Salt-Affected Soils and Their Native Vegetation in Hungary

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Abstract Approximately 13% of Hungary is considered to be salt-affected and with this large extent it is unique in Europe. There are large areas of naturally saline and sodic soils, but also secondary salinization is known to occur. Due to the geological and hydrological conditions, the country demonstrates the most characteristic features of natural continental (not marine) salinization, sodification and alkalinization. Since the most important direct source of soil salinization is the shallow groundwater level below the lowland surface, there is a chance of irrigation-related salinization in two dominant situations: when the abundant use of river waters causes waterlogging and rise of saline groundwater (salinization from below); and when typically saline tubewell-waters are used for irrigation (salinization from above). The spatial assessment of salt-affected areas began with the systematic mapping of salt-affected areas. There are a series of ten maps describing different aspects (salt-affected soil types, vegetation types, salt-efflorescences) of the salinity-status nation-wide from 1897 onward, with the latest survey finished last year. Besides the national scale of 1:500,000, soil salinity is also mapped at the scale of 1:100,000 on the "AGROTOPO" map sheets and 1:25,000 in the "Kreybig"-practical soil information (spatial vector data for maps and database for profiles and borings) systems. In spite of the two systems being digitally available, the most detail information collected at the scale of 1:10,000 is available only for 2/3 of the country and is not digitised. Very early maps at field scale, later at regional scale showed numerical salinity/sodicity values. At present field scale numerical maps are analysed in order to optimise salinity mapping in space and time. Parallel to soil studies, the assessment of the vegetation of saline and sodic lands is a traditional topic of Hungarian botanists. The vegetation of these areas is used for millennia by grazing and provides medicine and raw material for several purposes.

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1 Introduction

Traditionally the study of salt-affected soils (SAS) is one of the most popular topics among Hungarian soil scientists. The origin, properties and reclamation of these soils (in Hungarian "szik") were investigated thoroughly during the last two centuries. A complete list of the 22 monographs on salt-affected soils is reported by Tóth and Szendrei (2006). The mapping of these soils started in 1897, mapping at the scale of 1:25,000 was finished by the 1950s, and their last assessment, now of the areas covered with native halotolerant vegetation, was carried out in the years 2003–2006 (Bölöni et al. 2003), see Fig. 2. This summary is based on Tóth (2008).

2 Environmental Conditions in Hungary

About one third of the soils on the Great Hungarian Plain (N 46–48.5° and E 19–22.5°) are affected by salinity/sodicity, mainly by sodification, one third of the territory is covered by potential SAS, and one third does not have such soils. Potential SAS are defined as

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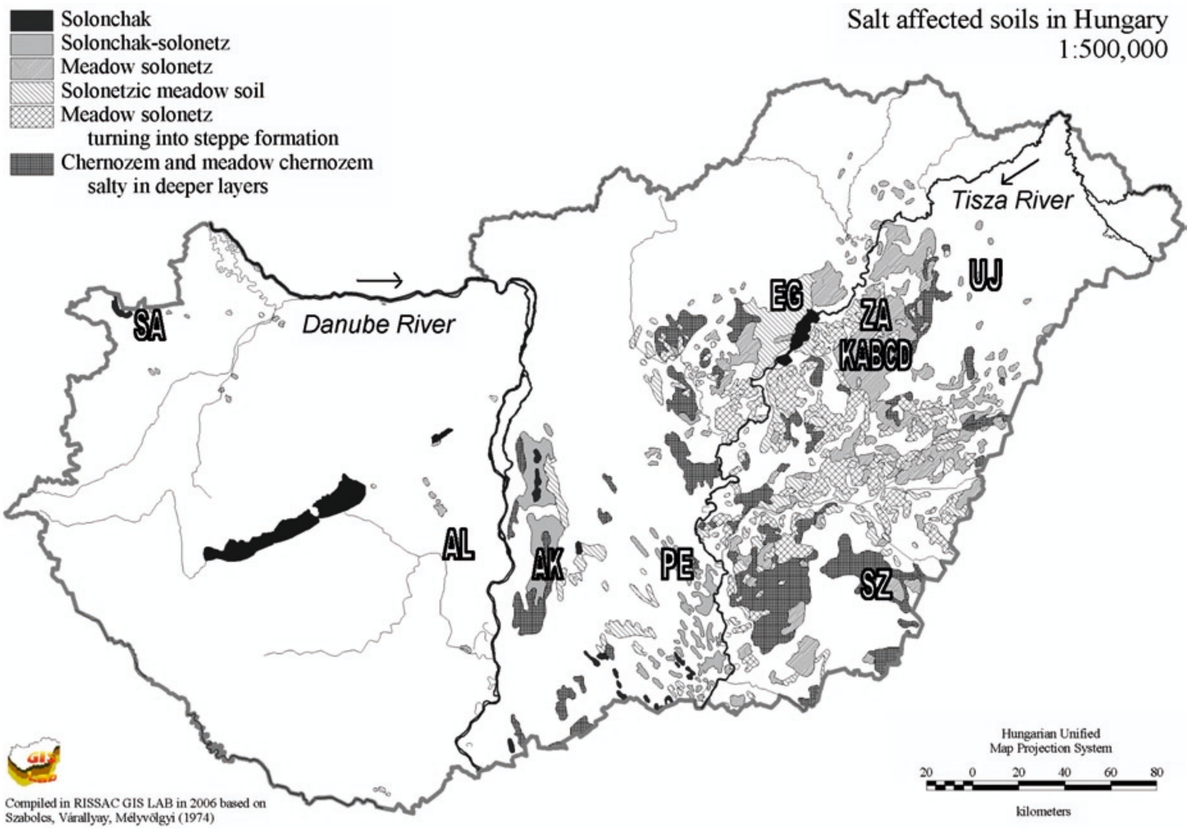

Fig. 1 Map of Hungarian salt-affected soils as published by Szabolcs (1974) and the location of the profiles described in Tables 2–4

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 (Fig. 1). Soil types Solonchak and Solonchak-Solonetz are concentrated mainly in the Danube-Tisza Interfluve, types "Meadow Solonetz" and "Deep Mollic Solonetz"[1] are more typical in the Tisza Plain.

3 Meteorological Conditions

The Great Hungarian Plain is the hottest and driest region of the Carpathian Basin, which is otherwise characterized by temperate climate. In the central region, where SAS are most common, data describing annual averages and dynamism is summarized in Table 1. The area of Hungarian SAS, is located at an elevation of 80–90 m above sea level, under temperate continental climate, with 10°C mean annual temperature of –2°C in January and +21°C in July, 527 mm average annual precipitation (June is the most rainy month with 71 mm, March has the least precipitation with 28 mm), and 900 mm mean annual pan evaporation.

4 Hydrological Conditions

The Great Hungarian Plain is a basin filled with sediments deposited by rivers and wind. Therefore, the position of surface waters had an important impact on soil formation. These rivers, as typical lowland rivers, affected a vast territory by the periodic floods, creating huge marshlands. According to their origin, sediments deposited from the rivers differ much and the base materials of soil formation reflect these differences.

[1] In this report the term "Meadow Solonetz Turning into Stepp Formation" of Szabolcs, 1966 and Szabolcs, 1989 p 245 has been replaced by the term "Deep Mollic Solonetz" for reasons of clarity.

