General Review of the Salt-Affected ("Slatina") Soils of Yugoslavia and Their Classification

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The term "Slatina" is commonly used in Yugoslavia to include both the saline soils which contain water soluble salt, and the alkali (sodic) soils which have a level of exchangeable sodium high enough to retard or limit plant production.

Recent data from general soil survey and cartography provide a precise view of salt-affected soils over scattered areas totalling 235.000 ha, in the province of Vojvodina alone. This represents a loss of 10% of the total productive land. In the south of the country, in Macedonia there are about 10.000 ha of salinic soils, too. Beside the continental salt-affected soils, in Yugoslavia on the Adriatic Sea-side (island Pag) are found maritime saline and alkali soils, formed by the action of sodium and chloride from sea water.

This report is concerned with Vojvodina, where the greatest part of these salt affected soils occurs.

Vojvodina is a region of very fertile, productive soils (mostly chernozems and its associated units) located in the northeastern part of Yugoslavia. It constitutes the southern part of the Pannonian Plain, (south of Hungary) and is mostly flat to gently rolling. This area is known as the granary of Yugoslavia. However, the productivity of the lands is considerably limited by the local climate with its unfavorable distribution of rainfall during the growing season (sometimes as low as 150 mm). In order to have an adequate supply of water available for crops during the growing season, construction of an irrigation system is being carried out, using the waters from the Danube and Tisza rivers.

Vojvodina has a continental climate with a semiarid character (after NEUGEBAUER), with 652 mm. of annual precipitation, an average annual temperature of 11 °C and sometimes the annual evaporation amounts to 1.000 mm.

Excess waters from surrounding mountains flow freely into and across the area of the Pannonian Plain via rivers and rivulets. In past most of the area was swampy and under periodical flooding. Because of that very extensive drainage system has had to be constructed to remove excess surface waters and the rivers are diked for protection from floods. Drainage is by shallow canals leading to pumping stations which lift the water over the dikes into the rivers.

Owing to the above climatic conditions, as well as the topography and hydrography of Vojvodina, the excess of moisture and strong evaporation in

the summer months cause salinization and accumulation of alkali salts in low position soils. Therefore, the meteorological conditions and the impermeable heavy textured subsoils appear to be the main factors causing salt-affected soils formation. Because of the uneven surface and subsoil relief different salty ground water tables exist, and as a consequence there is variable salinization often associated with alkalization in much of Vojvodina. However, the basic differences between certain salt-affected soils in Vojvodina are due to the different manners of their salinization:

In Bačka salinization from ground water causing the appearance of the solonchak soils (sodic, chloride-sodic and sometimes sodic-chloride) is typical. In former flooded districts in western and southern Bačka solonetz and soloth soils are found. NEUGEBAUER attributes the origin of these soils to alluvial salinization in the region of the rivers basins (Plazovic, Mostonga and Danube), as well as to good natural drainage of the lighter-textured soils and a somewhat larger amount of rainfall in this part of Vojvodina.

About two-thirds of the total area of the salt-affected soils of Vojvodina is in Banat. Solonetz is predominant here and as a rule it is noncalcareous, due to the alluvial manner of the salinization. Historically, before the technical reclamation, Banat was constantly flooded by the water of the Carpathian basin. These waters, although they did not contain large quantities of salts, caused, through evaporation, gradual salinization, accompanied by alkalization of the exchange complex. Frequent floods caused leaching, which aided the saturation of the exchange complex with sodium. After reclamation was carried out, weakly salinized and strongly alkalized soils were subjected to the natural process of desalinization and mostly shallow columnar and sometimes crusty solonetz soils were produced.

In southern Banat, the alkali soils originated as the result of alluvial-colluvial (lacustrine) salinization. This salinization was caused by drainage of the surface waters into large depressions, where salts accumulated around the borders after evaporation.

In Srem, soloth soils are present as the predominant type of salt affected soils. They originated by the natural process of desalinization.

