FIELD PEDOLOGICAL CHARACTERISATION OF TWO TRANSECTS ALONG THE INNER AND OUTER SIDES OF A SIXTY YEARS OLD TISZA DIKE – A CONTRIBUTION TO THE PROBLEM OF PRIMARY AND SECONDARY ALKALI GRASSLANDS

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Abstract

Two transects were studied by field pedological investigations and soil bulk electrical conductivity measurements in order to understand the effect of a 60 year old dike along the Tisza River on soil formation and vegetation composition. There were no great differences in the soil properties. The soil is more saline and wetter inside the dike and vegetation reflected this environment. We hypothesize that the increasing build up of the riverbed might contribute to the contrast in soil and groundwater salinity between the area inside and the area outside the dike, similarly as conceptualised by Kuti (1989) for the Danube area, but at a much smaller distance.

Keywords: Solonetz, pedology, soil morphology, soil formation, salinization, river regulation

1. Introduction

The lowland areas of Hungary are sedimentary basins filled by river deposits. Most of these areas were affected by regular (typically two times a year) floods before the large scale dike buildings of the period of 1843-1899 (Fig. 1). This area is characterised by a complex dynamics of several groundwater systems, including a shallow, often saline water table (Erdélyi, 1979). Obviously the formation of low-lying soils such as alluvial, “Meadow” (that is hydromorphic) and salt-affected soils is closely linked to the interaction of the impact of floods and water table regime.

Floods and diking can affect soils and vegetation to a great extent. Diking a river is a typical human intervention into the natural processes, such as soil formation and vegetation succession. Flooding affects the structure of soils considerably. In our study we aimed to verify these observations.

Fig. 1. Areas affected by floods before the large-scale diking in East Hungary. Taken from Ihrig (1952) and Schweitzer (2004). 1 = place and direction of flood water outbreak; 2 = inundated area, 3=study area.

About soil salinization issues, our study represents a special opportunity, since through the comparison of two transects along the inner and outer sides of the dike, the question of primary and secondary alkali grasslands could be addressed (Molnár-Borhidi, 2003). This question has been in the focus of vegetation studies. Shortly the “Two-Phase Theory” of Boros (1926, 1929) states that there were primary, natural alkali habitats in prehistoric times, which in the place of former floodplains later expanded due to human river control, and drainage. Following this paradigm, the primary alkali vegetation is found outside of late Holocene floodplains and the secondary on dried out floodplains (see in detail: Molnár - Borhidi 2003). On the place of secondary alkali steppes, the salt already existed in the soil profile, but because of the high water saturation, the effect was negligible for the vegetation (Szabolcs, 1961).

It is widely known or accepted that there are large salt-affected areas along the river Tisza. Szűcs (1954) observed that the alkali soils are quite frequent on the riverbank of Tisza. According to his opinion these soils were already salt-affected prior to the diking, but when they became drier, the effect of salts increased. The Solonetz soils here went through a stage of hydromorphic Meadow soils, after which the dropping groundwater level caused upward movement of salts in the profile. These ideas show close correspondence to the scheme suggested in Fig. 2. Similarly to Járó (1952), Arany (1989) also supports the observation that salt-affected soils are common in the Upper Tisza area. He lists three possible mechanisms for their formation, a) the sedimentation occurred on relict salt-affected soils, b) the leaching of salts is limited by an impermeable subsoil layer, c) the soils became salt-affected due to the effect of saline groundwater.

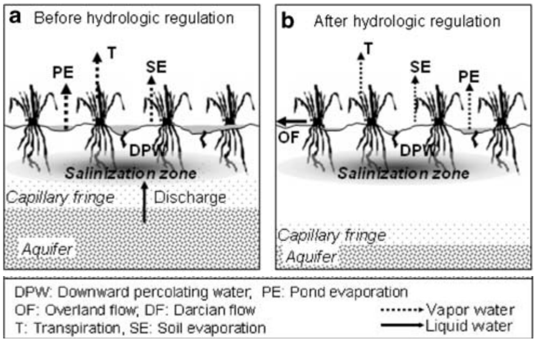

Fig. 2a–b. Conceptual model summarizing the range of hypothetical mechanisms which explain the salinization patterns observed in grassland before and after hydrological regulation. Before hydrological regulation (situation corresponding to the situation inside the dike) the water table was shallow enough to allow a discharge regime sustained by transpiration and a soil and river water evaporation leading to salt accumulation in the upper soil layers (a). After the hydrological regulation, (situation corresponding to the situation outside the dike) the water table was lowered and consequently the discharge regime interrupted, but the salts remained due to poor soil physical conditions (such as imperfect drainage and low permeability) preventing their total leaching (b). (Figure copied from Nosetto et al. 2007).

The river Tisza is currently cutting deeper its bed (Tóth et al., 2001) or building it up. For example during the 150 years since the diking, there was ca. 2 m of sediment deposition inside the channel at Szolnok (Schweitzer, 2004). Concerning the more recent sedimentary dynamics we could obtain the following figures recorded in the interval of 1970-1980: the individual floods resulted in 10-45 cm sediment accumulations. However the average sediment build-up for a period of seven years was about 30 cm (Oroszi et al. 2005). Since our study site is located between the Tiszalök and Kisköre dams we hypothesize that the controlled water level favours deposition of sediments.

This work is part of a multidisciplinary research involving botanists and pedologists. The purpose was to compare the soil characteristics and help understanding the differences in the vegetation associations of two soil sequences situated on both sides of a protection dike along the river Tisza, constructed 60 years before field observations. The soils outside of the dike (transect 1) are not inundated since the dike construction, while the soils inside the dike (transect 2) are on a temporary island and are part of the active floodplain of the river Tisza.

Our research hypothesis, presented in Fig. 2 is based on a lower groundwater level and a lesser degree of soil saturation outside the dike versus the inside area.

In this document only the pedological aspects and field observations are discussed. The assessment of the differences in vegetation has been already published in the second part of the publication of Molnár and Borhidi (2003), see especially the section "Evidence for the origin of secondary steppes" and Table 2 of the mentioned publication. A third paper (in preparation) will discuss the laboratory measured soil analytical data.

