Past, present and future of the Hungarian classification of salt-affected soils

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Abstract

As salt-affected soils (SAS) are widespread in Hungary, several classification schemes have been proposed for them during the last centuries. These soils are inherently related to soil salinity/sodicity/alkalinity and the consequential hydrophysical properties of the soil; therefore, they present severe abiotic stress for plants and animals. Based on the approach of the assessment of the soil, such as ecological conditions, need of reclamation, afforestation, etc, there are several concepts for the classification of SAS. Historically, the following schemes were used for SAS classification in Hungary: geomorphological; plant sociologic; based on the values of salt/soda concentration for direct soil utilization; for the purpose of afforestation; for the reclamation; soil genetic ones based on general chemical principles; soil genetic classification based on profile characteristics (current "official" classification). Several classification schemes are still in use. Elements of four classification schemes can be found in the current system used to denote SAS in Hungary. Meanwhile, from the currently used major world classification schemes none have been spread so far in the country, because the "official" Hungarian genetic soil classification system meets the requirements of the users of SAS. The categories of FAO-UNESCO schemes (including the WRB) seem to be easy-to-apply to the SAS in Hungary, and most of them would fall into few clearly understandable categories. On the other hand, the Hungarian SAS would fall into many categories of the SOIL TAXONOMY. The future of the classification of SAS in Hungary is forecasted as evolving parallel to the development of that in neighbouring countries, which have large areas of similar SAS. It would evidently lead to keeping the same soil types as used at present as classification units, but with the addition of quantitative, unambiguous diagnostic properties based on laboratory and field data.

Keywords: ecology, afforestation, soil reclamation, salinity, sodicity

Introduction

Salt-affected soils (SAS) are widespread all over the world. In addition to the constraints of scarcity or too much water in these soils, the basic fertility and land use capability of these soils is directly related to a few chemical properties, such as salinity and sodicity (Szabolcs, 1991). It is the reason why the study of SAS, as a pioneering branch of pedology, soil mapping, remote sensing, soil reclamation, soil utilization, has received so much attention (e.g. Richards, 1954, Bresler et al., 1982, Shainberg, I and J. Letey, 1984, Sumner and Naidu, 1998, Tinker and Nye, 2000). As some tenths of Hungary's complete territory is covered by such soils, there has been and there is now a detailed work going on SAS (Szabolcs, 1971, Szendrei, 1999, Pásztor et al., 2000).

Based on the simplicity of the chemical characteristics of SAS, their classification would be expected to be a simple case. It is indeed relatively simple in national and international classification schemes as well. What makes it so variable is the difference in the approaches of classification, ranging from the standpoint of the pedologist to the standpoint of foresters. In this paper we describe the history and present status of the classification of salt-affected soils in Hungary, also pointing to the further developments of the present system, because in our opinion this history brings lessons for a wide range of soil classifiers.

Specific features of salt-affected soils

SAS have some features important for their use, mapping and classification.
-i) soil salinity is linearly related to the yield, therefore, salinity-contour maps are directly useful on management. This aspect has received great attention in a series of papers (e. g. Maas and Hoffman, 1977).

Table 1. ECe (electrical conductivity of soil saturation extract) and the effects of salts on the yield of field crops according to the general scheme of Richards (1954).

ECe (mS/cm) class	Effect on plants
0-2	Salinity effects mostly negligible
2-4	Yields of very sensitive crops may be restricted
4-8	Yields of many crops restricted
8-16	Only tolerant crops yield satisfactorily
> 16	Only a few very tolerant crops yield satisfactorily

Table 1 shows the categorization of salinity (in electrical conductivity – EC units) regarding its general consequences for crops. According to the specific salt tolerance of a given crop it is straightforward to calculate the expected yield at a given EC of soil saturation extract with the following equation:

$YR=100-S * (EC_m - EC_t)$,
where R is relative yield; S – percentage of yield decrease = $50 / (EC_{Y_{50\%}} - EC_t)$;
EC_m – the average salinity in the root zone EC_e; EC_t – threshold soil EC_e

The following data from Maas and Hoffman (1977) illustrate the salt tolerance of some crops

Species	EC_t (mS/cm)	$EC_{Y_{50\%}}$ (mS/cm) EC causing 50% yield decrease
Barley	8	18
Wheat	6	13
Tomato	0.5	7.6
Squash	4.7	9.9

-ii) soil salinity status is closely related to environmental conditions, such as elevation, groundwater depth, and concentration of salts in the groundwater, soil and parent material texture (Table 2). There is a series of papers on the individual factors; recently the research group of authors published some papers on this topic (Tóth and Várallyay, 2001, Tóth et al. 2001, Tóth and Kuti 1999a, b).