Studies of salt-affected soils in what is now Vojvodina, had been done even before World War I. The investigations of TREITZ and 'SIGMOND are well known. Other studies were conducted before World War II but post-war investigations of NEUGEBAUER, MILJKOVIC and others are of special importance. Foreign experts (VERHOEVEN, EYSVOOGEL, HELLINGA and PAGE) have also contributed to the knowledge of the salt-affected soils in Vojvodina, especially with regard to their management and reclamation. Further study of the saline-sodic soils of Yugoslavia was of immediate practical and economic importance from the standpoint of improving and utilization of these lands in the new irrigation projects, for dry-land farming and for the protection of presently productive fields against the hazards of salinity and alkalinity.

Main characteristics of salt-affected soils

Briefly, the recent investigations of this group of soils showed the following:

1. All general types of salt-affected soils and their transitional forms occur in this province, where sodic soil (solonetz) predominates.

2. The hazard of salinity still exists, affecting approximately 1.000—2.000 ha per annum.

3. The mechanical analyses and values of the saturation percentages (40, 80, 120%) indicate that the fine textured soils, especially in the B-horizons, are more adversely affected by salinity. According to the texture, they belong to the clay loam and silty clay classes, with respectively 25 and 45% of <0.002 mm. clay.

4. Most of these soils have poor physical characteristics: extremely low hydraulic conductivities (less than 0.15 mm/min); and high soil moisture retentions by 1/3 and 15 atm. (20—40% and 10—23% by weight). These facts could be explained partly by the high degree of dispersion and the hydrophylity of illitic and montmorillonitic colloids in the B-horizons. The content and kind of salts present and the high percentage of exchangeable sodium are other contributing factors.

5. It should be noted that estimations of the degree of salinity from the electrical conductivity (E. C.) of the saturation extracts were more useful than those from saturation paste, because concentration of the saturation extract approaches the concentration of the natural soil solution in the active root zone. Besides, it is of interest, that this method avoids the errors due to electrical conductance of the soil particles and of exchangeable sodium in the saturation paste. The values of E. C. vary from 2—16 mmhos./cm.

6. The saturation extract determination further shows that of the anions, carbonates, bicarbonates and chlorides are dominant (attaining in come cases 150 me./l. of carbonates and 40—60 me./l. of chlorides), and of the cations, sodium was predominant, amounting to 200 me./l. in some cases.

7. Determination of the exchangeable ions reveals high exchangeable sodium percentages in most profiles, above 75%. The exchange complex of some solonetz profiles is almost completely saturated with sodium.

8. The determination of clay minerals in salt-affected soils by X-ray diffraction and DTA indicates no significant change in their composition and amount: illite was dominant in all horizons; montmorillonite appeared in B-horizons and chlorite with vermiculite were present to a lesser degree. These findings are in agreement with the values of the CEC of the fractionated clay.

9. The trace element boron has been determined in slatina soils in amounts toxic to many plant species, in some cases being 10 times above the safe limit of 1.5 p. p. m. of boron in the saturation extract. Therefore, it will be necessary to consider this element as a new and important diagnostic factor of these problem soils.

Summarizing the main characteristics of these soils, a classification is presented based on the genesis, morphology, salinity and alkalinity as well as on the productivity of salt-affected soils.

In a region such as Vojvodina, drainage, irrigation and salinity are all very closely interconnected and must be considered together if the soils are to be managed properly. For this reason a few words will be concerned with both the reclamation and the prevention of formation of saline and alkali soils.