2. Materials and Methods

The field work, summarised below, has been carried out on 19 and 20 May 1999 beside the village of Tiszabábolna (Hungary) at N 47o41'4" E 20o49'38". Mean air temperature and sum of precipitation at nearby Tiszafüred is JAN(-2.1 ^{o}C, 30 mm), FEB (-1.4 ^{o}C, 30 mm), MAR (2.9 ^{o}C, 28 mm), APR (9.1 ^{o}C, 41 mm), MAY (15.1 ^{o}C, 58 mm), JUN (17.9 ^{o}C, 78 mm), JUL (20.2 ^{o}C, 59 mm), AUG (20.1 ^{o}C, 58 mm), SEP (15.2 ^{o}C, 40 mm), OCT (10.0 ^{o}C, 36 mm), NOV (3.5 ^{o}C, 46 mm), DEC (-1.14 ^{o}C, 42 mm) according to NASA, 2002.

Fig. 3 shows that there was no dike at the time of topographic survey. The soil mapping by the team of Kreybig (1937) was carried out by Zakariás (1942), right after the diking. Fig. 4 shows a distinct actual land use on the two sides of the dike (hay meadows inside, pastures and arable fields outside). Both inside and outside and parallel to the dike, west-east oriented transects were delineated towards the deeper eastern end, reaching temporary water bodies. Along the transects, plant coenological assessment (Molnár and Borhidi 2003, Table 2), soil bulk electrical conductivity measurements (ECa) (Rhoades and Van Schilfgaarde, 1976) (at each meter distance) and soil profile observations were carried out. On each transect, two shallow and one deep profiles were opened. With an auger all six profiles were studied down to the water table. Latter was sampled and its electrical conductivity (EC) and pH measured in the field with hand-held Horiba meters.

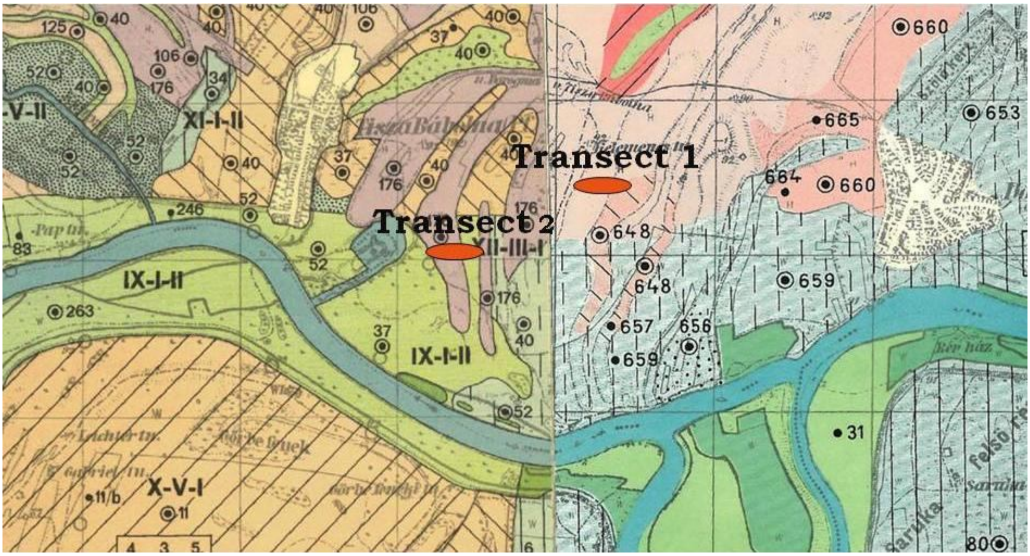

Fig. 3. The study area and the transects as shown by the soil maps (Kreybig, 1937). It can be observed that inside the bow of the river there are several roughly north-south oriented bended ridges which are covered by salt-affected soils, indicated by a purple colour.

Fig. 4. The area as shown by SPOT image with the approximate location of the transects (Google Earth, 2009 August).The west – east distance covered by the image is ca 5500 m.

The method of profile description was earlier described by Langohr (1994). This approach is more detailed than the method suggested by Szabolcs (1966) and allows answering better to the questions raised in this soil survey. Soil classification was carried out according to the Hungarian Soil Classification (Szabolcs, 1966).

3. Results

3.1. First transect

3.1.1. General information

This transect is situated outside of the dike. The landscape is gently undulating (see Fig. 6), with very small (tens of centimetres) differences in altitude. Three profiles have been observed along a toposequence parallel with the dike, going from a topographic high (Profile 1) to a depression (Profile 1B).

Present-day land use is pastureland. No moles or other burrowing animals of similar size are observed at the level of this transect and its immediate surroundings. In the years 60, the site has been used for crop production for about 5 years.

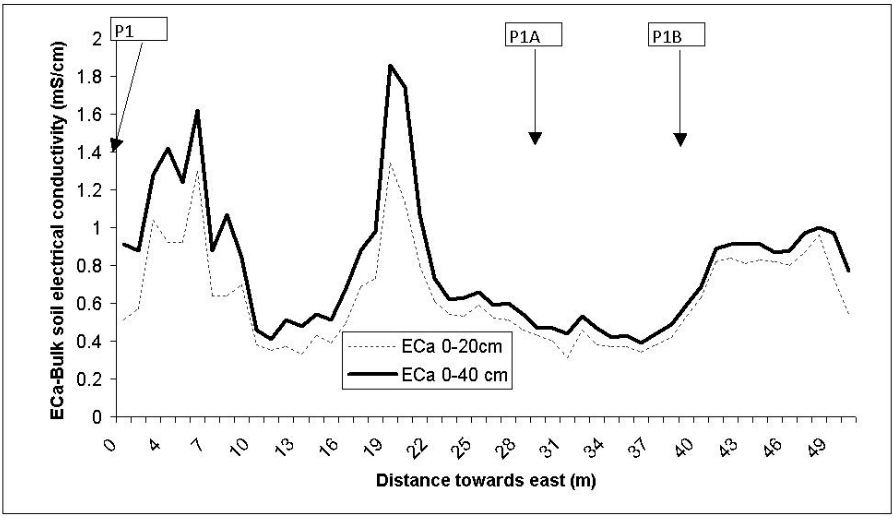

Fig. 5. Bulk soil electrical conductivity along Transect 1 (each meter) and the location of the profiles

Fig 5 shows the bulk soil electrical conductivity of Transect 1. From 42 m onwards there was standing water on the surface.