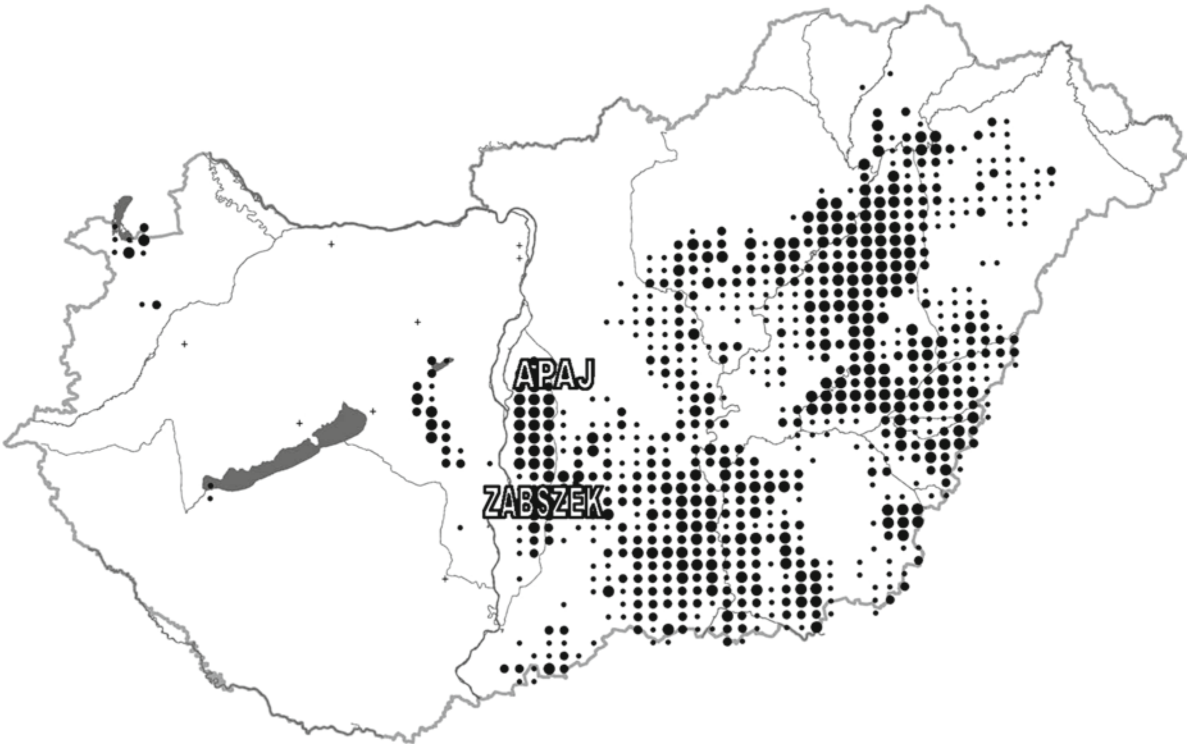

Fig. 2 The distribution of F2, "Salt meadow" habitat, copied from Molnár et al. (2008) and the location of study sites (Tables 5–6)

Table 1 Average meteorological parameters in the middle of the Great Hungarian Plain

Parameter (monthly)	1	2	3	4	5	6	7	8	9	10	11	12	Year
Precipitation (mm)	30	30	28	41	51	71	53	50	34	33	46	46	527
Potential Evaporation	12	19	40	78	112	136	156	144	106	58	25	14	900
Drought Index	0.40	0.63	1.43	1.90	2.20	1.92	2.94	2.88	3.12	1.64	0.54	0.30	1.71
Actual evap (mm)	11	15	27	63	102	91	76	58	35	21	16	12	527
Air temp (°C)	1.8	0.5	5.2	10.9	16.0	19.7	21.3	20.5	16.4	10.7	5.3	0.6	10.0

In the formation of salt affected soils a decisive role is played by saline groundwater, so the different types of SASs in the Hungarian soil classification system are closely related to distinct groundwater table depths. There are regional and local differences in the composition and concentration of groundwater that resulted in the wide variety of salt-affected soils.

5 Soil Conditions

According to the general Hungarian classification of soils, there are soils of the Atlantic region (Brown Forest soils) in the hilly marginal regions of the plain and of the steppe region (Chernozems) in the inner plateaus of the plain. Important "azonal" soils are the salt-affected soils and Meadow soils. These, together with the "intrazonal" Alluvial soils, form a catena. As the parent material between the Danube and Tisza$_{\text{Hungarian}}$ (=Theiß$_{\text{German}}$ or Tisa$_{\text{Slovakian\&Ukrainian}}$) rivers is rich in calcium-carbonate, the Solonchak and Solonchak-Solonetz soils developed on the alluvial sandy soils are classified as "Calcareous Sodic soils", whereas the more or less leached Solonetz-like soils that were developing on the more acidic sediments of the Tisza River (loamy and clayey parent material) are frequently referred to as "Non Calcareous Sodic Soils". The latter is characterized by higher clay-content and unfavourable hydrophysical properties, high ESP (Exchangeable Sodium Percentage) and high pH in the columnar B horizon and, as a rule, low salt content.

The unfavourable properties that limit the fertility of these soils are the consequence of the high clay content, high ESP, high pH and the resulting special moisture regime. The climatic conditions, e. g. the unequal distribution of the precipitation, the high aridity index and the high fluctuating saline groundwater call for a complex approach for improvement for agricultural purposes.

6 Groundwater Conditions

The Great Hungarian Plain consists of a variable layered and textured deep aquifer where the groundwater table varies between 0.5 and 4.0 m below surface, with an average fluctuation of 0.5–2.0 m. The shallow water table often causes waterlogging on the lower parts of the fields. Surface waterlogging appears also on the low-lying, low permeability plots at the end of winter, after snowmelt and/or during high-precipitation periods. The high salt content of the groundwater and its high $Na^+/(Ca^{++} + Mg^{++})$ ratio often result in salinization and alkalinization of the soils.

7 The Formation of the SAS of Hungary

At the beginning of the Miocene geological Era (23–5.3 million years before present) between the ancient "Carpathian" and "Dinaric" Mountains a vast gulf of the "Tethys" ancient sea flowed in to create the "Parathethys". This sea gulf later became detached from the Tethys and – known as the "Sarmathian" or "Pannonic" Sea – by the end of the Pliocene Era (5.3–1.8 million years before present) has been filled up with several hundred meter thick alluvial sediment. During the Pleistocene Era (1.8 million to 11,550 years before present) this process continued and loess formation took also place on the previously deposited alluvial sand. In some areas the sand was blown into dunes.

On the parent materials formed during the Pleistocene Era the influence of shallow fluctuating, saline-sodic groundwaters, as well as the permanent or temporary waterlogging created the conditions of SAS formation. The sodium ions, being considered as the most important factors, either dissolved from the Tertiary Era (65–1.8 million years before present) deposits into the groundwater (supported by data of Mádlné Szőnyi et al. 2005) or concentrated during consecutive drying and wetting of infiltrated water (as argued by Bakacsi and Kuti 1998). Szöőr et al. 1991 have shown that salinization has been present in the Great Hungarian Plain at least 30,000 years before. Among the anions in the groundwater and soil solutions there were plenty of bicarbonates, carbonate and other ions with alkaline hydrolysis and these caused almost irreversible sodium exchange processes.

8 Classification of Hungarian Salt-Affected Soils

In the late US classification of SAS the term "white alkali soil" stood for Solonchak soils and "black alkali" for Solonetz soils. The modern Hungarian soil classification is based on these categories as well. The categories like saline, sodic and saline-sodic as suggested by Richards 1954 and de Sigmond 1938, are also still in use. In agronomic practice the limit for a soil to be called SAS is 0.1% soluble salt content, as suggested by de Sigmond 1938 and Richards 1954.

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.

The Hungarian SAS, belonging to the "Main soil type" of "Halomorphic soils" of the national soil classification system (Szabolcs 1966) are divided into five soil types: Solonchak soils, Solonchak-Solonetz soils, Meadow Solonetz soils, Deep Mollic Solonetz, Secondary Salt-Affected soils. The following list shows the current "official" classification of the main types of "salt-affected soils" of Hungary (Szabolcs 1966; Guidelines 1989). The acreage of the soil types was calculated from the Agrotopographical Map Database (in short AGROTOPO) database, (described by Várallyay et al. 1985). The map of salt-affected soils as shown by Fig. 1 was compiled by Szabolcs (1974).

9 Solonchak Soils (Total Area 47 km²)

These soils are *per definitio* the saline soils, which are mainly located in low-lying areas, typically shorelines of saline/sodic lakes, in the region between the Danube and Tisza Rivers, but also occur in patches east of the Tisza River. These soils are characterized with 60–80 cm deep groundwater table and an average total soluble salt content of 0.3–0.5% at the surface. Dominant salts are sodium-carbonate, bicarbonate, sulphate and chloride. There is calcium-carbonate in the whole profile. It is difficult to distinguish horizons in the profile of this soil. These soils are not cropped, but sustain native halophyte vegetation which is grazed.

10 Solonchak-Solonetz Soils (Total Area 659 km²)

These saline-sodic soils are also located mostly between the Danube and Tisza Rivers, but above deeper groundwater level, ca at 1 m. In the profile a weakly developed columnar/prismatic natric (= solonetzic) B horizon can be distinguished. There is calcium-carbonate in the whole profile. These soils sustain native halophyte vegetation which is grazed.

