The Improvement of Solonetz Soils in Yugoslavia

N. MILJKOVIC and N. PLAMENAC

Faculty of Agriculture, University of Novi Sad, Novi Sad, and "Jaroslav Cerni" Institute for Development of Water Resources, Beograd, Yugoslavia

The total area of continental and maritime salt-affected soils in Yugoslavia is about 260,000 ha [3, 6, 10] However, continental salt-affected soils are predominant. In the province of Vojvodina (Granary of the country, southern part of the Pannonian Plain, south of Hungary) alone there are 235,000 ha, representing a loss of 18.6% of the total arable land area.

Salinization and the accumulation of alkali salts in low-lying soils result from excess moisture and high evaporation due to the semiarid continental climate. The topography and hydrography of Vojvodina are also important. Detailed data on natural factors of soil formation, characteristics and classification are given in many previously published papers [3, 6, 9, 10]. The authors, however, want to point out certain special features of Yugoslav salt-affected soils:

1. In spite of the aridity in Banat (annual precipitation 100 mm less than in Bachka), the prevailing type of salt-affected soils is solonetz versus solonchaks in Bachka. This genetic controversy is also characteristic for salt-affected soils in Hungary, where solonetz soils occur east of the Tisza river (in the so-called "Tiszántúl"), and solonchaks in the area between the Danube and Tisza rivers (in the so-called "Duna—Tisza köze"). This contradiction in the genesis and properties of salt-affected soils is caused by the different manner of their formation.

2. Anomalous salt composition (domination of carbonates, bicarbonates and chlorides) occurs in salt-affected soils of Vojvodina. Being in a steppe or forest steppe zone they are expected to contain soda-sulphate salt accumulation. This specific phenomenon is due to the fact that artesian waters, from neogen deposits in oil-field areas containing exclusively sodium chloride (without any sulphate), are in direct contact with (phreatic) ground water along the spillway, where maritime sediments are particularly close to the surface.

3. The exchange complex of most solonetz profiles is almost completely saturated with sodium. Although the exchangeable sodium usually causes the main morphological, physical and chemical properties or, in other words, it determines the intensity of solonization and the depth of columnar B horizon formation, the solonetz soils of Vojvodina, even with a high exchangeable Na content, are not always morphologically well developed. Therefore, the authors have the opinion that the solonetz soils of Vojvodina are relatively young. It seems that the annual precipitation of 650 mm does not leach the

profile and the ground water by its capillarity still has an influence on salt accumulation, even near the surface.

Finally, it should be recognized that much is known about the nature and properties of salt-affected soils in our country. However, a further study of these soils with regard to their management and reclamation and the protection of presently productive fields against hazards of salinity and alkalinity (secondary salinization) is of immediate economic importance. This report is concerned with the possibilities of utilizing and improving salt-affected soils, with special regard to the solonetz soils. Turning these soils into cultivated land would considerably increase their productive potential.

Possibilities of utilizing salt-affected soils

Yugoslav salt-affected soils, on account of their diversity, offer different conditions and possibilities of utilization. At present, most salt-affected soils are used for pasture (without previous chemical improvement) and only a small area is in cultivated land and meadow. In the southern part of the Pannonian Plain, however, entirely unproductive salt-affected areas are found. According to Hungarian experience, growing sod on sodic soils (so-called "salinic bee pasture" — *Atropis limosa* and quack grass — *Agropyron repens)* proved to be a very convenient way of utilizing them. Better yield were obtained by irrigating.

Growing *Matricaria Chamomilla,* ssp. *Bayeri* on solonetz soils (of IV class after 'SIGMOND) can be very profitable and inexpensive with a special agrotechnic described by NEUGEBAUER [8]. The profitability of the production of chamomilla is quite high, because Yugoslav pharmacies only consume about 100 tons of dry flower heads per annum, while about 600 tons [14] are exported. It seems that chamomilla culture can be a very profitable way of utilizing very poor salt-affected soils even without any investment. It also gives gradual reclamation.

Some of our salt-affected soils are suitable for rice production, too, but plenty of water is required [8]. The large Danube—Tisza—Danube hydrosystem, will considerably improve the water supply to the new rice fields.

In many locations salt-affected soils are used for artificial fish ponds.