Table 2. Schematic representation of the relationship of some factors that facilitate the mapping of salt-affected soils.

PRECONDITIONING FACTOR	MAIN VARIABLES	CONSEQUENTIAL VARIABLES
Relief	**Salinity⇔Sodicity⇔Alkalinity (pH)**	*Surface discoloration*
Hydrology	↓	*Mechanical properties*
Other soil forming factors	**Electrical conductivity**	Hydrophysical properties
		Extent of plant cover/biomass
		Species composition/abundance

Bold character = **main variable to map**, Underlined character = observable by remote sensing. *Italic* character = *covariable*.
-iii) soil salinity status is easy to describe with modern techniques, the methodology is standard (Rhoades, 1991). The most notorious is the use of electromagnetic probes, an ideal tool for fast assessment of soil salt concentration without establishing contact with the soil.
-iv) salinity and sodicity status affect soil physical properties, which are closely interrelated. Easy mapping of these soils is possible on the basis of recording color variability of the soil surface (Table 2).

Environmental conditions in Hungary

The area of Hungarian SAS, is located at an elevation of 80-90 m above sea level, under temperate continental climate, with 10 C^o mean annual temperature of, (-2^o in January, $+21^o$ in July), 527 mm average annual precipitation (June is the most rainy month with 71 mm, January has the least precipitation with 30 mm), and 900 mm mean annual pan evaporation. Further information, including a national map and ranges of properties of SAS is available on the Web (Tóth, 2002).

About one third of the soils on the Great Hungarian Plain (N $46\text{-}48.5^o$ and E $19\text{-}22.5^o$) is affected by salinity/sodicity, mainly by solonetz-forming processes, one third of the territory is covered by potential SAS, and one third does not have such soils. Potential SAS are defined as soils, which are not salt-affected at present, but which could become considerably saline or sodic as a consequence of irrigation (Szabolcs, 1974). The territorial segregation of some types of SAS is evident. Soil type numbers 2-6 of Table 3 are concentrated mainly in the Danube-Tisza Interfluve, numbers 7-10 are more typical in the Tisza Plain. With the exception of the grouping of calcareous SAS (No 4 and 6) with the solonchaks, soils in Table 1 are arranged according to decreasing salt concentration.

Challenges for the classification of Hungarian SAS

1. SAS represent great spatial and depth heterogeneity;
2. land-use modifies soil profile morphology and makes the classification of salt-affected soils more complicated;
3. land-use changes soil properties;
4. new field probes provide numerical values.

Table 3. The area covered by the categories of the map "Salt-affected soils of Hungary" inside the Great Hungarian Plain using the mapping categories of the map of Salt-affected soils of Europe (Szabolcs, 1974)

Original name of soil type on map (No of soil type on map)	Area km^2	Area % of all	Number of delineations	Number %
"Sodic solonchak" (No 2)	200.9	0.4	17	4.0
"Sodic solonchak-solonetz" (No 3)	1135.5	2.5	51	11.9
"Calcareous meadow solonetz" (No 4)	61.7	0.1	7	1.6
"Calcareous solonetzic meadow soil " (No 6)	462.4	1.0	19	4.4
"Meadow solonetz" (No 7)	3451.7	7.5	71	16.6
"Meadow solonetz turning into steppe formation" (No 8)	2503.5	5.4	67	15.6
Solonetzic meadow soil" (No 9)	1585.5	3.4	57	13.3
"Chernozem and meadow chernozem saline in deeper layers" (No 10)	3552.4	7.7	45	10.5
"Potentially salt-affected soils" (No 11)	16827.6	36.6	83	19.3
"Non salt-affected soils" (No 12)	16185.9	35.2	12	2.8
Total	45967.1	100.0	429	100.0

An overview of Hungarian classification systems for salt-affected soils is given below.

The first classification of Treitz in 1924 can be considered as a "geographer/geologist's view", in accordance with which he distinguished SAS based on geomorphic situation. Later, he turned to chemical characteristics for classification (Table 4). In this classification, presence of utilizable salt efflorescence (nitrates, soda), texture, chemical composition, and physiographic position were also considered). Categories 1,2 and 3A are solonchak, category 3B probably would be solonetz.