11 Meadow Solonetz Soils (Total Area 2,749 km²)

The typical "solonetz" soils of Hungary are the typical sodic soils on the Great Hungarian Plain, mostly east of the Tisza River, but also west of the Danube River. These soils are characterized by large exchangeable sodium percent and not high salt content. This latter can be low enough in the "A" horizon to permit cultivation on these soils. Otherwise these soils sustain native halophyte vegetation which is grazed. The fertility of the soil is proportional to the thickness of slightly saline "A" horizon. In the characteristic columnar/prismatic natric B_1 horizon, where the maximum of the sodium adsorption can be encountered, the value of exchangeable sodium percent (ESP) is at least 20–25%. The maximum of salt accumulation can be found in the B_2 horizon, where the soil structure is prismatic or "nutty" (= large subangular blocky). Calcium-carbonate is generally absent from the A and B_1 horizons. The depth to the groundwater table is between 150 and 350 cm.

12 Deep Mollic Solonetz (Total Area 2,122 km²)

When the groundwater table is lower (3–4 m below the soil surface) the leaching reduces the soluble salt and calcium-carbonate content of the upper horizons of these sodic soils. "Turning into steppe formation", the term originally used for this soil type by Szabolcs (1966) denotes soil forming processes similar to those of the steppe (Chernozem) soils. These soils are typically ploughed.

13 Secondary Salt-Affected Soil (Not Distinguished on the Agrotopo Database as Polygons)

This soil type comprises all soils, which were originally not salt-affected, but due to human influence became salt-affected. Besides the mentioned SAS there are other SAS types which belong not to the main type of "Halomorphic soils" but to other main soil types, such as "Solonetzic Meadow soils" with total area of 2,419 km², and "Chernozem soils with saline/sodic subsoil" with total area of 4,185 km². These soils are typically ploughed.

In Hungary the total area of salt-affected soils, based on the AGROTOPO database (printed on the map sheets by the Kartográfiai Vállalat in 1983), is 12,181 km². With this acreage the overall area of SAS covers 13% of the national territory. The map provided by the Hungarian Central Statistical Office, 2006 is almost the same as published by Stefanovits (1963), based on his map of the soils of Hungary at the scale of 1:200,000. Although there are differences in the acreages of the distinct SAS types between the two sources, but the total acreages, as 11,087 (Stefanovits 1963) or 12,181 km² (AGROTOPO) are close.

14 The Utilization of SAS in Hungary

Though the improvement (reclamation or amelioration) of these soils is scientifically well founded, it is a rather costly operation. This is a reason why large tracts of these soils are kept as grazeland or hayfield, land for afforestation, paddy field or fishpond. Most of the Hungarian National Parks have salt-affected grasslands, hayfields, marshes, reedlands, lakes and these provide habitat for protected animals (mainly birds), plants and attract lots of tourists. Many of the protected animals barely find a place for feeding and breeding on other soil types, since most of those are cropped or otherwise intensively utilized. In total some 88% of the surface of the country has no natural vegetation cover (cropland, tree plantations with exotic species, orchards, vineyards, settlements, roads, etc.).

Among the crops that may be grown economically on these soils the most important is winter wheat. It covers above the half of the area of the SAS. Other important crops are winter barley, sunflower, Sudangrass, vetch, rice and sometimes maize, sugarbeet and pea.

15 Information Available on the Spatial Extent of SAS

There is an outstanding record of collecting soil information in Hungary. The historical past is summarized in several publications (Ballenegger and Finály 1963). Just like in other countries in the early period of soil mapping, before the First World War there were two tendencies: special mapping of selected, usually small areas and preparation of very small-scale maps, based on scarce observations and continental-scale conceptual models. In Hungary the first Hungarian soil (that time called agrogeologic) map was compiled in 1861 (Szabó 1861) for the area of two counties at the scale of 1: 576,000. Few years later the soil map of Tokaj-Hegyalja intended to improve the production of the famous Tokaj wine in the region (Szabó 1865–6). A major achievement was the first complete soil map of Hungary prepared by Timkó in 1914. During the pre-war and after-war periods of 1935–1951 the “Kreybig” practical soil mapping was completed and displayed on maps at 1:25,000. From the 1960s the 1:10,000 scale mapping of the agricultural lands was performed. From 1989 no systematic large-scale soil mapping is carried out.

16 Agrotopo Map Database

It was the 1:100,000 scale AGROTOPO soil spatial database, which became available first digitally. This database, which was developed in 1990s, integrates the dominantly small-scale soil related data into digital format and is organized into spatial soil information systems (AGROTOPO: Várallyay 1989; HunSOTER: Várallyay et al. 1994; MERA: Pásztor et al. 1998). Information in the AGROTOPO is provided for nine properties, such as soil types, soil parent material, soil texture, clay-mineral composition, soil water regime category, soil reaction and carbonate status, soil organic matter stock, depth of solum and soil bonitation value. There are altogether 3,312 polygons for the total area of 93,000 km^2 of the country. As background to the soil polygons there is a general topographic sheet with landuse categories, elevation contour lines, settlements, waterways, roads, etc.

16.1 The 1:25,000 Soil Information System (Kreybig Digital Soil Information System)

The national soil mapping project initiated and led by L. Kreybig was unique, being a national survey based on both field and laboratory soil analyses and at the same time serving practical purposes (Kreybig 1937). Due to inactivity during the Second World War it was carried out between 1935 and 1951 in several stages. In the fifties, when the mapping was successfully completed, Hungary was among the first countries in the world to have such detailed soil information for the whole country. These maps still represent a valuable treasure of soil information. The soil and land use conditions were shown jointly on the maps. Altogether three characteristics were attributed to soil mapping units and displayed on each mapsheet. First feature distinguished was land use, both ploughland and grassland was not distinguished. Second was the chemical reaction shown by colours and third feature was the physical soil properties of the soil root zone. Some further soil properties were determined and measured in soil profiles. A very remarkable feature of the map series is that it distinguishes three different categories of SAS by colour codes:

Reddish purple colour: SAS suitable for cropping.

Light purple colour: SAS potentially suitable for cropping, can be reclaimed with $CaCO_3$.

Dark purple colour: SAS not suitable for cropping, which cannot be reclaimed with $CaCO_3$.

The GIS adaptation of soil information originating from the soil maps displayed on 1:25,000 scale is still under construction (Pásztor et al. 2006). There is much more utilizable information originating from this survey, than it was processed earlier and published on the map series and in reports, and what is provided by simply archiving them digitally. The surplus information should be exploited by the new technologies provided by GIS and DSM (digital soil mapping) and provide the basis of improved management of the soils.

16.2 Genetic Soil Maps of 1:10,000 Scale

In the early 1960s a mapping technology was elaborated by the Hungarian soil scientists, soil surveyors and soil-mapping specialists for the large-scale soil survey to satisfy the practical needs of soil information of large farming units (state and co-operative farms), which characterized the Hungarian agriculture between 1950 and 1990. Such maps were prepared for about one-third of the area of Hungary, representing two thirds of the cropland (ca 35,000 km^2). The mapping reports consist of four main parts: (i) genetic soil map, indicating soil taxonomy units, and the parent material; (ii) thematic soil maps on the most important physical and chemical soil properties; (iii) thematic maps, indicating recommendations for rational land use, cropping pattern, amelioration, tillage practice and fertilization; (iv) explanatory booklets including a short review on the physiographical conditions; description of soils, recommendations for their rational utilization; field description of soil profiles; results of field observations or measurements and data of laboratory analyses (Szabolcs 1966). These maps were widely and successfully used in Hungary and became an easily applicable scientific basis of intensive, large-scale agricultural production, in spite of the fact that generally these maps were not published in printed form and are available only as manuscripts at the given farming units or at the Plant and Soil Conservation Stations. The large-scale soil-mapping programme was restarted in 1986 within the framework of the National Land Evaluation Programme (Guidelines 1989). The aim of this Programme was to valuate the agricultural land based on soil survey at the scale of 1:10,000, but was also left uncompleted. These huge archives provide appropriate raw material for recent digitally based applications. Spatial soil information systems based on these data could be efficiently used in numerous fields.