Fig 6a and 6b shows Profile 1 (outside) and Profile 2 (inside the dikes) the landscape of transects outside and inside the dikes. Table 1 and 2 shows the parameters of groundwater (water table) and surface water sample.

Fig. 6a. Profile 1. See Fig 7 for field sketch and Table 3 for the description of horizons.

Fig. 6b. Profile 2. See Fig 11 for field sketch and Table 6 for the description of horizons.

Table 1. Depth of groundwater table and its electrical conductivity (EC) and pH for the profiles of the first transect

Profile number	***Horizontal distances***	***Hungarian Soil Classification based on field observations***	***Depth of the groundwater***	***pH***	***EC (mS/cm)***
1	0	Deep Meadow Solonetz	227 cm	8.36	0.58
1A	30 m	Meadow soil	138 cm (134 cm after 1 day)	7.68	0.81
1B	40 m	Meadow soil	192 cm (89 cm after 1 day)	7.44	0.72
Water at the surface	45 m		at the surface	6.4	0.20

Table 2. Brief description of the ground vegetation of the profiles at the first transect

Profile number	***Ground vegetation***
1	*Eryngium campestre, Achillea setacea, Trifolium species; Festuca pseudovina, Myosotis stricta, Scorzonera cana, Plantago lanceolata, Ornithogallum umbellatum, Potentilla arenaria, Cerastium dubium*
1A	*Poa pratensis, Alopecurus pratensis, Fragaria viridis, Artemisia absinthium, Eryngium campestre*
1B	*Alopecurus pratensis*

3.1.2. Profile 1

This profile was considered as a reference for the first transect and more detailed descriptions were made. The field morphology of the observed characteristics is presented in Fig. 8a and 8b. First a general characterisation of the main horizons and a few particular observations will be presented. The systematic observations are described in Table 3.

Profile 1 description (see Fig. 7).

- H1 Fresh straw.
- H2 Root mat with some mineral components.
- H3 Organic rich mineral horizon with abundant roots.
- H4 Light coloured, most probably eluvial horizon. Corresponds also to the densest part of a traffic pan.

    Horizontal section at 10 cm:
    patchy colours, ranging from very dark grey to very light grey (see Table 3). Compressed by puddling and/or machines. Silty accumulations along the ped faces from the overlying horizon. ECa 2.00 mS/cm.

- H5 Transition horizon. Corresponds also to the lower part of the traffic pan.
- H6 Very dark coloured horizon, most probably with clay and organic matter accumulation.

  Note: based on the morphology the possibility of a buried surface horizon has been discussed. Two ceramic fragments (at 25 and 30 cm) were also found in this horizon; they could be related to this surface horizon. Nevertheless, the movement downwards by bioturbation (burrowing animals, root turnover) may also explain this position of the artefacts above the more dense clay accumulation horizons.
- H7 Transition horizon, with organic matter and clay accumulation.
- H8 Brown, horizon developed in loess-like sediments, calcareous.

Auger observations further down:

* in depth, calcareous material, similar with H8;
* doll like small $CaCO_3$ concretions all over;
* starting from 135-140 cm a more sandy, non-calcareous layer;
* around 180 cm again more calcareous silty layer
* at 190 cm (and deeper) once more sandy material with very weak reaction to HCl.

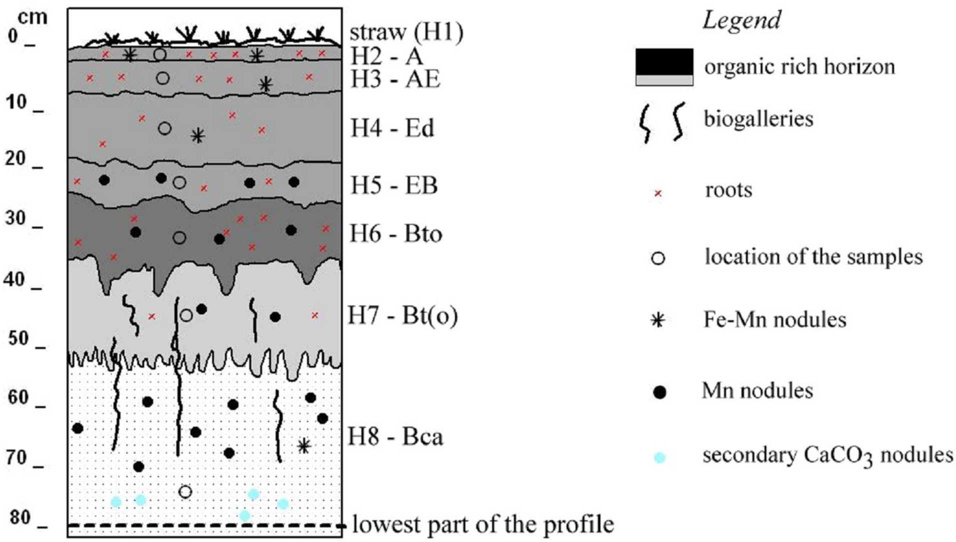

Fig. 7. Profile 1, field sketch, see also Fig 6a.

Profile 1- General comments and discussion

Some soil characteristics such as the evidences of organic matter and clay migration and the structure indicate the presence of alkali conditions during the pedogenesis. These conditions however are not active anymore and these soil characteristics are degraded now. Most probably this landscape position is today a recharge area. These are landscape positions where an excess of rainwater percolates sufficiently deep through the soil to bring the soluble elements out of reach of the capillary rise to the surface. This is in contrast with the discharge areas with an accumulation of soluble elements in the surface soil horizons as result of an excess of capillary rise versus the downwards water movement.

The upper part of the soil is affected by compaction (plough pan), which is most probably the result of agricultural practices, such as cultivation and traffic by cattle when the soil is moist or wet. The prismatic structure starts at the upper part of H4 and is mainly affecting this horizon. This structure developed after the compaction and is due to the shrinking related to desiccation of such a dense horizon. Under this horizon the original granular structure is preserved. Generally very limited worm activity is observable at present.

