Soil—Water—Plant Relationships in a Salt Affected Area of the Great Hungarian Plain

K. RAJKAI and E. MOLNÁR

Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, Budapest

The importance of water and soil, as ecological factors, is well known, [4] but their effect, and the mechanism of the effect, are not so evident. These two ecological factors generally affect plants through the soil. In soil—plant systems the soil is considered as the physical-chemical environment of the plants. In most cases different soil parameters (the genetic characteristics of the soil, the texture and structure of the genetic horizons, the chemical composition of the groundwater, the water content of the root zone, etc.) are given in order to characterize the actual status of the plant environment. This type of approach to the soil—plant system has a more descriptive, static, so-called classic aspect.

When the changes in certain soil parameters are determined as a function of time, the aspect becomes dynamic, but still descriptive (e.g. a certain plant community is characterized by seasonal changes in the groundwater table or the consecutive soil-water profiles, etc.).

The system aspect has developed quite rapidly in the last two decades and its application seems to be well justified. The system aspect includes all the descriptive elements of the partial systems (both plant and soil) and the dynamics of some of them, as well as the interactions between the descriptive factors.

The soil—plant system can be considered as a complex system which consists of two main partial systems, namely the soil and plant systems. Each sub-system has its own characteristics, which are reflected by the special dynamics of the system (soil forming processes, successive status of plant cover, etc.), and are characterized by special factors (e.g. layering and structural changes in the soil profile or change in species composition of the plant community). Together, the partial systems form a new system which shows a behaviour different from those of the separate sub-systems.

Materials and methods

A small area was selected on a salt affected land in the Szabadszállás—Fülöpszállás protected area of the Kiskunság National Park, located between the Danube and Tisza rivers in the Great Hungarian Plain, and its soil — water — plant relationships were studied by applying the system aspect.

Geologically this alluvial territory is situated on a 10—20 m thick sand and gravel layer settled on Pannonian clay. The present Danube valley was formed at the end of the last interglacial period of the Pleistocene [5]. The alluvial material of the Danube valley becomes finer and finer from the lower to the upper layers. One geomorphological consequence of that is the horizontal variation in these different texture deposits at the same level, combined with vertical heterogeneous layering. Pure eolic accumulation in the valley is quite rare because of the accumulation and denudation activity of the river. Generally, the higher territory, which was not constantly redeposited by the river, is covered by loessic material. These sedimented eolian and fluviatile deposits give the parent material of the soil forming processes and also store the very rich stratum water and groundwater resources of the valley.

Hydrologically the investigated area has some interesting features, too. There is no continuous groundwater table. The stratum water is simultaneously the groundwater in one place, but not in another. The water sources of the valley consist not only of local rainfall but also that falling at the border of the watershed. These waters alone percolate the impermeable layers below the surface and move hydrostatically toward the lower places in the basin. In the studied area the subsurface movement of the water becomes very slow, because there is a slight slope and the water can accumulate near to the surface as temporary (ponding) or stagnant surface water [2, 6]. The groundwaters generally have a high salt content ($>$ 600 ppm) with Na_2CO_3 dominant among the salts. The average depth of the groundwater table is between 1—3 m. The "critical depth" of the groundwater from the salinization point of view is about 2 metres [1].

On this territory the average annual rainfall is 550—600 mm. The potential evapotranspiration is 680—700 mm/year [2].

Floristically the Szabadszállás—Fülöpszállás area belongs to the *Pannonian flora, Eupannonicum flora* region and the *Praematricum flora* district [3]. Plant species with a wide ecological valency are dominant in the vegetation. The mesophilous, halotolerant species are the most frequent. More than 70% of the plants are hemicryptophytes and terrophytes. At present the least disturbed vegetation can be found on salt affected areas, on pastures and on sand hills with loessic spots.

In order to characterize the soils and the plant associations, the physical and chemical properties of the soils were surveyed on the basis of soil profiles characteristic of ecologically different spots on the mosaic-like territory. The actual level of the groundwater was also determined. The plant community covering the soil was coenologically described.

Results and discussion

According to the soil survey the investigated area is covered by two types of hydromorphic soils; one is non-saline meadow soil, while the other is saline meadow solonetz, solonetzic-meadow soil or solonchak-solonetz. In some places, where the surface is covered by water, the hydromorphic features are combined with organic matter accumulation and the soil has a peaty character (Fig. 1). These soil types and sub-types form microcomplexes.