Szabolcs (1966) described the methodology to be used in the detailed mapping of soils. For example in the case of SASs this method at the scale of 1:10,000 can be illustrated best with the set of individual map sheets which might make up a complete soil mapping document.

17 Exemplary Data of Hungarian Salt-Affected Soils

Twelve soil profiles were selected to demonstrate the characteristics of Hungarian salt-affected soil types from Jozefaciuk et al. (2006). Basic properties of the studied soils are presented in Tables 2–4. The studied profiles were described in different regions of the Hungarian Plain, a floodplain with varying thickness of alluvial sediments. Occurrence of salt-affected soils is closely related to groundwater depth and salinity, being the most important factors of salinization, and also to surface waters – the frequency and time of waterlogging. During the last 200 years great changes in the hydrological situation in the Plain took place and the distribution of salt-affected soils reflects these changes closely (Tóth et al. 2001). At most of the sampling sites the groundwater level has been sufficiently close to the surface and enough saline to cause salt accumulation.

Very slightly salt affected Karcag (K) profiles represent the best stands for crops: Chernozems (KA (irrigated), KB and KD) and a Vertisol (lower elevated site KC, irrigated). The native vegetation on higher areas is thick grasses and the soil is fertile. In the lowest patches fine particles have been settled and the soil is cracking, but also shows frequent waterlogging. As it is typical for such soils, sodicity is observed only in deeper layers of the subsoil (where the capillary water-rise affects the chemical features) and the topsoil is salt-free (Table 2).

Among the other soils taken from native sites, some occurred at relatively higher elevation in the toposequence (Egerlovo EG, Szabadkigyos SZ and Alap AL)

Table 2 Characteristics of the sites of the profiles

Site	Sarród	Egerlövő	Szabadkígyós	Zám	KarcagM1	KarcagM1K	KarcagM2	KarcagM2K
Code in Table 4	SA	EG	SZ	ZA	KA	KB	KC	KD
Description	Grassland	Grassland	Grassland	Grassland	Cropland	Cropland	Cropland	Cropland
Geographic coordinates northern	47º39.253′	47º43.600′	46º36.232′	47º31.669′	47º18.628′	47º18.650′	47º18.606′	47º18.655′
Eastern	16º48.764′	20º35.706′	21º5.815′	21º2.381′	20º48.737′	20º49.969′	20º48.632′	20º48.633′
Elevation m	118	95	91	94	88	87	86	87
Soil type	Stagnic	Vertic	Mollic	Haplic	Haplic	Haplic	Haplic	Haplic
World reference base	Solonchak	Solonetz	Solonetz	Solonetz	Chernozem	Chernozem	Vertisol	Chernozem
Hungarian classification	Solonchak	Medium Meadow Solonetz	Crusty Meadow Solonetz	Crusty Meadow Solonetz	Meadow Chernozem	Lowland Chernozem	Meadow Soil	Lowland Chernozem
Native plants	Salicornea europea Suaeda salsa Plantago maritima	Suaeda salsa Limonium gmelini Artemisia santonicum	Camphorosma annua Puccinellia limosa Artemisia santonicum	Salicornea europea Suaeda salsa Plantago maritima	na	na	na	na
Groundwater depth (cm)	190	180	204	250	200	200	220	220
EC	6.0	1.5	5.0	7.5	7.4	5.7	2.8	4.1
pH	7.7	7.8	8.0	8.1	8.5	8.4	7.7	8.2
SAR	19	4	68	65	49	43	11	24
Ca (me/l)	5	5	0.62	0.77	1.08	1.04	2.89	0.6
Mg	18	3	1	4	4.07	3.74	3.91	2.28
Na	66	9	61	100	79.4	67.2	20.95	28.8
K	0.25	0.24	0.07	1	0.04	0.03	0.04	0.03
SO_4	68	9	9	1	3.55	5.2	2.1	1.85
Cl	16	1	27	73	35.7	14.0	4.41	3.07
CO_3	4	2	7	2	4.66	2.54	0	1.2
HCO_3	13	7	20	26	19.44	27.31	8.44	17.70

Site	Újfehértó	Péteritó	Alap	Akasztó
Code in Table 4	UJ	PE	AL	AK
Description	Grassland	Grassland	Grassland	Grassland
Geographic coordinates northern	47º47.795′	46º34.635′	46º48.927′	46º40.578′
Eastern	21º41.250′	19º53.984′	18º39.503′	19º9.121′
Elevation (m)	114	93	92	94
Soil type world reference base	Stagnic Solonchak	Gleyic Solonchak	Calcic Solonchak	Salic Solonchak
Hungarian classification	Solonchak	Solonchak	Solonchak	Solonchak-solonetz
Native plants	Kochia scoparia	Puccinellia limosa	Camphorosma annua	Lepidium crassifolium
	Puccinellia limosa	Lepidium crassifolium Aster tripolium	Limonium gmelini	Puccinellia limosa
Groundwater depth (cm)	150	80	200	95
EC	4.7	11.0	11.0	7.5
pH	8.15	8.3	8.2	9.6
SAR	45	90	80	145
Ca (me/l)	1	0.1	1.4	0.05
Mg	2.5	7	6	1
Na	60	169	154	105
K	0.2	2.3	0.3	0.5
SO_4	2.3	0.9	121	7.2
Cl	5.2	31	37	16
CO_3	7.5	35	5.3	45
HCO_3	60	56	17.3	79

na – not applicable

Table 3 Colour, texture and structure of the horizons distinguished in the studied soil profiles

Site and date of sampling	Code of horizon	Depths (cm)	Wet colour	Texture	Structure
Sarród 2000 Aug 29	1	0–10	10YR5/2	SL	s-SUB
Sarród 2000 Aug 29	2	10–18	10YR3/2	C	s-SUB
Sarród 2000 Aug 29	3	18–52	2.5Y7/3	CL	s-SUB
Sarród 2000 Aug 29	4	52–54	10YR4/3	LS	nps
Sarród 2000 Aug 29	5	54–75	2.5Y7/2	CL	nps
Újfehértó 1999 Aug 16	1	0–4	5Y5/3	SL	PLA
Újfehértó 1999 Aug 16	2	4–14	5Y5/3	CL	ABL
Újfehértó 1999 Aug 16	3	14–40	2.5Y5/4	L	SAB
Újfehértó 1999 Aug 16	4	40–85	2.5Y5/6	L	SAB
Péteritó 2000 Jul 28	1	0–3	2.5Y4/2	SL	PLA
Péteritó 2000 Jul 28	2	3–13	2.5Y5/2	LS	s-SAB
Péteritó 2000 Jul 28	3	13–39	2.5Y4/2	LS	s-SAB
Péteritó 2000 Jul 28	4	39–58	2.5Y5/2	LS	s-SAB
Péteritó 2000 Jul 28	5	58–77	2.5Y6/1	LS	s-SAB
Alap 2OOO Aug 24	1	0–2 (efflorescence)	7.5YR2/2	SC	nps
Alap 2OOO Aug 24	2	2–28	7.5Y2/2	SC	COL
Alap 2OOO Aug 24	3	28–57	7.5Y3/2	SC	SAB
Alap 2OOO Aug 24	4	57–71	2.5Y7/4	SG	SAB
Alap 2OOO Aug 24	5	71–82	2.5Y7/6	SL	SAB
Akasztó 1998 Jul 30	A	0–3	5Y5/2	SL	s-SAB
Akasztó 1998 Jul 30	B	3–19	5Y6/2	CL	COL
Akasztó 1998 Jul 30	BC	19–38	5Y6/3	L	SAB
Akasztó 1998 Jul 30	C1	38–58	5Y6/3	L	SAB
Akasztó 1998 Jul 30	C2	58–90	5Y6/3	L	SAB
Akasztó 1998 Jul 30	C3	90–92	5Y5/3	LS	SAB
Egerlövö 2000 Aug 9	A/e	0–8	2.5Y3/1	L	PLA
Egerlövö 2000 Aug 9	B1	8–21	2.5Y2/1	CL	PRI
Egerlövö 2000 Aug 9	B2	21–46	2.5Y3/1	CL	l-SAB
Egerlövö 2000 Aug 9	B3	46–78	2.5Y2/1	C	ABL
Egerlövö 2000 Aug 9	BC	78–118	2.5Y3/1	C	ABL
Egerlövö 2000 Aug 9	C	118–130	2.5Y4/1	LC	SAB
Szabadkígyós 2000 Sep 8	A	0–2	10YR4/2.5	L	PLA
Szabadkígyós 2000 Sep 8	B1	2–17	10YR2/1	CL	COL
Szabadkígyós 2000 Sep 8	B2	17–36	10YR2/2	CL	SAB
Szabadkígyós 2000 Sep 8	BC	36–67	2.5Y4/3	CL	PRI
Szabadkígyós 2000 Sep 8	C	67–90	2.5Y4.5/5	CL	PRI
Zám puszta 2001 Aug 23	A/e	0–7	2.5Y3/2	L	PRI
Zám puszta 2001 Aug 23	B1	7–22	2.5Y3/2	C	s-SAB
Zám puszta 2001 Aug 23	B2	22–38	2.5Y3/2	C	ABL
Zám puszta 2001 Aug 23	BC	38–68	2.5Y4/2	C	ABL
Zám puszta 2001 Aug 23	C1	68–75	2.5Y5/3	C	SAB
Zám puszta 2001 Aug 23	C2	100–120	2.5Y5/3	C	SAB
Karcag_M1 1998 Oct 22	Ap	0–18	10YR3/1	CL	ABL
Karcag_M1 1998 Oct 22	A	18–32	10YR3/1	CL	ABL
Karcag_M1 1998 Oct 22	B	32–51	2.5Y3/1	CL	s-SAB
Karcag_M1 1998 Oct 22	BC	51–92	10YR3/2	CL	s-SAB
Karcag_M1 1998 Oct 22	C	92–100	10YR4/3	CL	s-SAB
Karcag_M1K 1998 Oct 22	Ap	0–21	10YR2/2	CL	s-SAB
Karcag_M1K 1998 Oct 22	A	21–46	10YR3/1	CL	s-SAB
Karcag_M1K 1998 Oct 22	B	46–68	10YR3/2	CL	SAB
Karcag_M1K 1998 Oct 22	BC	68–111	2.5YR4/2	CL	ABL
Karcag_M1K 1998 Oct 22	C	111–118	2.5YR4/3	CL	ABL