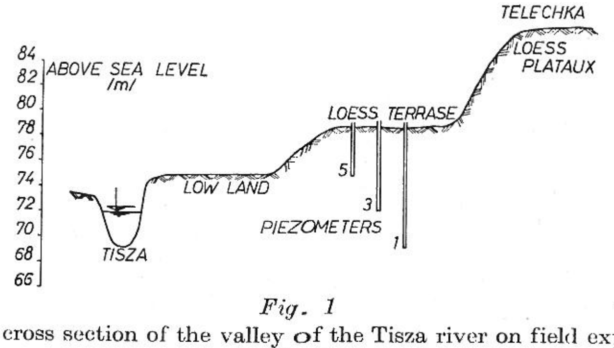

Fig. 1

Geomorpological cross section of the valley of the Tisza river on field experiment, south of Kanjiza

This often represents the only means of utilizing strongly salt-affected soils. Considering the relief, the most suitable areas for fish ponds are soils found in natural depressions. There must be no danger from hydrostatic pressure and no increase of ground water table on neighboring cultivated soils. A conflict arose among farmers before World War II because of the deterioration of their arable land caused by new fish ponds near Echka. Some attempts have been made with afforestation of certain salt-affected soils, but this experiment was interrupted and is not yet completed.

Chemical improvements (lime and gypsum) in the future should enable more complete utilization of salt-affected soils. Furthermore, after constructing the Danube—Tisza—Danube hydrosystem, there will be more possibility for utilizing salt-affected soils with, or even without, previously conducted reclamation.

Our experience with the improvement of solonetz soils

Foreign experience and procedure in solving the problems of the reclamation of salt-affected soils, especially Hungarian, are of great importance for Yugoslavia. The Yugoslav salt-affected soils are very similar to the Hungarian ones.

However, due to the great diversity of salt-affected soils, it seemed advisable to establish some field experiments on representative solonetz soils in our country.

Some earlier results of gypsum applications [5] were obtained in the period 1951 to 1953. Field tests carried out by ZIVKOVIC with gypsum on solonetz soil (near Srpski Miletic) showed good results [15]. In 1953 (the second year after treatment: gypsum + manure), the 10 tons gypsum treatment gave the best results with an increase in yield of winter wheat of 574 kg/ha in comparison with the check plot.

The Institute for Agricultural Research in Novi Sad (A. Muci) also carried out an experiment with gypsum on salinized smonitza under irrigated conditions. The smallest dose of gypsum (5 tons per ha) gave an increase in corn yield of 430 kg/ha or 8.7% more than control plot.

For sunflower, the addition of gypsum (5 to/ha) and manure (250 mc) has been established as the most suitable treatment. It gave an increase in yield under irrigation of 400 kg of grain per ha or 14% and without irrigation 102 kg/ha of grain or 4.5% in relation to the check plot.

Sugar beets did not show a remarkable increase in yield after treatment, because of the tolerance of this crop to salts. It may be concluded that gypsum has beneficial effects even at low rates with irrigation.

In 1961 an experiment was set up involving a small test area, surrounded by channels in which water was kept at or below 2 m by pumping from a series of piezometers across the experimental area. Amendments, such as sulphur and manure were tested. The main purposes of this field experiment were to measure the effect of applied reclamation measures on the water regime and changes in salinity and alkalinity of the soil.

According to KLIMOVIC [4] the field test was carried out from 1961 to 1966. The area of the test field was 10.5 ha. It was located on sheep pasture about 5 km from Kanjiza. Geomorphologically, this area represents loess terrace of the Tisza river (Fig. 1). The parent material is resedimented loess, gleyed and alkalized, 1.5 m thick over fine sand (Fig. 2). The slightly mineralized ground water table is permanently at 1 to 2 m. However, annual fluctuations in the ground water table were related to water level variations in the Tisza river. The chemical analyses of the ground water indicated that it was of the Na bicarbonate type, with dissolved solids varying from 250 ppm in the spring to 420 ppm in the fall. Boron was present in an average amount of 0.54 ppm.

The average annual rainfall is 569 mm with 324 mm (or 57%) falling in the period April—September. The average annual temperature is 11.1 °C. The summers are warm with a maximum of about 40 °C in July. There is a very dry period from August—September. The average annual evaporation is about 885 mm.

