.8—7.3 centners per hectare was obtained (Table 2).

Tests conducted in Rumania show that agrochemical measures may have different effects on sodic soils (Colibas et al. [3], Bucur et al. [2], Maianu et al. [4], Sandu et al. [10], Stepanescu et al. [13], Tesu [15]).

Table 3. shows that on a shallow-columnar solonetz (passing into medium-columnar) of sodium-sulphate salinization which occurs in the locality of Socondor, the highest yield of green sudan-grass (average data for three

Table 4

Yields of winter wheat and sudan-grass (green, mass) on a shallow- and medium columnar solonetz in locality of Socodor (three years' average)

Treatment	Yields, centners/ha			
	Wheat	Yield increase	Sudan grass	Yield increase
1. Control	5.77	—	66.36	—
2. Non-reclaimed but fertilizers applied	13.61	7.97	113.56	47.10
3. 0.5 to/ha of phosphogypsum	16.52	10.88	122.83	36.47
4. 1 to/ha of phosphogypsum	19.95	14.31	145.20	78.84
5. 4 to/ha of phosphogypsum	19.40	13.76	149.16	82.80
6. 8 to/ha of phosphogypsum	20.24	14.60	144.60	78.24
7. 4 to/ha of phosphogypsum before ploughing + 1 to/ha annually by spreading	17.29	11.65	132.13	65.77
8. 8 to/ha of phosphogypsum before ploughing + 1 to/ha annually by spreading	17.84	12.00	116.06	49.70
9. 4 to/ha of phosphogypsum before ploughing + 1 to/ha annually by spreading	9.37	3.73	82.76	16.40
10. 8 to/ha of phosphogypsum before ploughing + 1 to/ha annually by spreading	8.14	2.50	88.03	21.67
LSD — 5%	2.75		15.75	
LSD — 1%	3.76		21.80	
LSD — 0.1%	5.11		29.73	

Note: In treatment 2—6, 40 to/ha of manure and 200 kg/ha of ammonium sulfate were applied.

years) on the first and second cuttings was obtained by applying 30 tons of phosphogypsum and 96 kg of N and 54 kg of P_2O_5 per hectare. The green yield for this treatment reached 204.26 centners per hectare, an increase of 79.20 centners per hectare.

Table 4 shows that the green yield of sudan grass varied from 82.76 to 88.03 centners per hectare with a definite increase over check on a shallow-columnar solonetz (passing into medium-columnar) occurring in the locality of Socodor by phosphogypsuming at rates of 4 and 8 tons per hectare before ploughing and at an annual rate of 1 ton per hectare (treatments 9 and 10).

On applying reclamative agents in combination with chemical and organic fertilizers in various doses, green yields of 144.60–149.16 centners per hectare were obtained (treatments 6 and 5). Such definite increases show that a complex approach is effective.

By applying phosphogypsum alone before ploughing and annually for winter wheat (treatments 9 and 10), definite yield increases were obtained. The highest yields were recorded in combination (treatments 6, 4 and 5).

Table 5

Rice yields on alkali solonetz in Socodor (3 years' average)

Treatments	Yields		Yield increase centn./ha
	centn./ha	%	
1. Control	5.26	100	—
2. 5 to/ha of gypsum	9.57	181	4.31
3. 10 to/ha of gypsum	12.51	237	7.45
4. 20 to/ha of gypsum	16.32	310	11.06
5. 20 to/ha of gypsum + N_2P_3	21.48	405	16.22
6. 6 to/ha of phosphogypsum	14.56	276	9.30
7. 12 to/ha of phosphogypsum	14.75	280	8.49
8. 24 to/ha of phosphogypsum	21.12	401	15.86
9. 24 to/ha of phosphogypsum + N_2	16.91	321	11.65
10. 10 to/ha of liquid manure	5.76	109	5.00
LSD — 5%	8.12		

The degree to which the soil surface was covered with vegetation had positive effects on reclamative processes (OPREA et al. [6]). An autumn sowing of a vetch-oats mixture and a spring sowing of fodder crops brought about an appreciable improvement in the physics (water-permeability, texture, plasticity), and hence biochemistry of the soils.

The alternation of annuals and perennials varying with the degree and type of salinity is also reclamative (especially of such crops as alfalfa and sweetclover).

Reclamation of sodic soils by rice growing

Sodic soils with average reclamative status and satisfactory internal drainage can be reclaimed through rice-growing.

By establishing a drainage network (capable of collecting, draining and removing mineralized water and soil solutions) and applying reclamative agents, it is possible to maintain an incessant flow of water and thus remove harmful salts down profile (OBREJANU et al. 1966). On an alkali solonetz in the locality of Socodor, rice yields increased with increasing rates of gypsum and phosphogypsum. The highest yields were obtained in the first instance by applying 20 tons and 24 tons of reclamative agents per hectare (Table 5).