(continued)

Table 3 (continued)

Site and date of sampling	Code of horizon	Depths (cm)	Wet colour	Texture	Structure
Karcag_M2 1998 Oct 22	Ap	0–20	10YR2/1	CL	ABL
Karcag_M2 1998 Oct 22	A	20–36	10YR2/1	CL	PRI
Karcag_M2 1998 Oct 22	B	36–75	10YR2/1	CL	ABL
Karcag_M2 1998 Oct 22	BC	75–95	10YR2/1	CL	PRI
Karcag_M2 1998 Oct 22	C	95–105	10YR3/2	CL	ABL
Karcag_M2K 1998 Oct 22	Ap	0–28	10YR2/2	CL	ABL
Karcag_M2K 1998 Oct 22	A	28–45	10YR2/2	CL	ABL
Karcag_M2K 1998 Oct 22	B	45–68	10YR2/2	CL	ABL
Karcag_M2K 1998 Oct 22	BC	68–105	10YR3/3	CL	ABL
Karcag_M2K 1998 Oct 22	C	111–115	2.5YR4/3	L	ABL

SL sandy loam, *L* loam, *CL* clay loam, *C* clay, *PLA* platy, *SAB* subangular blocky, *ABL* angular blocky, *COL* columnar, *PRI* prismatic, *l* large, *s* small, *nps* no pedological structure has developed

Table 4 Selected properties of the studied profiles

Sample	pH	OM	Carb.	Clay	CEC	SP	EC	Na	SAR
SA5	8.98	0.89	22.1	15	6.1	33	27	345	45.1
SA14	8.93	0.93	33.7	38.1	12.9	62	16.2	167	33.5
SA35	8.94	0.56	57.9	45	10.6	55	15.3	162	30.8
SA53	9.21	0.48	26.6	17.8	7.9	33	11.2	110	26.5
SA65	9.13	0.42	53.7	36.6	8.6	57	11.6	111	26.2
EG4	8.08	4.31	1.3	29.4	25.4	66	25.2	440	69.7
EG14	8.66	2.33	9	50.6	32.3	93	21	342	64.2
EG34	9.11	1.55	14.8	50	32	128	14	192	73.6
EG62	9.14	1.3	13.3	46.9	31.4	143	8	97	71
EG98	9.24	0.99	12.6	42.2	28.3	140	2.7	28	40.8
EG124	9.39	0.71	28.2	38.1	22.3	98	2.5	11.2	21.8
SZ1	9.26	2.2	4.24	30	23.6	53	21	380	223
SZ9	9.56	2.37	12.7	44.5	26.3	67	25.4	456	357
SZ26	9.8	1.74	18.2	41.1	23.7	69	19.5	345	361
SZ53	9.92	1.18	20.4	38.5	20.4	73	11.8	187	258
SZ78	9.97	0.59	22.9	37.1	16	86	6.9	100	171
ZA3	9.21	2.05	0.3	28.5	18.2	52	36.2	489	409
ZA14	9.68	1.56	0.3	34.7	21.8	66	22.8	289	282
ZA30	9.75	1.41	0.8	44.9	25.6	93	16.3	200	249
ZA53	9.73	1	5.6	48.2	25.7	116	10.5	117	137
ZA71	9.72	0.84	21.4	44.3	19.5	98	8.3	87	110
ZA110	9.48	0.49	20.6	33.6	16.6	88	7.2	75	77.4
UJ2	10.2	0.79	6.72	10.3	6.3	37	20	405	684
UJ9	10.4	0.4	11.13	21.8	9	44	8	138	223
UJ27	10.3	0.38	36.8	28.8	11	57	4.7	82	160
UJ62	10.3	0.21	26.25	22.8	11	50	3.5	62	111
PE2	9.95	1.29	15.2	7.1	5.2	37	71	1080	620
PE8	10.2	0.69	20.2	10.7	3.7	33	7.9	100	197
PE26	10.4	0.3	13.5	9.8	3.9	33	6.3	80	169
PE48	10.4	0.22	20.2	15.8	3.8	47	6.2	75	180
PE68	10.3	0.22	31.6	20.4	3.9	44	6.2	74	136
AL1	9.87	1.18	2.5	14.2	8.3	33	78	1750	2060
AL15	9.84	1.17	4.2	22.7	15.2	48	25	386	387
AL43	10	0.68	16.9	21.7	9.6	46	16.2	220	339
AL64	10.2	0.06	13.9	4.2	3.8	33	10	124	560
AL76	9.87	0.16	23.2	17.2	10.5	73	9.5	114	260

(continued)

Table 4 (continued)

Sample	pH	OM	Carb.	Clay	CEC	SP	EC	Na	SAR
AK2	9.88	1.19	29.3	9.2	5.4	35	70	1000	2100
AK11	10.2	0.63	33.9	20.1	7.3	39	29	398	3370
AK28	10.1	0.2	38.2	17.8	7.3	43	27.5	374	7780
AK48	10.1	0.23	33.9	13	7.5	40	24.3	329	10,000
AK74	10.5	0.23	26.3	3	5.8	35	12.7	120	10,000
AK92	10.5	0.13	18.7	3.6	4.9	30	12.8	134	484
KA9	7.33	5.32	0	41.3	26.7	47	1.1	3.8	2.05
KA25	6.91	4.08	0	40.8	33.3	46	0.7	2.3	1.69
KA42	7.67	3.15	1.4	41.4	34.5				
KA72	8.51	2.59	7.2	41.7	33.2	52	0.5	3.6	5.19
KA96	9.52	0.94	8.8	39.3	15.7	51	1.2	12	19
KB11	7.4	6.48	0	40.2	24.3	48	0.8	2.7	1.62
KB33	7.84	2.99	1.2	39.5	24.4	52	0.6	2.5	1.94
KB57	8.38	2.54	5.8	40.3	27.3	53	0.5	2.9	3.08
KB89	9.25	1.83	9.5	40.3	17	47	1	9.3	13.4
KB114	9.72	0.07	9.9	35.9	14	56	2.1	22	30.7
KC10	7.47	5.61	0	39	24.1	48	0.6	3.5	3.46
KC28	7.67	3.87	0	40.1	21.6	45	0.7	5.6	6.55
KC56	8.76	2.91	0	49	31.8	46	1.2	11	15.9
KC85	8.95	1.99	0	47.8	29.8	49	2.6	27	31.1
KC100	8.97	1.22	0	46.6	19.6	55	2.6	27	33.2
KD14	7.53	5.42	0	40.1	27.7	48	1.1	9.1	10
KD26	7.39	3.37	0	40.3	31.5	53	0.6	3	2.92
KD56	8.05	2.71	4.9	38.5	22.3	55	0.5	2.2	2.05
KD87	8.28	2.02	8.8	39.8	18.8	52	0.5	2.9	3.34
KD113	9.03	1.54	11.4	37.8	20.3	46	0.7	6	8.81