Table 4. Classification of Treitz, 1924 of the saline and alkali soils of Hungary

1. Saline soils yielding nitrates
2. Soils yielding soda (temporary salt efflorescences)
3. Alkali soils (there are no salt efflorescences)
   - A. Alkali soils on sand
   - B. Alkali soils on clayey substances

-alkali soil of plateaus
-alkali soil without $CaCO_3$
-alkali soil with $CaCO_3$
-alkali soil in depressions

The classification of de Sigmond, 1927, was based on the properties of samples taken from 0-30 cm and 30-120 cm (Table 5). The author defined his scheme as a "practical botanical classification". This is a typical artificial classification system based on the ranges of total salt concentration and soda (Na_2CO_3). As we shall show later, this system was actively used by botanists and foresters. Since the appearance of this classification in Hungary the lower limit of a soil qualified as SAS is 0.1% salt content in the soil. The limit for solonchak is 0.25% salt content in the topsoil.

Table 5. Classification of salt-affected soils by de Sigmond, 1927

	Salt %(sa)	Soda %(so)
Class I	< 0.1	0.-0.05
Class II	0.1-0.25	0.05-0.1
Class III	0.25-0.5	0.1-0.2
Class IV	>0.5	>0.2

Combination of the two Classes Class_sa and Class_so as

I = Isa/Iso
IIa= IIsa/Iso or Isa/Iiso, IIb=IIsa/IIso or IIIsa/Iso
IIIa=IIIsa/IIIso or IIsa/IIIso, IIIb=IIIsa/IIIso or IVsa/Iiso
IVa=IVsa/IIIso or IIIsa/IVso, IVb=IVsa/IVso

Table 6. Practical classification of Hayward and Wadleigh, 1949

Soil	EC_e	ESP	pH
Non saline	<4mS/cm	<15	<8.5
Alkali(=sodic)	<4mS/cm	>15	>8.5
Alkali(=sodic) saline	>4mS/cm	>15	<8.5
Saline	>4mS/cm	<15	<8.5

A probable follow up of the de Sigmond's scheme is the "Practical classification" of Hayward and Wadleigh, 1949, as discussed by Richards in 1954 (Table 6). At the beginning it contained only two properties, EC and pH. These two characteristics correspond to the salinity and soda content in soils. There is a close relationship between soda concentration and pH, therefore, the first version of the practical classification of Hayward and Wadleigh was very similar to that of de Sigmond. The use of the old term „alkali soil" has been replaced by the term:"sodic soil", consequently „salt-affected soil" basically includes saline and sodic soils as it is indicated by the title of the book of Bresler et al, 1982: Saline and sodic soils.

de Sigmond's classification did not make allowance for the physiographic position of the soil in the landscape, but during its use in the field for describing plant associations it proved to be suitable by adding two "QUALIFIERS" such as DRY or WET stands of native grassland vegetation. This work was done by Magyar, 1928 (Table 7).

Table 7. Correspondence between de Sigmond's salinity/sodicity (numerical limits in Table 5) classes and *Magyar's* (Magyar, 1928) *botanical* classification of plant associations for "dry" and "wet" stands

-------------*ON DRY SURFACES*--
Class I
Lolium perenne-Cynodon dactylon-Poa angustifolia
Class II

Festuca pseudovina association*, Achillea-Inula* subassociation
Class III
Festuca pseudovina association*, Artemisia-Statice* subassociation
Class IV.
Camphorosma annua association

--------------*ON WET SURFACES*--
Class I
Agrostis alba-Alopecurus pratensis, Glyceria fluitans var. poiformis association
Class II
Agrostis alba-Eleocharis uniglumis-Alopecurus geniculatus association
Class III
Agrostis alba-Beckmannia eruciformis association
Class IV.
Puccinellia distans association

The qualifiers corresponded to zones in the toposequence, where there was no waterlogging during the year, or there were some periods with stagnant water. The combination of wet/dry stands of Table 7 can be aligned in a toposequence to receive the elevational zoning of the plant associations from the lowest to the highest (W_ indicates WET, D_ indicates DRY stand) in the following way:

Class W_I W_III W_II W_IV D_IV D_III D_II D_I

It is evident that in Hungary the maximum salt accumulation in the landscape can be found at intermediate elevation zones: W_IV and D_IV. This distributional pattern is very characteristic of the Hungarian solonetzic landscapes.