The “dry” feeling of H3 can be related to either, or both, (*1*) the higher density of this calcareous horizon with hence a lower porosity and lower water content and (*2*) the presence of a perched water above this more dense horizon.

Table 3. Profile 1, systematic description of the soil characteristics, see also Fig 6a. Legend: see below.

Horizon	***Horizon symbol***[1]	***Depths (cm)***	***Colour***[2]	***Clay content*** *(moisture status)*	***Reaction with HCl***[3]	***Root distribution/ Bioporosity***	***Pedality***	***Redoximorphic features***	***Particular features***
H1	L	+05-0			-	straw layer			
H2	A	0-2	10YR 5/2.5	16-20 % (slightly dry)	-	Abundant			
H3	AE	2-7/9	10YR 4/2.5	20-25 % (slightly dry)	-	Common			
H4	Ed	7/9-19/21	dominant: 10YR 4/1.5 light patches: 10YR 6.8/1 dark patches: 10YR 1.9/1	20-25 % (slightly moist)	-	* some fine roots inside the prisms; * common roots in the cracks; * roots going horizontally at the lower boundary, * very few earthworm galleries; few 3-4 mm other channels;	6-12 cm prismatic as a results of cracking of the traffic pan; inside the prisms traces of an ancient angular blocky pedality	* greyish reduced matrix; * faint fine Fe mottling along biogalleries * few Fe-Mn nodules in the matrix ;	clay-humus migration in the larger channels; roots going horizontally at the lower boundary
H5	EB	19/21-24/28	10YR 5/1.5	30-35 % (moist to slightly moist)		* some roots along the prism faces and inside prisms; some horizontal roots; (no preferential root distribution)	prismatic as above, breaking in angular to subangular blocky; 30-60 % complete; some granular aspect		the lower boundary seems to correspond to an ancient plough layer

Continuation of Table 3

Horizon	*Horizon symbol*[1]	*Depths (cm)*	*Colour*[2]	*Clay content (moisture status)*	*Reaction with HCl*[3]	*Root distribution/ Bioporosity*	*Pedality*	*Redoximorphic features*	*Particular features*
H6	Bto	24/28-35/43	10YR 2.5/1	40-45 % (moist)	-	* common roots; * all roots are transped	3-6 mm diameter, 35 % complete granular to conchoidal angular blocky; 10-15 % of the faces represent mini-slickensides	* few 1-2 cm d. Mn nodules ("buckshot")	Clay humus illuvial horizon
H7	Bt(o)	35/43-50/55	10YR 4.5/2.5	50-60 % (moist)	- (+)	* markedly less roots: the roots are transped;	20-25 % complete angular blocky; no slickensides on the ped faces, but some pressure faces	* few to common hard Mn nodules as above; * faint Fe accumulation along galleries;	loess like aspect, traces of clay and humus migration, but less intensive in comparison with H6; locally weak reaction with HCl
H8	Bca	50/55-85	2.5Y 6.5/5	15-20 % (slightly dry)	++	* no roots	irregular prismatic with clay-humus coating on the ped faces, polygonal pattern in horizontal section ECa 3.08 mS/cm	*common 3-4 mm Mn nodules	* common clay-humus infiltration; * common paleobiogalleries in the lower part * few soft CaCO3 and Mn impregnative nodules in the lower part

Legend for Table 3:
[1] - non-traditional symbols:
d - dense horizon
o - organic rich subsurface horizon
[2] – colour moist, measured in the field with the Fujihara Industry (1990) colour chart
[3] - reaction with HCl
no reaction
-/(+) local weak reaction
++ moderate reaction

3.1.3. Profile 1A

Situated at 30 m to the east from the first profile and towards the lower landscape position.

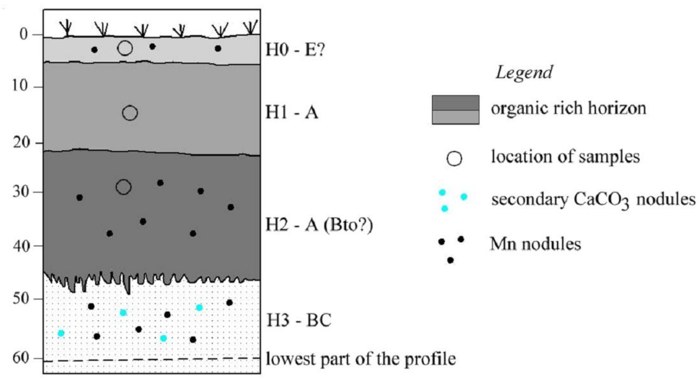

Fig. 8. Profile 1A, field sketch

Profile 1A description (see Fig. 8).

- H0 0-5 cm Seemingly an eluvial horizon. Coarse sandy material with few Mn concretions. Non-calcareous.
- H1 5-22 cm A Organic rich horizon, slightly lighter coloured than the underlying. No hydromorphy. Incomplete granular to angular blocky, no prisms observed. Roots go through the peds. Non-calcareous
- H2 22-46 cm A or Bto Strongly organic rich horizon, most probably as a result of clay and organic matter illuviation. Common up to 4 mm diameter Mn nodules. Non-calcareous.

- H3 46-60 cm BC Reaction with HCl. Common up to 8 mm diameter Mn nodules. Very dry character as H8 of Profile 1.

Auger observation:

* At 80 non-calcareous sand.
* At 100 cm very dark sandy, non-calcareous to weakly calcareous sediment.
* At 120 cm more silty, with common loess "dolls".

Profile 1A - General comments and discussion

No puddling, no trampling and no densification features. The origin of the dark horizon can be attributed to the accumulation of clay and organic matter as a result of past alkali conditions. The “dry” feeling of H3 can be related to the processes discussed for H8 in Profile 1.

3.1.4. Profile 1B

Situated at 40 m to the east from the first profile (Profile 1), towards the lower landscape position.