Sample is identified by horizon depth mid-point (cm). pH H_2O, *OM* organic matter %, *Car.* carbonates %, *Clay* clay %, *SP* saturation percentage, *EC* electric conductivity of the soil saturation extract (mS cm^1), *Na* sodium concentration in the soil saturation extract (mM dm^{-3}), *SAR* sodium adsorption ratio

where the salt efflorescenses can be found in small patches only. Solonetz is the typical soil type in this situation, but Solonchak limited to small patches is found also. The latter soil type is the most typical one in waterlogged areas and beside saline lakes. The above soils have *Artemisia santonicum* as the dominant plant species. Intermediate elevation is occupied at (Akaszto AK), which was earlier a temporary lake, already being dried out and covered by sparse vegetation stands of *Camphorosma annua*. From lower elevations we sampled Ujfeherto (UJ) and Zam (ZA) profiles, temporary waterlogged sites, where *Kochia scoparia* and *Salicornia europaea* are characteristic plant species, respectively. The lowest elevation sites (Sarrod SA and Peterito PE) are close to typical saline lakes, where *Suaeda salsa* and *Aster tripolium* plus *Puccinellia limosa* (more hydrophytic vegetation) dominate, respectively, although these soils are not usually covered by lake water. The drier, upland sites of highly saline soils are grazed by sheep and the lowland ones, especially those beside lakes, are grazed by wild geese.

Chernozem and Vertisol profiles at Karcag are more brown (10YR) than salt-affected soils. Profiles close to lakes are paler in colors. The variable layering of the subsoil of Sarrod profile, caused by depositions, is evidenced in color and texture as well (Table 4).

The texture of the studied soils ranges from loamy sand to clay. The eluvial A/E horizons of Solonetz soils have coarser texture and a lower clay content than the illuvial horizons. In Solonetz soils prismatic and columnar structure reflects high sodicity. The amount of clay in soils of higher salinity is usually the highest in illuvial B horizons while in less saline or non-saline soils this is rather uniform throughout the whole profile.

The presence of calcium carbonate is common all over the Hungarian Plain because of the frequent occurrence of loessial and carbonatic deposits of River Danube. All studied profiles contain carbonates except the Vertisol profile KC. As it is typical for chernozems, calcium carbonate occurs in deeper layers in KA, KB and KD. Leached (low carbonate) topsoil layers are characteristic for Solonetz soils, whereas Solonchak contain rather high amounts of carbonates right at the surface (Table 4).

Electrical conductivity of the saturated soil extracts ranges between 2 and 78 dS/m for salt-affected soils and this is significantly lower for slightly salt-affected soils. Solonchak soils show continuously decreasing EC values down from the topsoil. Solonetz soils show small electric conductivities at the surface and a maximum in B2 horizons. In non saline soil types (Chernozem and Vertisol) largest EC values are found in the deepest horizon, affected mostly by saline groundwater. The electric conductivity of the saturated soil extracts decreases in general with the profile depth for all soils which is also noted for the sodium adsorption ratio (Table 4).

Except one horizon all samples are alkaline and mostly reach pH values higher than 9. More leached horizons of slightly saline and Solonetz profiles can have neutral pH at the surface. Soil pH increases down the profiles, similarly as the carbonate content (Table 4).

As a minimal value, soil organic matter of 0.8% was determined. Solonchak soils typically do not have SOM larger than 1.5%. SOM content around 3% can be found in the uppermost horizon of Solonetz soils. Chernozem and Vertisol profiles show SOM above 5%. The amount of soil organic matter accumulated in the profiles studied is closely related to their pH. Presence of such dependence was very surprising for us, because amount of soil organic matter in soils depends on many environmental factors, conditions of soil genesis and physical soil properties, and not on a single parameter. However all studied soils are located within rather small area and, as far as the pH is a main parameter responsible for organic matter leaching, one may suspect that at higher pH its accumulation has been prevented by the extreme conditions for plants and microbes. Where there is better plant growth there is larger soil organic matter content, that dissolves $CaCO_3$, plants use the Ca and it results in a decrease in pH.

18 Vegetation of Saline and Sodic Areas

The list of plant species of saline and sodic habitats is best represented by the floras of the National Parks. Out of the ten National Parks, there are five parks possessing saline and sodic areas. The first flora was written about the first Hungarian National Park, the Hortobágy National Park (Szujkó-Lacza et al. 1982) and others followed.

Soó (1980) listed the 25 saline and sodic plant associations, belonging to the division "*Puccinellio-Salicornea*" in two association class, 4 association series, 7 association groups. The most frequent of these are the following: *Salicornietum prostratae, Suaedetum pannociae, Salsoletum sodae, Crypsidetum aculeatae, Puccinellietum limosae, Pholiuro-Plantaginetum tenuiflorae, Hordeetum hystricis, Camphorosmetum annuae, Lepidio crassifolii-Puccinellietum limosae, Agrostio-Alopecuretum pratensis, Eleochariti-Alopecuretum geniculati,Agrostio-Beckmannietum,Achilleo-Festucetum pseudovinae, Artemisio-Festucetum pseudovinae*.

There are other associations, which are related to saline and sodic soils, such as *Bolboschoenetum maritimae continentalis, Glycerietum maximae*, typical for salt marshes.

There is a sodic woody association, the *Galatello-Quercetum roboris* and on its clearings the *Peucedano-Galatelletum*.

Recently a full list of associations was given by Molnár and Borhidi (2003).

Molnár et al. (2008) summarizes the actual distribution of saline vegetation. Here we copy their map (Fig. 2) only on one habitat, the salt meadows (Code F2 according to Bölöni et al. 2003), which are the most frequent grassy habitats in the country. Most characteristic associations belonging to this category are *Agrostio-Alopecuretum pratensis, Agrostio-Caricetum distantis, Eleochari-Alopecuretum geniculati, Agrostio-Glycerietum poiformis, Agrostio stoloniferae-Beckmannietum eruciformis, Rorippo kerneri-Ranunculetum lateriflori, Loto-Potentilletum anserinae.*

19 Example of the Soil and Vegetation Conditions in Two Characteristic Kiskunság Sites

The soil properties and vegetation at two nearby sites is described here based on Tóth et al. (2003). The study region is the Danube valley where there was a drop in groundwater level and soil desalinization was observed together with a shift in vegetation (Table 5). Data on more than five years monitoring are presented here.

The "Artemisia saline puszta" vegetation at Apaj is a result of gradual drying and groundwater sinking. Right after the drainage of the area probably Bolbo schoenetum maritimi, after which Lepidio crassifolii-Puccinellietum limosae plant associations was characteristic, of these two characteristic species was found in the quadrats. The official nomenclature of the present plant association is Artemisio–santonici–Festucetum pseudovinae Soó (1933) 1947 corr. Borhidi 1996 (Molnár and Borhidi 2003).

This plant community is named as ***Artemisia* saline puszta (15.A113)** by Devillers and Devillers-Terschuren (1996) and we use this name in the text. Its characteristics are described under the code of F1a by Molnár et al. (2003) and can be summarized as:

- Typical soil is Solonetz, the soil is affected by shallow groundwater and surface waterlogging as well.
- There are no shrubs or trees among these grasses, neither tall grasses.
- Most characteristic species are *Artemisia santonicum* subsp. *monogyna* subsp. *patens*, *Festuca pseudovina*, *Limonium gmelini*, *Podospermum canum*, *Trifolium retusum*, *Trifolium angulatum, T. parviflorum*, *Ranunculus pedatus*, *Bupleurum tenuissimum*, *Gypsophila muralis*, *Lotus tenuis* (*L. glaber*), *Cerastium dubium*.
- They occur in an elevation zone between Pannonic *Puccinellia limosa* hollow (lower neighbor) and slightly saline **Grassy saline puszta** or **nonsaline Pannonic loess steppic grasslands** (upper neighbor) (names according to Devillers and Devillers-Terschuren 1996).
- Regenerative potential is good, but the details are not known.