Table 8. Tury's (1957) classification for afforestation

de Sigmond's class for topsoil (A+B horizon)
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de Sigmond's class for subsoil (C horizon)

Additional index shows depth of layer limiting root growth, e.g.

I/III-80 : leached out topsoil, saline subsoil with limiting layer at 80 cm depth
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There was only a slight modification of de Sigmond's scheme by Tury, 1957 (Table 8), which is still used for afforestation of SAS. Here categories I-IV are deduced from de Sigmond's original ones.

Bodrogközy, a plant sociologist approached the task of classifying SAS with a perfectionist' bias, and intended to match with full detail the plant sub-associations distinguished within subtypes and variants of SAS (Table 9). His newly introduced soil variants (Bodrogközy, 1965) were not used by other soil scientists.

Table 9. Excerpt from the corresponding classification of plant associations and soil variants suggested by Bodrogközy (1965).

SOIL TYPE **Soil subtype/variant**	ASSOCIATION GROUP Plant subassociation
MEADOW SOLONETZ	PUCCINELLION LIMOSAE
Strongly leached silty meadow solonetz	
	Pholiuro-Plantaginetum myosuretosum
Weakly leached silty meadow solonetz	
	Pholiuro-Plantaginetum puccinellietosum

Table 10. Classes of soil reclamation according to Prettenhoffer (1969).

Genetic soil type	**Reclamation class**	*Technique of reclamation*
Deep meadow solonetz, step.	**Acidic, non-calcareous**	*Liming*
Deep and medium m. solonetz, step.	**Neutral, non-calcareous**	*Spreading gypsic subsoil (digo-earth)*
Medium m. solonetz, -crusty m. solonetz	**Non-calcareous, slightly alkaline**	*Lime+gypsum or gypsic subsoil spreading*
Medium-crusty m. solonetz	**Alkaline or calcareous with soda**	*Lignite powder, $CaCl_2$, H_2SO_4, HCl*
Solonchak-solonetz	**Calcareous, with soda**	*Lignite powder, $CaCl_2$, H_2SO_4, HCl*

A practical classification for the reclamation of SAS was developed by Prettenhoffer (1969) (Table 10), so that a decision on the necessity of soil reclamation could be made easily. Although the plot-wise reclamation of SAS is performed on the basis of analytical data and 1:10 000 scale maps, the above scheme is a useful aid in the determination of the type of chemical reclaiming material. In this classification the genetic classes of soils and the reclamation classes form a hierarchical system.

Table 11A. shows the scheme of de Sigmond from the year 1938, from his book of “Principles of Soil Science”. This is a chemical classification system based on basic constituents (stage I: organic or mineral), the degree of degradation (stage II) and dominant components (stage III) of the soil. The significance of his classification scheme is more academic than practical, but it was applied for the first completed detailed map of Hungarian soils, the “Soil-use maps” prepared by Kreybig et al. in the scale of 1: 25 000. Fortunately, the subdivision of Na-soils as shown in Table 11B, can be considered to be a permanent one, as the same categories can be found in the present classification of SAS as well.

Table 11. Classes of salt-affected soils according to de Sigmond, 1938

A. General overview

STAGE I	*STAGE II*	STAGE III
1.Organic soils	*1. Raw*	1.Base-poor, 2.Base-rich, 3.Saline turfs
	2. Humified	4.Acid, 5.Neutral, 6.Saline peats
2. Organic mineral soils	*3. Raw*	7.Endo-, 8.Ekto-, 9.Pseudoadynamic soils
	4. Humic siallites	10.H-, 11.Ca-, 12. Na-soils
	5. Ferric siallites	13.Brown, 14.Red, 15.Yellow earth
	6. Allites	16.Pure, 17.Siallitic, 18.Bauxitic allites
3. Purely mineral soils	*7. Raw*	19. Mixed rock debris, 20.Min., 21.Fine dust
	8. With decomposition	22.Ca, 23. Si partly mobilized
	9. With end-products of decomposition	24.With easily, 25.Slowly soluble salt crust

B. Classes of salt-affected soils: “Soil order 12. Sodium soils” according to de Sigmond, 1938

STAGE IV.
Main type 1:Saline soils=solonchak
Main type 2:Saline alkali soils=solonchak-solonetz
Main type 3:Leached alkali soils=solonetz
Main type 4:Degraded alkali soils=solod
Main type 5:Regraded alkali soils= salinized again soil