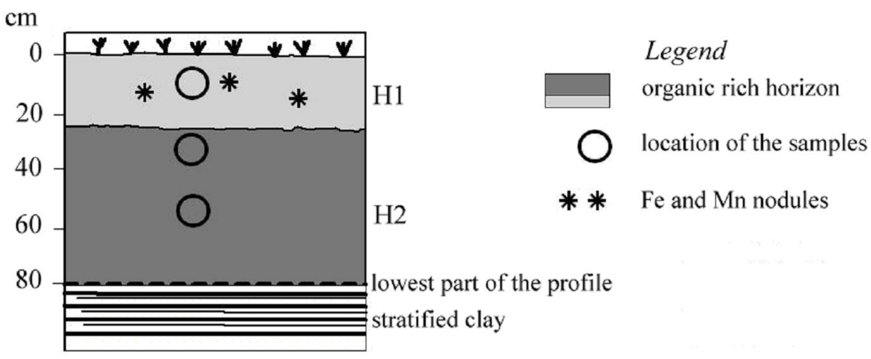

Fig. 9. Profile 1B, field sketch

Profile 1B description (see Fig. 9).

The upper 20 cm is water saturated from the surface; deeper it is more dry, indicating the presence of a perched water-table.

- H1 0-27 cm A Surface organic rich horizon, same as underlying one. Active reduction in the upper 10 cm. Slightly reduced matrix and abundant Fe mottling. Non-calcareous.
- H2 27-80 cm A(Bto) Very organic rich horizon. Up to 30-35 % clay. Almost complete granular (real Meadow soil). Non-calcareous.

Auger observation:

* + 80 cm: strongly clayey, compact, stratified sediment with prominent orange (10YR 5.5/8) Fe mottling; non-calcareous.

Profile 1B - General comments and discussion
Excellent root development and very good pedality down to 80 cm depth.
The clayey sediment observed under 80 cm might be an older consolidated sediment or an alluvial sediment of the Tisza river.

3.2. Second transect

3.2.1. General information

Situated inside of the dike, in the active alluvial plain of the Tisza River. Gently sloping landscape (see Fig. 6), with very small (tens of centimetres) differences in altitude. Three profiles have been observed along the toposequence, from a topographic high (Profile 2) to the lowest landscape position, which corresponds to the border of a depression actually flooded by high river water (Profile 2B).

No anthropic land use was noted, which is the result of the fact that the site is situated on an island in the active alluvial plain. In the 1930-s this landscape has been used as combined meadow and hay production. However no traces of puddling and trampling could be observed in the studied profiles.

The studied soilscape was covered by a thin, light coloured, non-calcareous sediment, which represents most probably the recent alluvial deposits. Thick undecomposed dry vegetation was observed all over as well.

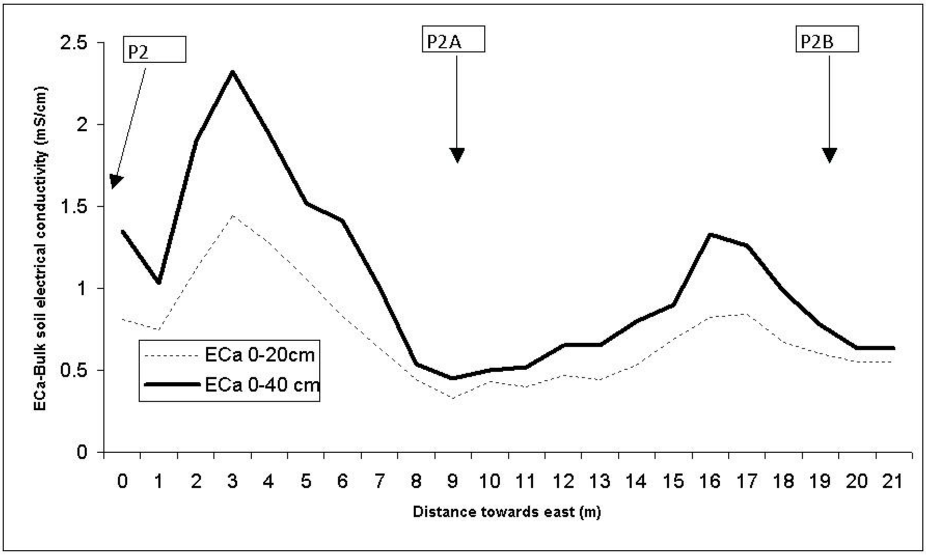

Fig. 10. Bulk soil electrical conductivity along Transect 2 (each meter) and the location of the profiles

Fig. 10 shows the bulk soil electrical conductivity of Transect 2. From 21 m onwards there was standing water on the surface. Table 4 and 5 shows the parameters of groundwater (water table) and surface water sample. In the case of Profile 2B the presence of slowly soluble salts in the suspended particles was suspected, which might have been dominated by sodium carbonate.

Table 4. Depth of groundwater table, its electrical conductivity and pH for the profiles of the second transect

Profile number	*Horizontal distances*	*Hungarian Soil Classification based on field observations*	*Depth of the groundwater*	*pH*	*EC (mS/cm)*
2	0	Deep Meadow Solonetz	141 cm (97 cm after half an hour	7.80	2.41
2A	9 m	Meadow soil	151 cm	7.83	1.23
2B	20 m	Meadow soil	132 cm (23 cm after 2 hours)	7.93 (8.3 after 2 hours)	3.30 (4.35 after 2 hours)
River water	+/-21		at the surface	7.7	0.40

Table 5. Brief description of the ground vegetation along the second transect

Profile number	***Ground vegetation***
2	*Alopecurus pratensis, Carex praecox., Limonium gmelini, Peucedanum officinale*
2A	*Iris spurea, Gratiola officinalis, Alopecurus pratensis*
2B	*Alopecurus pratensis, Amorpha fruticosa, Carex melanostachya, C. gracilis*

3.2.2. Profile 2

This profile was considered as a reference profile for the second transect and a more detailed description was made. First a general characterization of the main horizons and a few particular observations will be presented. The systematic observations are described in the Table 6 below. Fig. 11 shows the field morphology of the profile.

The soil was water saturated (above field capacity) during the observations.