Drastic reclamation of sodic soils by the complex approach

Most of the sodic soils in the Socialist Republic of Rumania can best be reclaimed by the complex approach, i.e. a combined application of hydraulic engineering, agrotechnical, biological and agrochemical measures. Their timely and exacting implementation is absolutely essential to land reclamation.

Hydraulic engineers should attend to straightening and deepening the beds of rivers and other watercourses in order to improve soil drainage, prevent inundations and make available enough water through its economical use for irrigation and the removal of mineralized water in the process of reclamation.

On test plots in the Calmatui River Valley (Rusetu, Smeeni, Batogu), trials are being held designed to develop sodic soils by the complex approach which involves the installation of drainage, levelling, leaching and irrigation, the use of mole drainage, chiselling the soil, conditioning the soil with synthetic polyelectrolytes, the application of fertilizers, etc.

The trials are being held under difficult soil-reclamative conditions of the following soils: a solonchak-solonetz, a solonetz-solonchak, a columnar solonetz and sodic soils.

Table 6

Grain yields of maize (variety HO-208) depending on phosphogypsuming doses; 3rd treatment on plot with drainage in the locality of Rusetu after leaching; the 2nd year of reclamation (1967); centners per hectare

Treatments	Leaching doses, m^3/ha			
	5.000	7.500	10,000	15,000
1. Control	19.80	34.50	26.50	25.80
2. 4 to/ha of phosphogypsum	28.70+	42.40	33.80	37.10++
3. 8 to/ha of phosphogypsum	33.90++	47.00++	38.80++	45.10+++
4. 12 to/ha of phosphogypsum	36.50+++	45.50++	43.10+++	54.20+++

Note: In nature, the soils are a columnar alkali solonetz in combination with a solonetz-solonchak.

The tests in the locality of Rusetu have shown that in complex reclamation (tile drainage, levelling, leachings, the application of reclamative agents), the amount of soluble salts removed from the soil increases with increased leaching. When the soil was leached with 5,000 m^3 of water per hectare, the amount of water-soluble salts moved down the profile to a depth of 1.8 m (bottom of drains) was equal to 85.11 tons per hectare after the first leaching and 35.51 tons per hectare after the second leaching, while with 15,000 m^3 of water per hectare, the amount of salts moved in the first instance was 150.5 tons and in the second 31.5 tons per hectare.

The soils had a content of exchangeable sodium exceeding 45 per cent of the total exchange capacity. After leaching and applying reclamative agents to the plot with closed tile drainage, a considerable drop was recorded in exchangeable-sodium content in a 60 cm deep layer. Thus, leaching with 5,000 m^3 of water per hectare and applying 12 tons of phosphogypsum per hectare decreased the exchangeable-sodium content by 12 per cent of the initial content after the first leaching and 35 per cent after the second. Leaching with 15,000 m^3 of water and applying 12 tons of phosphogypsum per hectare, decreased the exchangeable-sodium content by 35 per cent after the first leaching and 67 per cent after the second.

The reclamation was also evident in the uniform development of maize, a crop poorly resistant to salinity. Its yield varied only with the extent and quality of reclamation (leachings, irrigations, the application of reclamative agents and fertilizers).

On a columnar solonetz after the second leaching, maize developed normally and phosphogypsuming increased yields (Table 6).

Table 7

Yields of maize grain (variety HO-208) depending on doses of nitrogen fertilizers and irrigation; the second year of reclamation; irrigation dose 5,000 m^3 per hectare; (centners per hectare)

Treatments	Non irrigated	Irrigated
1. Control	26.00	28.40
2. 80 kg/ha of N*	27.30	36.40+
3. 120 kg/ha of N	26.80	40.20++
4. 180 kg/ha of N	29.80	41.60
LSD — 5%	9.70	7.50
LSD — 1%	13.00	10.00
LSD — 0.1%	17.00	13.00

* Nitrogen applied in ammonium-sulfate form.
Note: In nature, the soils are shallow- and medium-columnar solonetz.

In reclaiming sodic soils, as long as water soluble salts still remain in the soil solution, irrigation is important. In fact, without irrigation, no effects were recorded from the application of nitrogen, while with irrigation, the application of nitrogen brought about definite increases in yield (Table 7).

Prevention of the secondary alkalinization of drained and irrigated areas under sodic soils

Secondary alkalinization prevails on the Western Rumanian Plain where extensive drainage was operated late in the last century. Inadequate drainage caused soda-bearing ground waters to rise.