At present the site is grazed by sheep.

The "Pannonic Puccinellia limosa hollow" vegetation at Zabszék lake is the result of continous drying of the lake and the shifting of lake margin towards the bottom of the lake. The previous stage might have been lake-margin vegetation and *Bolboschoenetum maritimi* plant association. The official nomenclature of the plant association is Lepi diocrassi folii–*Puccinellietumlimosae* Soó 1947–puccinellietosum.

This plant community is named as **Pannonic Puccinellia limosa hollows (15.A131)** by Devillers and Devillers-Terschuren (1996) and EUNIS(2002) and as used in this text. Its characteristics are described under the code of F4 by Bagi and Molnár (2003) and can be summarized as:

- Typical soil is Solonchak. A condition of its occurrence is shallow saline groundwater and repeated waterlogging, typical on the bank of saline lakes. The spring and late summer aspects might be very different.
- Physiognomy is determined by waterlogging. If there is no waterlogging the *Puccinellia limosa* is small, on wet places it grows high, forms tussocky patches.
- Most characteristic species are *Puccinellia limosa*, *P. festuciformis* subsp. *intermedia*, sometimes important species are *Lepidium crassifolium* (*L. cartilagineum*), *Aster tripolium* subsp. *pannonicus, Artemisia santonicum* subsp. *santonicum* and subsp. *patens, Plantago maritima.*
- They occur in the neighbourhood of saline lakes.
- Regenerative potential is very good.

At present the only major grazing animals are wild geese, mostly *Anser anser*.

The two sites represent the most typical salt-affected habitats of Kiskunság region, Hungary.

Although the clay percent is similar at the two sites (Table 6), the "Pannonic Puccinellia limosa hollow" site has less sand and more silt particles, which is the result of the effect of the sedimentation onto the lake bottom. The same process might have resulted in the larger $CaCO_3$ content of the soil in the same community. These differences are reflected in the Cation Exchange Capacity values, water retention values and soil hydraulic conductivity values as well. The surface soil of "Pannonic Puccinellia limosa hollow" site binds the water with stronger force and permits its movement less (Tóth and Kuti 2002).

Due to the complete plant cover at the "Artemisia saline puszta" site, the soil organic matter content is larger. The surface salinity is shown by the electrical conductivity (EC) of the saturation extract (Richards 1954). This standard indicator of soil salinity was analyzed for the profile characterization from the soil genetic horizons one time and showed three times as large EC at the "Pannonic Puccinellia limosa hollow"

Table 5 Some characteristics of the main species of the two exemplary associations based on Horváth et al. 1995 and the sources indicated

Name	Festuca pseudovina Hack. ex Wiesb.	Artemisia santonicum L. (ssp.)	Bromus hordaceus L. ssp hordaceus	Plantago maritima L.	Podospermum canum C. A. Mey.	Puccinellia limosa (Schur.) Homberg.	Aster tripolium ssp. pannonicus (Jacq.) Soó
Synonym	–	Artemisia maritima L.	–	–	Scorzonera cana (Mey.) Griseb.	–	–
Family	Poaceae	Compositae	Poaceae	Plantaginaceae	Compositae	Poaceae	Compositae
Mean (min–max) cover%	50.5 (5–76)	11.7 (0–29)	1 (0–9)	0.95 (0–4)	0.50 (0–2.5)	36 (0–80)	0.22 (0–4.75)
Site	Artemisia saline puszta	Artemisia saline puszta	Artemisia saline puszta	Artemisia saline puszta	Artemisia saline puszta	Pannonic Puccinellia limosa hollow	Pannonic Puccinellia limosa hollow
Raunkiaer life-form	Hemicryptophyton	Chamaephyton-Hemicryptophyton	Therophyton	Hemicryptophyton	Hemicryptophyton-Hemitherophyton	Hemicryptophyton	Hemicryptophyton
Vertical distribution	Plain–mountain	Plain	Plain-subalpine	Plain–mountain	Plain–mountain	Plain	Plain–hill
Flora element	Continental	Eurasian	Cosmopolitan	Circumpolar	Pontic-Submediterranean	Pannonian endemism	Eurasian
Vegetative propagation (Csontos 2001)	Bunching grass	Bunching grass	None	None	None	Bunching grass	Bunching grass
Dispersion of seeds (Thompson et al. 1997, Csontos et al. 2002)	Endozoochory	Anemo-, endozoo-, epizoochory	Endozoochory	Anemo-, endozoochory	Anemochor	Endozoochort	Anemo-, zoochory
Flowering (months)	6, 7	7, 8, 9, 10	5, 6, 7,	6, 7, 8, 9	5, 6, 7, 8, 9, 10,	6, 7	7,8,9
Seed ripening (months)	7	8, 9, 10,11	6, 7, 8	8, 9, 10	6, 7, 8, 9, 10	7, 8	8.9
Naturalness (Simon, 1988, 1992)	Disturbance tolerant native species	Native accessorial species	Disturbance tolerant native species	Native accessorial species	Native accessorial species	Native accessorial species	Native accessorial species
Strategy (Borhidi, 1995)	Competitor	Competitor	Disturbance tolerant	Generalist	Generalist	Competitor	Specialist
Heat supply (Borhidi, 1995)	Submediterranean woodland and grassland belt	In accordance with thermophilous forest or woodland belt	In accordance with submontane broad leafed forest belt	In accordance with mesophilous broad-leaved forest belt	Submediterranean woodland and grassland belt	In accordance with thermo-philous forest or woodland belt	In accordance with thermophilous forest or woodland belt

(continued)

Table 5 (continued)

Name	Festuca pseudovina Hack. ex Wiesb.	Artemisia santonicum L. (ssp.)	Bromus hordaceus L. ssp hordaceus	Plantago maritima L.	Podospermum canum C. A. Mey.	Puccinellia limosa (Schur.) Homberg.	Aster tripolium ssp. pannonicus (Jacq.) Soó
Soil moisture (Borhidi, 1995)	Xero-tolerants, but occasionally occurring on fresh soils	Xero-tolerants, but occasionally occurring on fresh soils	Plants of semi-humid habitats under intermediate conditions	Plants of fresh soils	Plants of semi-dry habitats	Plants of moist soils not drying out and well aerated	Xero-indicators on habitats with long dry period
Soil reaction (Borhidi, 1995)	Basiphilous plants	Basifrequent plants, mostly on basic soils	Mostly on neutral soils, but also on acidic and basic ones, generally widely tolerant more or less indifferent plants	Basiphilous plants	Basiphilous plants	Basifrequent plants, mostly on basic soils	Basiphilous plants
Nitrogen supply (Borhidi, 1995)	Plants of moderately oligotrophic habitats	Plants of sub-mesotrophic habitats	Plants of mesotrophic habitats	Plants of moderately oligotrophic habitats	Plants of habitats very poor in nitrogen	Plants of mesotrophic habitats	Plants of moderately oligotrophic habitats
Light intensity (Borhidi 1995)	Full light plants of open habitats	Full light plants of open habitats	Halflight plants mostly livingin full light, but shadow tolerant	Light plants	Light plants	Full light plants of open habitats	Full light plants of open habitats
Continentality (Borhidi, 1995)	Subcontinental, area in eastern CE	Continental species, reaching only eastern part of CE	Oceanic–suboceanic species area in whole Central Europe (CE)	Continental–subcontinental species, main area in Eastern Europe	Continental–subcontinental species, main area in Eastern Europe	Continental–subcontinental species, main area in Eastern Europe	Eucontinental species, main aera in Siberia and Eastern Europe
Salinity tolerance (Borhidi, 1995)	Beta-mesohaline plants living in soils of little chloride concentration 0.3–0.5%	Alfa-mesohaline plants living in soils of intermediate chloride concentration 0.7–0.9%	Species not occurring in saline or alkali soils	Polyhaline plants living in soils with high chloride concentration 1.2–1.6%	Alfa-mesohaline plants living in soils of intermediate chloride concentration 0.7–0.9%	Euhaline plants living in soils of very high chloride concentration 1.6–2.3 %	Polyhaline plants living in soils with high chloride concentration 1.2–1.6%