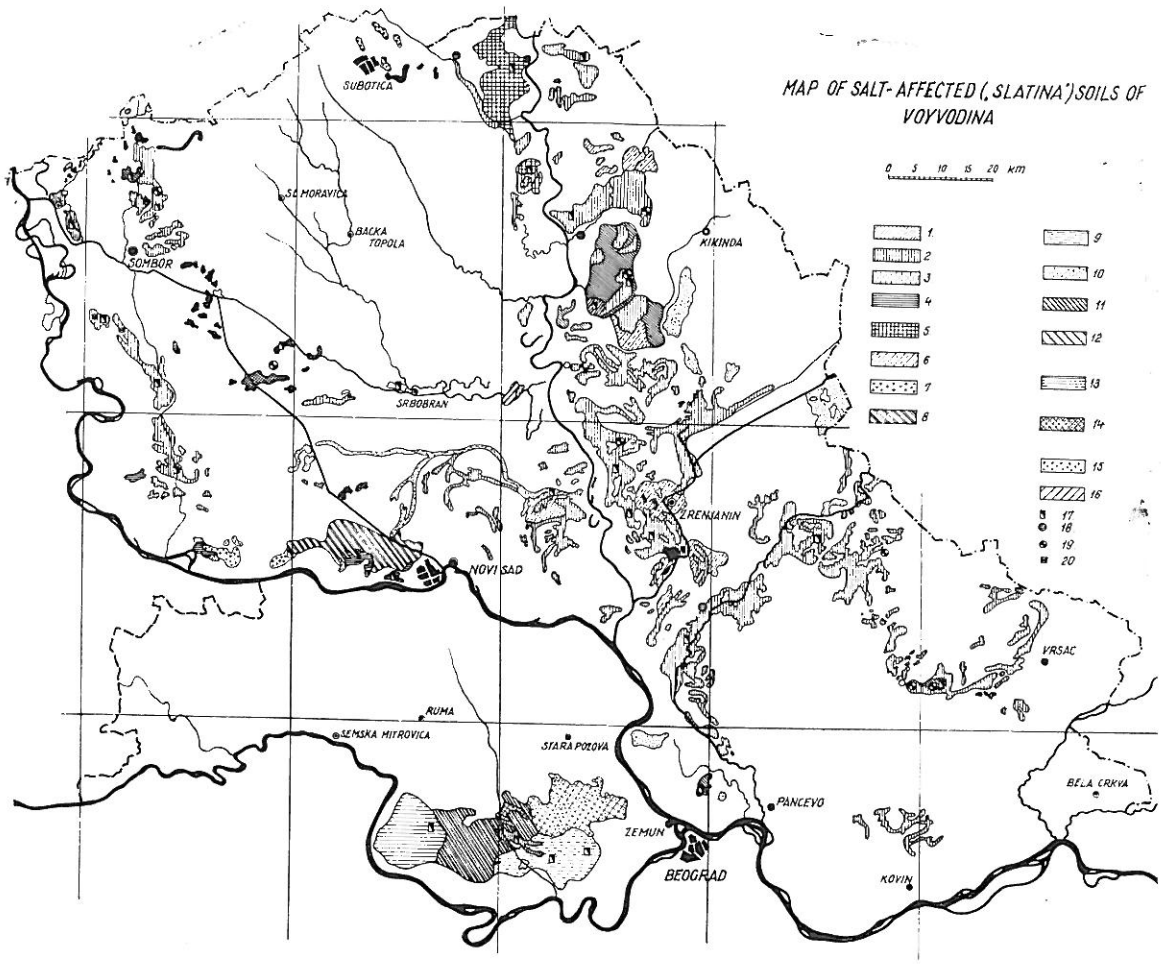

Fig. 1.

Map of Salt-Affected ("Slatina") Soils of Vojvodina

1. Solonchak. 2. Solonetz. 3. Soloth. 4. Solonetz-Soloth. 5. Solonchak and Salinized Chernozemlike Meadow Soil. 6. Chernozem Salinized and with Signs of Salinization. 7. Chernozemlike Meadow Soil with Signs of Salinization. 8. Chernozem like Meadow Soil and Chernozem Partially Degraded or Solonetz. 9. Soloth Soils with a Few Spots of Solonetz Solodized Hydromorphic and Smonitza Soils. 10. Smonitza Salinized and with Signs of Salinization. 11. Hydromorphic and Smonitza Soils Solonetz Soils with a Few Spots of Solonchak. 12. Brown Forest Soils with Spots of Soloth, Solodized Brown Forest Soils, Partially Considerable Surfaces with Soloth and a Few Spots of Solonetz Soils. 13. Brown Forest Soils (Soloth) with a Few Solonetz and Hydromorphic Soils. 14. Limeless and Degraded Chernozem with a Few Spots of Hydromorphic, Soloth and Solonetz Soils. 15. Hydromorphic Soil (Sandy) with Signs of Salinization. 16. Alluvium Salinized. 17. Soil Sampling Sites. 18. Surface Water Sampling Sites from Rivers and Rivulets. 19. Ground Water Sampling Sites from Profiles and Wells. 20. Sampling Sites of Plant Materials

Table 1.