Secondary alkalinization manifests itself in the flood lands of the Danube and other rivers of the Rumanian Plain, in the zone of the pre-terrace flood lands, and depressions on the bottoms of water logged, insufficiently drained, low portions of relief. In order to prevent secondary alkalinization and reclaim patches of sodic soils it is necessary to build water collecting canals to intercept water and salts flowing from the terraces and foothills. This is done in combination with other reclamative measures.

With the construction of irrigation projects on depressed terraces

(Calaras, Simnichea), secondary alkalinization is caused by a rise in ground water level. The occurrence of soda in the waters and soils of the Rumanian and Western Plains, which are under irrigation, poses a very real danger of secondary alkalinization, especially to soils developed under a meadow-water regime (in natural conditions, such soils are very fertile). In view of this, it is absolutely essential to build drainage works in the areas of sodic soils. Before the construction of irrigation projects, it is very important to solve the problems of desalinizing the soils and obtaining a decrease in the level and mineralization of ground waters.

References

[1] Bucur, N., Baloiu, V. & Popovici, G.: Amelioration of salt affected soils in the Bahluiului–Valley. (In Russ.) Probleme agricole. **8.** 1966.

[2] Bucur, N., Baloiu, V. & Popovici, Gh.: Contributii la rezolvarea problemelor de ameliorarea saraturilor din Lunca Bahluiului prin lucrari de regularizare. Bul. Institutului Politehnic Iasi. 1965.

[3] Colibas, I. & Colibas, M.: Effect of phosphogypsum, organic and mineral fertilizers on sodic solonetz and on crop yields at the Socodor Experiment Centre. (In Russ.) Stiinta Solului **3.** 1965.

[4] Maianu, Al., Dondera, S. & Pop, M.: Contributii la stabilirea efectului de amendare al citorva tratamente aplicate pe doua soloneturi din Lunca Calmatuiului. Probleme de Pedologie. 1958.

[5] Obrejanu, Gr., Maianu, Al., Albescu, I. et al.: Amelioration of secondary salinized soils under rice in the Danube Plain and the plant fertilization system during amelioration. (In Rum.) Analale Institutului de Cercetari Agronomice. Seria A. **23.** 1960.

[6] Oprea, C. V.: Saline and alkali soils in Rumania and their amelioration (In Rum.) Biol. stiint. Agric. **9.** (1–2). 1962.

[7] Oprea, C. V. et al.: Transformation of salt affected soils into productive soils. (In Rum.) Agro-silvica de Stat. Bucuresti. 1962.

[8] Oprea, C. V., Romosan, St. & Contres, E.: Contributii la cunoasterea efectului ameliorativ al amendamentelor asupra solonetului dintre Mures si Crisul Alb. Lucrarile stiintifice ale Institutului Agronomic Timisoara. Seria Agronomie. **9.** 1966.

[9] Pop, M. & Maiănu, Al.: Rezultatele cultivarii citorva plante de nutret pe soluri saraturoase din Lunca riului Calmatui. Communicarile Academiei R.P.R. **9.** (5). Bucuresti. 1959.

[10] Sandu, Gh., Colibas, I., Vlas, I. et al.: Ameliorarea solurilor alcalice de la Centrul Experimental Socodor, prin aplicarea amendamentelor si ingrasamintelor. I.C.C.A. Analele Sectiei de Pedologie. **32.** 1964.

[11] Sandu, Gh., Vlas, I., Stepănescu, E. et al.: Reclamation of alkali soils by amendment and fertilizer application Socodor Experimental Centre. (In Rum.) An. Sect. Pedol. **32.** 283–300. 1964.

[12] Stanciu, I., Muresan, P. & Oprea, C. V.: Contributii la studiul saraturilor din partea de vest a tarii. Studii si cercatari de biologia si stiinte agricole. **1–4.** Timisoara. 1954.

[13] Stepànescu, E., Vlas, I. & Colibas, I.: Effect of amendments and fertilizers on yield of some crops on the saline and alkaline soils of the Cris river plain. (In Rum.) Probleme agric. **10.** 33–42. 1966.

[14] Serbanescu, I.: Amelioration of native meadows on the salt affected soils of the Rumanian Plain without ploughing. (In Rum.) Studii pedologice **2.** (11) Seria C. 209–237. 1963.

[15] Tesu, C.: Arable and pasture saline soils in the Jujia-floodplain. (In Rum.) Lucrare de dizertatie pentru obtineres titlului de doctor in agronomie. Iasi. 1967.

[16] Vlas, I. & Oprea, C. V.: Influenta amendamentelor, ingrăşămintelor si epocii de insamintare asupra plantei Atropis (Puccinelia) Distans. Lucrările stiintifice ale Institului Agronomic. Timisoara. **10.** 1967.

[17] Vlas, I., Stepànescu, E. & Colibas, M.: Results of low-rate liming on alkali soils at Socodor. (In Rum.) Stiinta Sol. **6.** 4–11. 1968.