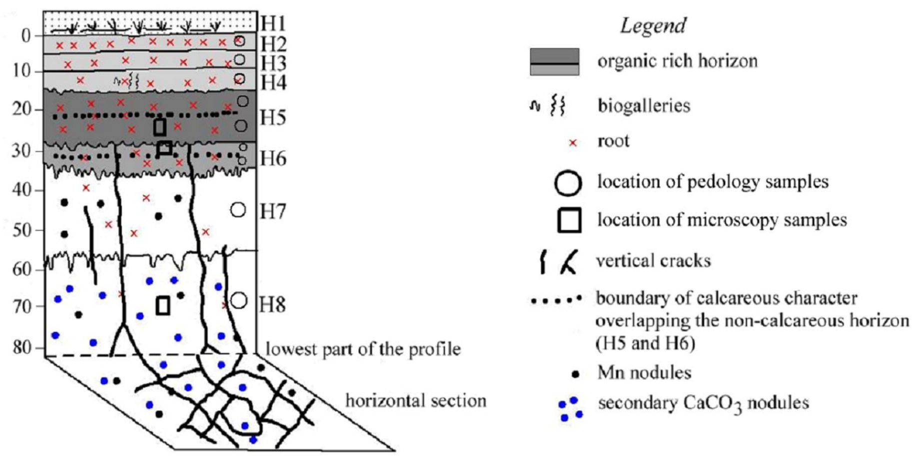

Fig. 11. Profile 2, field sketch, see also Fig 6b

Profile 2 description (see Fig. 11)

- H1 Straw layer with alluvial silt, non-calcareous.
- H2 Organic rich surface horizon with abundant root mat.
- H3 More reduced surface horizon.

- H4 Lighter coloured (eluvial?) horizon. Undulating lower boundary.
- H5 Very dark, organic rich horizon: The upper part is non-calcareous, while the lower part is moderately calcareous.
- H6 Transition horizon. The upper part is moderately calcareous, the lower part is weakly calcareous.
- H7 Brown horizon of decalcification.
- H8 Calcareous parent material with secondary $CaCO_3$ accumulations.

Profile 2 - General comments and discussion
At 80 cm active polygonal pattern filled with organic matter coatings on the prism faces. This characteristic is not present in Profile 1.
No traffic pan or trampling features observed.

The absence of humus-clay coatings and of slickensides (compare to Profile 1H6) is indicative of less pronounced alkali conditions in comparison with Profile 1. A particular aspect is the moderately to slightly calcareous character crossing partially H5 and H6. This might be related with a recalcification due to capillary rise and/or variability in the original sediments (see below).

Concerning the origin of the sediments, two hypotheses have been discussed:

1 . The parent material of the studied soils seems to be a calcareous silty sediment, which might be a
Holocene calcareous dust, decalcified and recalcified afterwards. In this case no dominant alluvial deposits are present.

2. Mixed alluvial (non-calcareous) and aeolian (calcareous) sediments. The variability in the calcareous character might be related to the differences in the proportions of sediment components.

Table 6. Profile 2, systematic description of the soil characteristics, see also Fig 6b. Legend: see below.

Horizon	***Horizon symbol***	***Depths (cm)***	***Colour***[1]	***Clay content (wet)***	***Reaction with HCl***[2]	***Root distribution/ Bioporosity***	***Pedality***	***Redoximorphic features***	***Particular features***
H1	L	+0.5-0			-	straw layer			
H2	A	0-4	10YR 2.5/3	20 %	-	abundant roots (root mat)	microgranular	reduced matrix with oxidation along the roots	
H3	A	4-9	10YR 4.5/2	22-25 %	-	abundant roots in all directions	incomplete granular to subangular blocky;	* more reduced matrix in comparison with H2 ; * few faint root rust * few hard Mn nodules (buckshot)	
H4	E	9-13/14	10YR 5.5/1	35 %	-	common roots all through			* water saturated and smelly ; no puddling and no polygonal pattern ; * common beetle larvae ; * common biogalleries filled with sediment rich in dark organic matter;
H5a	A	13/14-20	10YR 1.5/1	45-50 %	-	* common roots in all directions, but mostly vertical	3-10 cm diameter prismatic, with material from the overlying horizon in the cracks		* The upper part of the horizon (H5a) is non-calcareous, while the lower part is weakly calcareous * Patchy aspect in horizontal section (at 19 cm) ; * pH=9.2 ; EC=1.0 as observed in the field

Continuation of Table 6

Horizon	***Horizon symbol***	***Depths (cm)***	***Colour[1]***	***Clay content (wet)***	***Reaction with HCl[2]***	***Root distribution/ Bioporosity***	***Pedality***	***Redoximorphic features***	***Particular features***
H5b	A	20-26/28			++				* No clay -humus coatings, no secondary $CaCO_3$, no slickensides, no pressure faces. Part of these observations might be related with the moisture status.
H6a	AB	26/28-30	10YR 4.2/1	50 %	++	* common, but less abundant roots in comparison with H5	incomplete fine angular blocky to subangular blocky		* no secondary carbonates, no clay coatings, no slickensides, no pressure faces;
H6b	AB	30-32/36			(+)				
H7	B	32/36-53/58	10YR 6.3/5 <u>the coating:</u> 10YR 5.5/1.5	55-60 %	(+)	* few transped roots	2 mm to 2-3 cm diameter angular blocky 810-25 % complete)	up to 4 mm d. Mn nodules	* accumulation of clay and organic matter , but only in the fissures; * no slickensides
H8	Cca	53/58-80	2.5Y 7/5	20-25 %	+++ §	roots along the cracking system, but no inped roots	polygonal, but massive inside the prisms		* secondary $CaCO_3$ accumulations represented by small nodules, hypocoatings and irregular impregnation ; * clay, silty and sand accumulations along the cracking system and the few larger channels

Legend for Table 6:
[1] - measured in the field with the Fujihara Industry (1990) colour chart
[2] - reaction with HCl

-	no reaction
(+)	weak reaction
++	moderate reaction
+++	strong reaction

§ the strongly calcareous character seems to be related with the secondary accumulations; the sample taken with the auger 40 cm deeper from the lowest part of the profile is only slightly calcareous;

3.2.3. Profile 2A

Situated 9 m east towards the river.