Proposed classification for salt-affected ("Slatina") soils in Vojvodina

A) Saline and alkali soils

I. *Solonchak soils*

1. Typical

a) According to manner of formation:
Ground water salinization
Surface water (alluvial) salinization

b) According to the degree of salinity:

Slight, with E. C.* of sat. extr.	2— 4 mmhos/cm.
Moderate, with E. C. of sat. extr.	4— 8 mmhos/cm.
Strong, with E. C. of sat. extr.	8—15 mmhos/cm.
Very strong, with E. C. of sat. extr.	>15 mmhos/cm.

c) According to the degree of alkalinity**

Slightly alkali	<20% exch Na^+
Moderately alkali	20—50% exch Na^+
Strongly alkali	>50% exch Na^+

2. With signs of desalinization
   a) In slight degree
   b) In stronger degree (transitional form to solonchakic solonetz)

3. Secondary (regraded)
   a) By natural change of conditions
   b) By the influence of man (irrigation)

II. *Solonetz soils*

1. Solonchakic solonetz

   a) Takyr***
   b) Noneroded
   c) Eroded

2. Solonetz, very strongly alkali, with	> 75% exch. Na^+
3. Solonetz, strongly alkali, with	50—70% exch. Na^+
4. Solonetz, alkali with	30—50% exch. Na^+
5. Solonetz, moderately alkali, with	20—30% exch. Na^+
6. Solonetz, slightly alkali with	10—20% exch. Na^+
7. Solodized solonetz to	< 10% exch. Na^+

III. *Soloth soils (limeless, acid-degraded "slatina" soils)*

B) Slightly salinized-alkalized ("Slatinasta") soils**

I. *Solonchakic (salinized) soils*
II. *Solonchakic-solonetzic (salinized-alkalized) soils*
III. *Solonetzic (alkalized) soils*
IV. *Solodic (solodized desalinized and dealkalized leached) soils*

* E. C. 25 °C — electrical conductivity of sat. extr. expressed in reciprocal value mmhos/cm.

** The solonchak soils under natural conditions of this province are more or less alkalized, therefore correspond to the American term saline-alkali.

*** Takyr is a naked hard smooth irregular system of polygons with surfacial cracks.

**** The limit between A and B subgroup is for salinity E. C., less than 2 mmhos/cm, and for alkalinity, less than 10% exch. Na.

Reclamation of existing saline and alkali soils

The possibility of reclaiming the „slatina" soils for additional agricultural production is obviously justification for considerable work on these soils. No short cut solutions to problems of alkali reclamation in Vojvodina are available and reclamation plans should only be based on a study of all the factors involved, including economic considerations.

Most of the problem soils are sodic soils which occur in depressions or basins where drainage is poor. In the past some attemps at drainage have been made but usually in the form of a shallow canal effective only to remove surface water, which collected during the winter and early spring.

Observation of the wells or test borings in the vicinity revealed water tables standing at 1—1.5 m. at many locations even as late as the middle of August. It seems obvious that no treatment could be justified without providing drainage. With regard to topography, on a local scale, this would require a pump installation to keep the ground water below two meters. It should not be expected that immediate reclamation of these lands is in prospect. Therefore a proposal is made.

An experiment could be set up which would involve a small test area surrounded by a canal in which water was kept at or below 2 meters by pumping, with a series of piezometers or test wells across the experimental area and outside the area together with various rates of amendments such as gypsum and manure. Gypsum requirement determinations indicate that rather large amounts of gypsum (10—25—55 tons/ha.) should be applied for effective reclamation.