Table 12. Current genetic classification of Hungarian salt-affected soils

HALOMORPHIC SOIL TYPES

Subtypes

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22. **Solonchak**
    22/1 "Carbonatic" 22/2 "Carbonatic-sulfatic" 22/3 "Carbonatic-chloridic"
23. **Solonchak-solonetz**
    22/1 Carbonatic 22/2 Carbonatic-sulfatic 22/3 Carbonatic-chloridic
24. **Meadow solonetz**
    24/1 Crusty 24/2 Medium depth 24/3 Deep
25. **Meadow solonetz soils turning into steppe formation**
    25/1 Medium depth 25/2 Deep
26. **Solods**
27. **Secondary salinized/sodificated soils**
    27/1 Solonchaky 27/1 Solonetzic

The current classification system of Hungarian SAS meets two requirements: it fits the general principles of genetic soil classification, first developed in Russia (described in Gerasimov, 1960) and later further developed in Europe (Kubiena, 1953) and USA (Marbut, 1927, Soil Survey Staff, 1951) up to the middle of the twentieth century, and it keeps the traditional categories of Hungarian SAS. Table 12 shows the current "official" classification of the main types of "salt-affected soils" of Hungary (Szabolcs, 1966 and Guidelines, 1989), some of its properties will be discussed later in the paper.

Table 13. Major classes of the Map of European salt-affected soils (Szabolcs,1974)

SALINE SOILS
(=Cl and SO_4 solonchak)
ALKALI SOILS WITHOUT STRUCTURAL B HORIZON
(=soda solonchak and solonchak-solonetz)
ALKALI SOILS WITH STRUCTURAL B HORIZON_calcareous
(=solonetzes and solonetzic meadow soils)
ALKALI SOILS WITH STRUCTURAL B HORIZON _non-calcareous
(=solonetzes and solonetzic meadow soils)
POTENTIAL SALT-AFFECTED SOILS
(=chernozems with saline subsoil)

A further development of these pedogenetic approaches was found in the classification system published by Szabolcs (1974). A regrouping of the Hungarian categories was necessary to match those used on the map of European SAS. As Table 13 shows, this consisted of a simplification and also a separation. Simplification meant for example joining meadow solonetzes, "solonetzes turning into steppe formation" (original term) and solonetzic meadow soils into the category of "alkali soils with structural B horizon". Separation included distinguishing classes of "alkali soils with structural B horizon" based on the presence of $CaCO_3$ in the profile. This has been conducted only at the level of variants, one level lower than the level of subtypes in the classification of Table 12. Table 3 illustrates this classification, and shows its more detailed categories.

Place of Hungarian salt-affected soils in the international systems

It is indispensable to have correlation tables for national classification schemes, but it has not been made explicitly for the Hungarian soils yet. Table 14 shows the place of Hungarian SAS in the World Reference Base (WRB, 1994). Due to the small number of Major Soil Groups it is easy to use. Nevertheless, the use of Qualifiers (formative elements for naming soil units) would increase the number of distinct categories largely, but would not change the simple structure of categories.

Table 14. Categories of the World Reference Base for Soil Resources, Wageningen/Rome, 1994 under which Hungarian salt-affected soils fall

MAJOR SOIL GROUPS	*Soil units*
SOLONCHAKS	*Gleyic, Stagnic, Calcic, Sodic, Haplic*
SOLONETZ	*Gleyic, Stagnic, Salic, Albic, Mollic, Calcic, Haplic*
VERTISOLS	*Salic, Sodic*
HISTOSOLS	*Salic*

Table 15. shows the correlation of US Soil Taxonomy (Soil Survey staff, 1990) with the Hungarian SAS. This table was prepared with the help of Dr. E. Michéli (Tóth, 2002). Evidently there are numerous orders/suborders/great groups for the Hungarian SAS that complicate the classification.

Classification of salt-affected soils in neighbouring countries

In order to overview the possible ways of improving the classification of Hungarian SAS we will take a look at the relatively new systems of two neighbouring countries. These countries have large salt-affected territories in the Carpathian Basin with the same formation conditions as Hungary has.