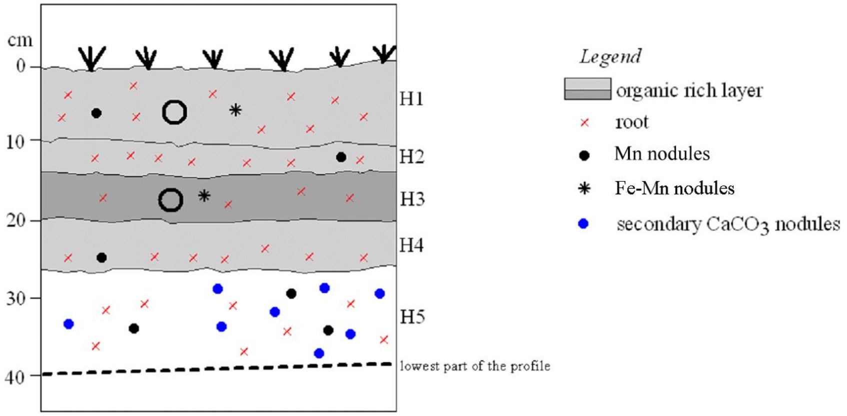

Fig. 12. Profile 2A, field sketch

Profile 2A description (see Fig. 12)

Thicker alluvial silt on top of the soil in comparison with Profile 2.

- H1 0-10 cm Root mat. 25 % clay; granular pedality.
- H2 10-14 cm Transition horizon. Good granular pedality.
- H3 14-20/23 cm Black, organic rich horizon. 35-40 % clay.
- H4 20/23-26 cm Transition horizon.
- H5 26-40 cm Calcareous subsurface horizon with common secondary $CaCO_3$ accumulations.

Profile 2A - General comments and discussion

It presents similar characteristics as Profile 2, but less deep soil development. Interestingly, the ground water level was deeper than in Profile 2 (see Table 4). The non-calcareous alluvial silty sediment (see Oroszi et al. 2005) on top of the soil is thicker in this landscape position as compared with Profile 2. More oxidised than Profile 2, and no greyish reduced horizon observed. The upper part of the soil is wet, water saturated, while the lower part is somewhat drier, but still wet. Common roots all through and in all the directions; very good root penetration. Abundant Fe-Mn nodules all through. Except H5, no reaction with HCl all through.

3.2.4. Profile 2B

Situated at 20 m east from the Profile 2 and at the border of the river.
Only a 50 cm deep profile could be dug due to the water seepage which starts already at 10 cm.

Profile 2B description

- H1 0-10 cm Surface horizon with abundant roots.
- H2 10-30 cm Organic rich, dark horizon.
- H3 30-40 cm Non-calcareous transition horizon.
- H4 40-50 cm Slightly calcareous subsurface horizon with few secondary $CaCO_3$ nodules.

Profile 2B – General comments and discussion

Interestingly, although it is just on the border of the river, the chemical conditions of the groundwater are markedly different from the river water (see Table 4 above). In fact, the measured chemical data are similar to those of Profile 2 and Profile 2A, indicating the influence of the lateral flow in the water dynamics of this transect.

The soil presents a similar morphology to Profile 2 and Profile 2A, with the following characteristics: all through: abundant roots; very reduced; abundant root rust (but moving water and somewhat more root rust in the upper part of the profile); common hard Mn nodules ("buckshot") and a 2-5 cm diameter angular blocky pedality. Non-calcareous down to 40 cm depth.

4. General conclusions

4.1. Groundwater characteristics

In general the depth to the groundwater table followed the usual tendency: with decreasing elevation, it became shallower.

There was a difference in the groundwater depth: outside the dike it was deeper and its salinity lower than inside the dike. The same tendency was observed for the standing water: it was less saline outside the dike than the river water.

4.2. Bulk soil electrical conductivity

The mean ECa and its standard deviation (Fig. 5 and 10, Table 7) were higher inside the dike. Also the ranges of the semivariograms were shorter (7.5 m) inside than outside (9.5 m) the dike, indicating patches of distinct soil salinity with shorter diameter (the details of the semivariogram calculation are not shown).

Table 7. Means and standard deviations (St.D) of bulk soil electrical conductivity (ECa) in two depths along the two transects

Transect No	***Number of points***	***ECa 0-20 cm (St. D.)***	***ECa 0-40 cm (St. D.)***
1, outside the dike	50	0.63 (0.25)	0.79 (0.35)
2, inside the dike	24	0.71 (0.28)	1.03 (0.50)
significance (p) of the difference between means		0.22	0.02

4.3. Origin of the sediments

The alluvial sediments seem to be non-calcareous (see second transect), yet calcareous subsurface horizons have been observed in all the profiles. This calcareous material might be related with calcareous dust input during the Holocene. The extension of these deposits must be discussed taking into consideration the analytical data. Alternatively it is possible that some groundwater movement carried carbonates into the profile where they precipitated. In this case, all carbonates would be secondary precipitates in a non-calcareous matrix. The study of soil thin sections under the microscope could allow checking this pattern.

4.4. Organic rich subsurface horizon

Along both of the transects a dark coloured, organic rich subsurface horizon has been observed. Two hypothesis have been discussed for the origin of this horizon; it could correspond to

- a former surface horizon buried under new sediments;
- a humus-clay accumulation horizon, resulting from processes active in alkali conditions.

Also here the study of soil thin sections under the microscope could allow checking this pattern.

Both morphological and field measured chemical soil characteristics indicative of alkali conditions have been observed in the transects. The appearance of these conditions was however more difficult to observe in the more water-saturated soils inside the dike.

4.5. Soil water dynamics

Perched rain water has been observed in all the profiles. The evidence of dominant lateral flow was particularly evident in the transect inside the dike (see discussion Profile 2B).

4.6. Compressed layer

The upper horizons of Profile 1 are compressed, a feature most probably related to ploughing activities in the years 60 and cattle grazing since then. No similar morphology was observed in the other profiles.

4.7. Soil classification

Since the profiles were located in the higher topographic positions, the effect of recent sediment deposits was not dominating. Therefore the soils could be characterized as Meadow soils, except for the highest lying Meadow Solonetz soils in both transects.