Prevention of formation of salt-affected soils

At present major interest and efforts are being directed toward irrigation. It appears to be an attractive possibility for additional agricultural production especially in South Bačka, on the best soils, which are topographically only slightly higher than the affected areas. With the increase of irrigation a danger seems to exist from a higher water table (2—2.5 m.) of frequentlu poor quality (1000—4000 p. p. m. dissolved solids and $Ca^{2+} + Mg^{2+}/Na^{+}$ from 1.0—0.1) which might rise higher as a result of over-irrigation and canal-losses. For this reason it is almost an axiom that the first requirement of irrigation agriculture is adequate drainage to insure safety from salinity hazarb, because "the soil is too valuable to allow any risks" (after EYSVOOGEL—HELLINGA). This does not mean an argument against irrigation, but it is felt that the problem of drainage and the possibility of secondary salinization (which has occurred elsewhere in the world) is not receiving adequate attention, as a result of a division of responsibility and lack of intercommunication of technical and agricultural services.

In conclusion it should be recognized that there is and will continue to be a problem of sodic soils in Vojvodina. Therefore a strong effort should grow for coordination of all people who are involved with water, soils and plants, because the alkali problems are joint responsibilities.

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Обзор по засоленным почвам (слатина) в Югославии и по их классификации

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Резюме

Данные почвенных исследований и картирования почв показали, что только в районе Воеводина насчитывается 235 000 га. засоленных почв, что составляет 10% всех угодий. Район Воеводина расположен в северо-западной части Югославии, к югу от Венгрии, и представляет собой довольно плодородный район, особенно там, где встречаются черноземные почвы и их разновидности.

Климат описываемого района континентальный, умеренно сухой, среднегодовое количество осадков равно 650 мм, среднегодовая температура 11° С, испарение в среднем за год достигает 1000 мм.

В прошлом большая часть района была заболочена и периодически затоплялась водой.

Климатические и гидрологические условия — избыточная влажность и сильная испаряемость в летние месяцы — способствуют образованию засоленных почв и накоплению в них, особенно в пониженных элементах рельефа, щелочных солей. Вызванное частыми затоплениями, выщелачивание способствовало насыщению поглощающего комплекса почвы ионами натрия.

На основе новейших исследований, засоленные почвы характеризуются следующими признаками:

1. Существует опасность засоления почв и ежегодно ей подвержены приблизительно 1—2 000 га. территории.

2. Среди почв различного типа засоления содовые (солонцы) почвы встречаются чаще всего.

3. Большая часть этих почв обладает неблагоприятными физическими свойствами, очень низкой водопроницаемостью (меньше 0,15 мм./мин.), высокой влагоемкостью, что объясняется тяжелым механическим составом почв (тяжелые суглинки и иловатые глины) и, особенно в горизонте-В, гидрофильностью коллоидов иллита и монтмориллонита.

4. Определение суммы солей по электропроводности показало различные результаты в содержании солей.

5. Анализы водных вытяжек показали, что среди анионов преобладают карбонаты, бикарбонаты и хлориды (в некоторых случаях содержание их достигает величины 40—60 и 150 мг.экв./л.).

6. В некоторых солонцах поглощающий комплекс почти полностью (больше чем на 75%) насыщен ионами натрия.

7. Из глинистых минералов почти в каждом горизонте преобладает иллит; монтмориллонит встречается в горизонте-В, хлорит и вермикулит встречаются в незначительных количествах.

8. В засоленных почвах (слатина) имеется большое количество бора, вредно влияющего на растения. Поэтому необходимо обращать внимание на этот важный фактор в проблемах изучения этих почв.

Подводя итоги особенностям засоленных почв Югославии, автор приводит классификацию почв, проведенную на генетических и морфологических основах, на основании степени засоленности и щелочности, а также их плодородия.

В конце работы автор приводит некоторые концепции по мелиорации засоленных почв (слатина), а также останавливается на процессах вторичного засоления, происходящих от переполивов и фильтрации воды в каналах.