The type of soil of the experimental area is a crust columnar calcareous solonchakic solonetz. This corresponds to the Hungarian term: "meszes-szódás, szikes talaj" [1]. The natural vegetation consists of *Camphorosma ovata, Statice gmelini, Matricaria chamomilla.*

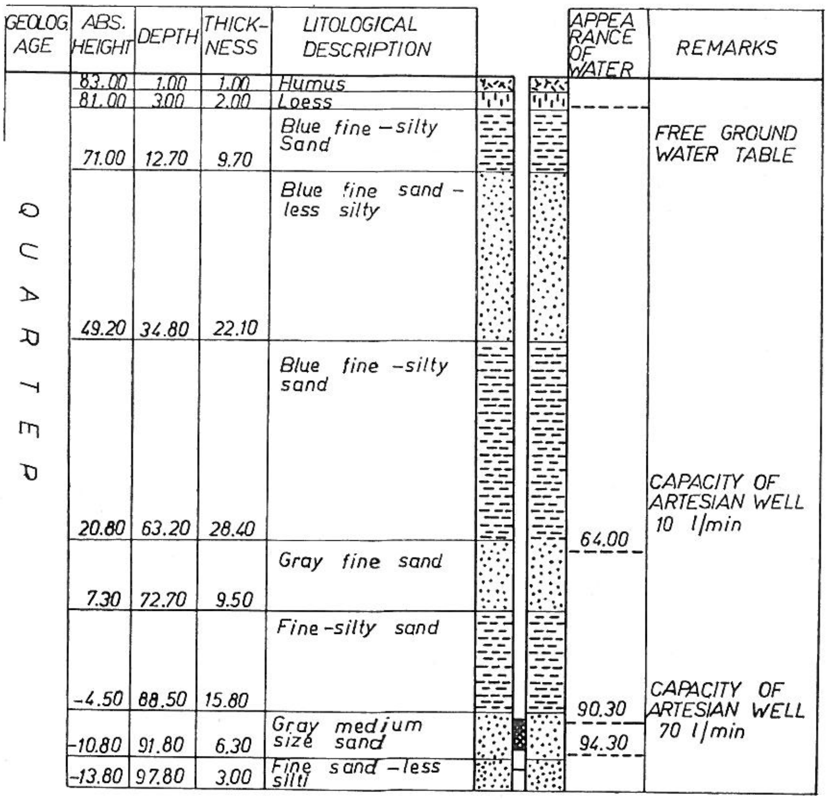

Fig. 2

Geological strata on field experiment south of Kanjiza

Morphological description of profile No. 51 [4]

0— 6 cm	A_0 horizon, gray, dry, calcareous, sandy loam, laminar structure;
6— 14 cm	B horizon, dark gray, calcareous, loam in dry and gray-brown in most state, compact with columnar structure;
14— 20 cm	B_2 horizon, brown calcareous loam, compact, prismatic structure;
20— 40 cm	B_2 horizon, light brown calcareous sandy loam, blocky nut-like structure;
40— 60 cm	B_2C horizon, pale yellow loess-like material, calcareous sandy loam, compact, irregular blocky structure;
60—180 cm	C horizon, the same colour, calcareous sandy loam, with plenty of fossils of swampy snails, manganese punctums and lime concretions at the depth of 180 cm;
180—220 cm	Yellow loamy sand with gleyish spots;
220—270 cm	Yellow loamy sand with gleyish spots, strongly calcareous;
270—290 cm	Blue gleyed calcareous sand;
290—360 cm	Brown, moist, sandy loam, mixed with organic matter; ignition loss 15.64%. Humus content 10.7%. Lime content 31.6%.
360—510 cm	Gray sand, motley with gleyish spots, calcareous with 27.28% $CaCO_3$.

From the data in both Table 1 and the graph in Fig. 3:

1. The high saturation percentages (57—70%) indicate fine textured soil (clay loam or light clay) readily adversely affected by alkalinity.

2. Poor physical characteristics because of the high soil moisture retention at 1/3 and 15 atm (31—35 vol.% and 10—20 vol% resp.) and the extremely low hydraulic conductivity (0.05 m/24 h).

3. Strong alkalinization in the B horizons at a depth ranging from 6—60 cm.

4. Moderate soluble salt content ranging from 2.5 to 9 mmhos/cm in the saturation extracts. The highest concentration of these salts appeared at a depth of 14—40 cm. Carbonates and bicarbonates predominated. Chlorides and sulphates were negligible.