Czechoslovakia

Although this country no longer exists, the soil classification system, developed lately (Morfogenetic classification of the soils of Czechoslovakia.1991) is still in use. In recent years the classification system has been revised, but no changes were made in the group of saline soils. The system is based on three diagnostic horizons: solonchakous S, solonetzic Bn and solonetzic-solodic Bnd horizons. Within the group of saline soils, two types are distinguished, solonchak (typical and solonetzic subtypes) and solonetz (typical and solodic subtypes). Salinity and sodicity are also considered in the classification for three other soil groups, Mollisols, Fluvisols and Anthropogenic soils. The definition of diagnostic horizons is similar to that of WRB, with slight differences.

Romania

Although there is an edition of "The Romanian system of soil classification", newer than 1980, within the system the classification of SAS has not changed. The system is based on two diagnostic horizons, salic and natric, but both have variants (salinized, alkalized), allowing less strict limits in respect to the concentration of salts and exchangeable Na percentage. In the group of halomorphic soils only solonchak and solonetz types are distinguished with the following subtypes: typic, mollic, gleyic, alkalinized solonchak soils and typic, luvic, albic, glossic, cambic, mollic, salinized, gleyic solonetz soils. Salinity and sodicity are also considered in the classification for seven other soil groups, Mollisols, Argiluvisols, Cambisols, Hydromorphic soils, Vertisols, Histosols and Inceptisols. The definition of diagnostic horizons mainly contains chemical limits.

Table 15. Tentative correlation between USDA (GREAT GROUP level) and Hungarian (*soil type level*) nomenclature of typical soils occurring in salt-affected landscapes in the Great Hungarian Plain

Soil Order	Suborder	GREAT GROUP *Hungarian soil type* ESP>15	 ESP<15
Vertisols	Aquerts	NATRAQUERT *Solonetzic meadow soil*	CALCIAQUERT *Meadow soil*
„	„		ENDOAQUERT

			Meadow soil
„	Usterts		CALCIUSTERT *Meadow soil*
„	„		HAPLUSTERT *Meadow soil*
Mollisols	Albolls	NATRALBOLL *Meadow solonetz (solod)*	
„	Aquolls	NATRAQUOLL *Solonetzic meadow soil* or *Meadow solonetz*	ENDOAQUOLL *Meadow soil*
„	Ustolls	NATRUSTOLL *Meadow solonetz*	CALCIUSTOLL *Chernozem*
„	„		VERMUSTOLL *Chernozem*
„	„		HAPLUSTOLL *Chernozem*
Alfisols	Aqualfs	NATRAQUALF *Meadow solonetz*	
„	Ustalfs	NATRUSTALF *Meadow solonetz*	
Inceptisols	Aquepts	HALAQUEPT *Solonchak*	

Future of the classification of Hungarian SAS

We have proposed the following principles for the development of the classification of Hungarian salt-affected soils:

- adaptation to changing environmental conditions and land use
- adaptation to changing field/laboratory instrumental techniques
- compatibility with previous national, but also with internationally used categories

Table 16. shows that Hungarian halomorphic soils can be described adequately by WRB categories. For the classification of soil types not belonging to halomorphic soils, such qualifiers as Endosalic, Hyposalic, Endosodic might be useful. Details of the suggested classification scheme will be presented later.

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Table 16. Soil properties of Hungarian salt-affected soil types in two classification systems. Presence of specific features is indicated with +(yes) and -(no).

		Present Hungarian genetic classification					World Reference Base			
		SOIL PROPERTIES					*HORIZONS*		*PROPERTIES*	
SOIL TYPE	Code	Presence of horizons	Maximum of soil salt content (%)	Depth of salt maximum	Presence of columnar B horizon	ExNa in horizon B %)	Salic horizon	Natric horizon	Salic	Sodic
Solonchak	22	-	> 0.15	surface	-	>25	+		+	
Solonchak-solonetz	23	+	> 0.15	near surface	+	>25	+	+	+	+
Meadow solonetz	24	+	> 0.10	below surface	+	>25		+		+
Meadow solonetz turnig into steppe formation	25	+	> 0.10	below surface	+	>25		+		+
Solod	26	+		below surface	+			+		+
Secondary salinized soil	27/1	+	> 0.15				+		+	
Secondary sodificated soil	27/2	+				>5		+		+

↑ Presence of horizons ↑ Salic horizon
↑ Maximum of soil salt content (%) ↑ Natric horizon
↑ Depth of salt maximum ↑ Salic
↑ Presence of columnar B horizon ↑ Sodic
↑ ExNa in horizon B %)

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