4.8. Soil evolution

Our results support the basic hypothesis that the increasing build-up of the riverbed might contribute to the contrast in soil and groundwater salinity between the areas inside and outside the dike. Previously the river was cutting deep into the land surface providing an opportunity to carry some of the salt load of the upland groundwater flowing downwards into its bed. At present such transport is hampered since the river bed gradually filled up with sediments and less and less vadose groundwater is flowing into the bed position. This process can give clue to the higher salinity of the soils, the groundwater and the water observed inside the dike versus the outside position. Kuti (1989) presented a hypothesis on the formation of the salt-affected areas of Danube valley due to the groundwater traps. In his figure the surface of the salt-affected soil surface lies at 94 m, the top of the dike is at 96 m and the top of the sand ridge towards east is 130 m above sea level at the distance of 60 km away. These traps are formed under the effect of groundwater flowing from two directions: the river bed and the ridges. A similar mechanism can be responsible for the increased salinity inside the dike in the case of river Tisza, as presented in Fig. 13.

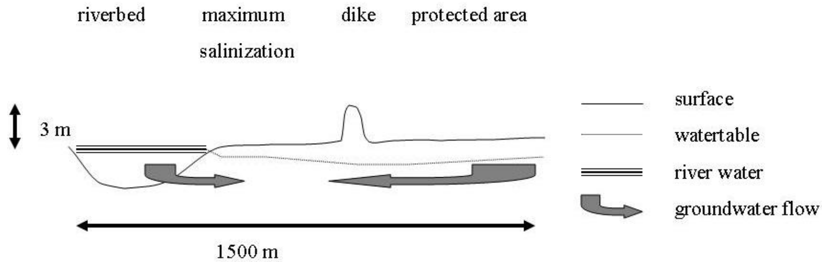

Fig. 13. The formation of a maximum salt-affected zone along the river Tisza

In comparison with the sandy and strongly sloping Danube area, the Tisza study concerns silty and clayey soils that display low slope angles. The scale of the soil system dynamics is distinct too, the maximum distance between the dike and the river being 1.5 km, and the maximum difference in elevation between riverbank and topographic high reaching only 3 meters (Fig. 13).

The soil-geomorphic configuration of the Tisza floodplain being very complex (see Fig. 3) it would be very interesting to perform similar interdisciplinary studies in other areas in order to check and enlarge the hypotheses formulated in this study.

References

Arany, S. (1989): Soils of Hungarian alluvial areas. *Debreceni Agrártudományi Egyetem Tudományos Közleményei* **22:** 175. (in Hungarian)

Boros, Á. (1926): Szemle. (Review) Soó: Die Entstehung der Ungarischen Puszta. *Föld és Ember* **6**: 226-227.

Boros, Á. (1929): Flora and geobotany of Nyírség. Summary. *Mathematikai és Természettudományi Értesítő* **46**: 48-59. (in Hungarian)

Erdélyi, M. (1979): Hydrodynamics of the Hungarian Basin. VITUKI. Proceedings. No. 18.

Ihrig, D. (1952): Water dynamics, deposits and regulation of the flooded area of our rivers. *Erdészeti Kutatások* **5 (**6) (in Hungarian)

Fujihara Industry (1990): Revised Standard Soil Colour Charts. Tokyo: Fujihara Industry Company.

Járó, Z. (1952): Soil conditions for the afforestation of floodplains. *Az erdő* **1**(1): 80-85. (in Hungarian)

Kreybig, L. (1937): The methods of soil survey and mapping used at the geological insitute. MÁFI. Budapest. (in Hungarian)

Kuti, L. (1989): Young unconsolidated sediments and their chemical interaction with the groundwater stored in them. *Annual report of the Hungarian Geological Institute of 1987*: 441-454.

Langohr, R. (1994): Directives and rationale for adequate and comprehensive field soil data bases. In: Stoops, G. (ed). New Waves in Soil Science. ITC-Gent Publications series. n° 5, 1994. pp. 176-191.
Molnár, Zs. – Borhidi A. (2003): Hungarian alkali vegetation: Origins, landscape history, syntaxonomy, conservation. *Phytocoenologia* **33**: 377-408.
NASA (2002): Langley Research Center Atmospheric Science Data Center; New et al. 2002
Nosetto, M.D. – Jobbágy E.G. – Tóth, T. – Di Bella C.M. (2007): The effects of tree establishment on water and salt dynamics in naturally salt-affected grasslands. *Oecologia* **152**: 695-705.
Oroszi, V. – Sándor, A. – Kiss, T. (2005): Deposition due to spring flood by a short transect of Maros and Middle-Tisza, 2005. in Kiss et al. (eds.): Landscape, Environment and Society. Szeged University, Department of Meteorolgy and Regional Geography and Department of Physical Geography and Geoinformatics, Szeged. pp. 551-560. (in Hungarian)
Rhoades J.D. – Van Schilfgaarde, J. (1976): An electrical conductivity probe for determining soil salinity. *Soil Sci. Soc. Am. J.* **40**: 647-650.
Schweitzer, F. (2004): Catastrophe or strategy. *Élő Jászkunság* **1** http://vfek.vfmk.hu/00000096/002.htm. Accessed on 9 Aug. 2009. 08. 09. (in Hungarian)
Szabolcs, I. 1961. The effect of drainage and irrigation on the soil formation in the Transtisza Region of the Hungarian Plain. Akadémiai Kiadó, Budapest. (in Hungarian)
Szabolcs, I. (ed.). 1966. Handbook of genetic soil mapping of fields. OMMI, Budapest. (in Hungarian)
Szűcs, L. (1954): Data for the characterization of the soils of Tisza Valley and the Szolnok loess plateau. *Agrokémia és Talajtan* **3**: 3-18. (in Hungarian)
Tóth Cs. – Félegyházi E. – Szabó J. (2001): The study of the Middle Tisza region dead riverbeds from the aspect of landscape rehabilitation. In: (eds.: L. Buzek – M. Rzętala) Man and landscape. Ostrava – Sosnowiec pp. 148-155.