Table 6 Abiotic characteristics of the studied sites

Plant community	Artemisia saline puszta	Pannonic Puccinellia limosa hollow
Site	Apaj	Zabszék
Coordinates latitude	N 47º 05′14.0″	N 46° 50′ 34.8″
Coordinates longitude	E 19° 05′ 54.7″	E 19° 10′ 37.1″
Soil type	Solonetz	Solonchak
Soil clay % in 0–40 cm depth	30	34
Soil sand % in 0–40 cm depth	13	8
Soil physical properties in the uppermost layer of 3–9 cm		
Soil bulk density (g/cm^3)	1.7	1.76
Soil water retention at 0.1 kPa (saturation) (gravimetric %)	22	23
Soil water retention at 20 kPa (field capacity) (gravimetric %)	18	20
Soil water retention at 1500 kPa (wilting) (gravimetric %)	4.5	13
Soil saturated hydraulic conductivity (cm/day)	0.07	0.028
Chemical properties of 0–10 cm layer		
Soil organic matter in 0–10 cm layer %	2.2	0.9
Soil $CaCO_3$ content %	12	32
Exchangeable Na %	23	39
Cation exchange capacity-me/100 g soil	23	31
pH	8.3	8.5
Electrical conductivity of saturation extract (mS/cm)	1.8	5.3
Equivalent Na in cation composition of saturation extract (%)	76	98
Equivalent Ca in cation composition of saturation extract (%)	13	1
Equivalent Mg in cation composition of saturation extract (%)	1	1
Equivalent Cl in cation composition of saturation extract (%)	23	34
Equivalent SO_4 in cation composition of saturation extract (%)	18	14
Equivalent HCO_3 in cation composition of saturation extract (%)	53	44
Equivalent CO_3 in cation composition of saturation extract (%)	6	8
Average dynamic groundwater and lakewater properties		
Average (minimum, maximum) depth of groundwater level (m)	1.62 (0.6–2.3)	0.95 (0.7–1.5)
Average (minimum, maximum) EC of groundwater (mS/cm)	4.0 (0.92–5.5)	3.19 (1.45–3.82)
Average (minimum, maximum) pH of groundwater	8.7 (8.1–9.2)	8.2 (7.5–8.9)
Average (minimum, maximum) elevation of lake water level (m)	–	−0.26(−0.55+0.27)
Average (minimum, maximum) EC of lake water (mS/cm)	–	8.3 (2.2–31.9)
Average (minimum, maximum) pH of lake water	–	9.3 (8.1–9.9)
Average dynamic properties of 0–40 cm layer		
Average (minimum, maximum) $EC_{2.5}$ of soil in 0–40 cm layer-mS/cm	0.85 (0.45–1.17)	1.0 (0.75–1.78)
Average (minimum, maximum) pH of soil in 0–40 cm layer	9.6 (9.0–10.2)	10.0 (9.7–10.4)
Average (minimum, maximum) pNa of soil in 0–40 cm layer	2.36 (1.99–2.89)	2.2 (1.69–2.9)
Average (minimum, maximum) soil moisture of soil in 0–40 cm layer (%)	17.6 (5.2–38.3)	20.9 (14.6–29.3)

site than at the "Artemisia saline puszta" site in the surface layer. The reason for the difference is the contrastive soil types, which is Solonchak at the more saline "Pannonic Puccinellia limosa hollow" site. This soil type has the maximum of salt accumulation right at the surface. On the other hand, the Solonetz of the "Artemisia saline puszta" site has less saline, and alkaline, somewhat leached surface horizon, and reaches its maximum of salt concentration at greater depth. Consequently plants with low salt tolerance can live on Solonetz soils. On the other hand the differences in the temporal, depth average values (0–40 cm depth, 67 months) were not great.

The chemical composition of saturation extract of the surface layer (Table 6) shows that there is more Ca ion and less Cl at "Artemisia saline puszta" site, indicating the tendency of evaporative concentration of solutes. With increasing concentration of solutes Ca has a tendency of precipitating and Cl the tendency of increasing concentration, since this anion is the last to precipitate (Tanji 1990).

The groundwater was shallower at the lakeside "Pannonic Puccinellia limosa hollow" site and both average levels corresponded well to the characteristic groundwater depths in Solonchak (<1 m) and Solonetz (1.5–3 m) soils. The salinity of groundwater is only slightly higher at "Artemisia saline puszta" site probably due to less effect of atmospheric water. During the 5.5 years study period extreme low values were observed in one winter and were related to shallow groundwater. The average pH of soil at surface and in 0–40 cm layer is slightly higher at lakeside "Pannonic Puccinellia limosa hollow" site. There is an opposite tendency in the pH values of the groundwater, since it fluctuates in the more saline layers of "Artemisia saline puszta" site (Solonetz) and less saline layers of "Pannonic Puccinellia limosa hollow" site (Solonchak). The average value of lake elevation shows that it was 0.26 m deeper than the surface of the "Pannonic Puccinellia limosa hollow" site. During the driest period, when the salinity of lake water approached the concentration of sea, the level of lake was 0.55 m deeper. On the other hand the maximum level was 0.27 m above the surface, when the data collection was suspended for 16 months in the year 1999 due to extreme large precipitation. Lake water pH showed a clearly positive linear relationship to the EC. The dilution of the lake water by precipitation results in the lower dominance of carbonates (Dvihally 1960; Tóth et al. 2003).

Average dynamic properties of 0–40 soil layers showed the tendencies expected because of soil type (salinity = $EC_{2.5}$, pH) and presence of lake (moisture). The largest average moisture percentages measured at the two sites were within the limit of "available moisture range" defined between the field capacity and wilting point. On the other hand in the surface 0–10 cm layer soil moisture decreased below wilting capacity from time to time.

The plant composition of the sites, being dominated by Poaceae, Compositae and Plantaginaceae as shown in Table 5 is very similar to other temperate inland saline habitats and reflect the abiotic conditions. Compared to "Artemisia saline puszta" site the plants in "Pannonic Puccinellia limosa hollow"site prefer wet soil, light places and tolerate high salinity.

At "Artemisia saline puszta" site out of the five dominant plants four are typical for Pannonic saline grasslands. *Bromus hordaceus* is a common weed and its spreading is a relatively new feature in these vegetation types (Bagi 1989). Most of the ecological characteristics of *B hordaceus* are very different from the other four dominant species and show that the site is in change. At the surface where the plant roots live the conditions has become permissible for this plant.

At "Pannonic Puccinellia limosa hollow" site *Puccinellia limosa* is an endemic species, and the accompanying *Aster tripolium* is represented by an endemic subspecies. As Table 6 indicates, the surfaces of the quadrats were not covered completely with green vegetation during most of the study period. The bare surface changed between 0% when large stalks and leaves covered the soil surface and 100% during and immediately after waterlogging.

20 Utilization of Halophytes in Hungary

The first and most important utilization of the native vegetation is the grazing by domestic animals. Earlier grazing was typical for each of the saline and sodic vegetation types ranging from the tall grass occurring in the highest lying areas down to the lowest lying marshes. At present grazing is not typical in the wetlands. Loess steppes and taller grass sodic grasslands were and are grazed by horses and cattle. Shortgrass sodic grasslands were and are grazed by sheep. In the salt meadows typically there is no grazing, but hay cutting. Water buffalo and pigs were grazing the wetlands earlier. Also the Hungarian Grey Cattle are able to graze wet habitats, including reeds.

Besides grazing and hay cutting, reed (*Phragmites australis*) cutting is also typical in the wetlands belonging to saline and sodic vegetation. Also cattails (*Typha* sp) are collected here.

Bare sodic habitats have *Matricaria chamomilla* (chamomile) stands, which are collected as medicinal plant. Also *Achillea* sp*, Artemisia* sp*, Symphytum officinale, Althaea officinalis* are collected for medicinal purposes. *Limonium gmelini* and *Aster sedifolius* are collected from time to time as decorative plants.

Among mushrooms it is the *Agaricus bernardii* and *Marasmius oredes* which are collected most.

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