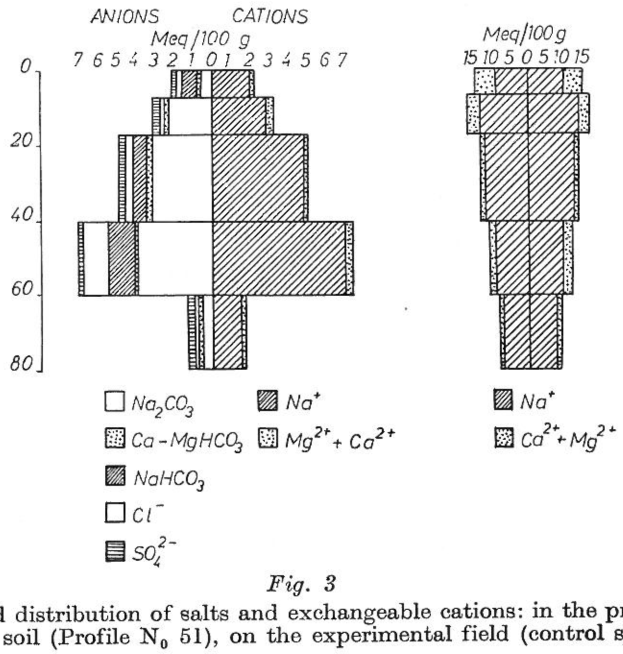

Fig. 3

Composition and distribution of salts and exchangeable cations: in the profile of a solonetz soil (Profile N_0 51), on the experimental field (control spot.)

Table 1

Some analytical data on solonetz soil of experimental field before treatment

Horizon	Depth cm	SP %	Moisture retention 1/3 atm (volume per cent)	Moisture retention 15 atm (volume per cent)	$CaCO_3$ %	pH in saturated paste	E.C. mmhos/cm saturation extracts	CEC meq/100 g	Exchangeable Na meq/100 g	Exchangeable Na %
A	0—6	67.9	35.0	19.7	13.0	9.25	2.5	14.78	9.18	62.09
B_t	6—14	70.0	32.0	18.2	23.0	9.75	3.1	16.46	13.20	80.20
B_2	14—40	61.2	31.0	15.9	37.0	10.05	7.3	13.12	12.20	92.95
B_2C	40—60	57,6	31,0	9,5	42,0	10.25	9.0	11.02	9.53	83.62
C	60—80	52.7	32.0	9.1	39.0	9.70	8.3	8.61	7.20	83.62

5. The pH varied from 9.25—10.25 indicating the presence of exchangeable Na, carbonates and bicarbonates.

Since a water table occurred at 1—2 m, even as late as the middle of August, it seemed obvious that no treatment could be justified without providing drainage. Thus the field experiment included:

1. Treatment with sulphur at 25 mc/ha.
2. Manure applied at 400 mc/ha.
3. Tillage (ploughing + loosening) to a depth of 40 cm.
4. Tile drains 4—5 m apart at a depth of 160—180 cm or just above the layer of lime concretions at 200 cm.

An attempt was made to mole drain also, but the physical conditions of the soil were not satisfactory (Table 2).

Data from Table 2 indicate the following changes in soil properties due to the effect of the treatments:

1. Removal of soluble salts from the soil profile.
2. Replacement of the exchangeable sodium by calcium mobilized from native calcium carbonate.
3. Significant decrease in pH.

As a result of the application of sulphur, drainage and tillage, certain improvements in the hydrophysical properties of the treated soil were also observed. Very similar effects of sulphur were obtained 5 years after application (1629 kg per acre) to alkali soil near Fresno, California [1].

Economic aspect and perspective of the improvement of salt affected soils

The possibilities of improving salt-affected soils for additional agricultural production in Yugoslavia obviously justify considerable work. In our opinion no short-cut solutions to the problems of alkali reclamation in our country are available. Reclamation plans should only be based on a study of all the factors involved, including economic considerations. For the time being, slightly salt-affected soils (about 50,000 ha) mainly cultivated with low production should be subject to reclamation, because little amendment will be necessary (3—5 tons of gypsum per ha). This is in accordance with Hungarian experience [13]. From the economic point of view, the problem

Table 2

Some analytical data for solonetz soil on the experimental field after 4 years of treatment with sulphur [4]

Depth cm	SP %	pH in saturated paste	E.C. Mmhos/cm saturation extracts	CEC	Exchangeable Na	
				me/100 g		%
0—10	52.7	7.8	0.8	22.85	1.26	5.51
10—20	53.0	7.9	1.3	22.29	1.79	8.41
20—30	52.2	7.9	1.1	19.35	4.71	24.34
30—40	51.1	8.6	0.9	15.94	5.41	33.96
40—60	50.6	9.6	1.6	8.7	12.36	40.54
60—80	45.9	9.8	2.5	7.3	5.92	82.10

of reclamation has two aspects: 1. Index of rentability, which is based on "input and output". (For evaluation of rentability, net income was considered as a result of the new investment), and 2. Social effectiveness, because society may be interested in reclaiming salt-affected soils only in case production may attain very high intensiveness on improved soil.

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