Profile K I

Vegetation: Artemisio — Festucetum pseudovinae. Relief: Flat plain. *Profile depth:* 150 cm. *Groundwater table:* 140 cm. *Thickness of humus layer:* 33 cm. *Phenolphthalein reaction:* 4 cm.

Genetic horizons:

A 0— 2 cm:	Grey (10Y 6/1) dry, loose, very densely rooted layer with sharp boundary.
B_1 2—12 cm:	Grey (10Y 5/1) dry, highly compacted, silty loam with columnar structure. Densely rooted with sharp transition zone.
B_2 12—20 cm:	Pale grey (10Y 5/1) fresh, slightly compacted silty loam with small polyhedric structure. The transition zone is continuous.
B_{Ca} 20—33 cm:	Pale grey (10Y 6/1) dry, highly compacted layer with calcium carbonate accumulation, and well-defined prismatic and laminar structures. The transition is quite sharp.
C_1 33—65 cm:	Greyish (10Y 5/1)-yellow (7.5Y 7/3) wet, compacted, horizontally cracked, loamy silt with laminar-polyhedric structure. There are a lot of iron and humic patches. The transition is continuous.
C_2 65—110 cm:	Yellowish-grey (7.5Y 6/2) wet, compacted loamy silt with coarse polyhedric structure dotted with hydromorphic marks. Transition is sharp.
C_3 below 110 cm:	Greyish-yellow (5Y 5/3) wet, slightly compacted sandy silt becoming looser downwards with weak polyhedric structure.

Soil type: Calcareous, sodic meadow solonetz.

Profile K II

Vegetation: (Thymo-)Festucetum pseudovinae. Relief: Microbulge. *Profile depth:* 170 cm. *Groundwater table:* 170 cm. *Thickness of humus layer:* 34 cm. *Phenolphthalein reaction:* —

Genetic horizons:

A 0—18 cm:	Blackish-brown (10YR 4/2) slightly compacted loam with excellent granular structure. There are lots of roots. Transition zone is continuous.
B 18—34 cm:	Brownish-black (2.5Y 4/1) dry, compacted clayey loam with polyhedric structure. The transition is sharp.
B_{Ca} 34—53 cm:	Blackish-grey (10YR 7/2) highly compacted silty loam with prismatic structure. There is calcium carbonate accumulation in the layer. Transition is sharp.
C_1 53—75 cm:	Yellow (2.5Y 6/4) slightly compacted, wet, silty sand with slightly prismatic structure and a few hydromorphic marks. Transition is continuous.
C_2 75—110 cm:	Yellowish-grey (5Y 6/1) loose, wet and without structure. There are hydromorphic marks.

Soil type: Calcareous meadow soil with $CaCO_3$ accumulation.

Profile K III

Vegetation: Camphorosmetum annuae. Relief: Flat, in microdepression. *Profile depth:* 110 cm. *Groundwater table:* 135 cm. *Thickness of humus layer:* 35 cm. *Phenolphthalein reaction:* from the surface.

Genetic horizons:

B_1 0—25 cm:	Pale grey (10Y 5/1) dry, compacted silty loam with fine polyhedric structure. Quite densely rooted. Transition is gradual.
B_2 25—50 cm:	Grey (10Y 5/1) fresh, highly compacted loam with fine prismatic-polyhedric structure. On the surface of the structural elements a white coating can be seen. Sparsely rooted. Transition is sharp.
C_1 50—70 cm: C_2 70—85 cm: C_3 below 85 cm:	as K I.

Soil type: Sodic solonchak-solonetz

Profile K IV

Vegetation: *Bolboschoenetum maritimi.* *Relief:* in depression. *Profile depth:* 80 cm. *Groundwater table:* 80 cm. *Thickness of humus layer:* 44 cm. *Phenolphthalein reaction:* —

Genetic horizons:

A 0—14 cm:	Brownish-black (2.5Y 4/1), wet, slightly compacted with fine granular structure. Densely rooted. Transition is sharp.
B_1 14—25 cm:	Blackish-grey (7.5Y 5/1), wet, compacted silty loam with fine polyhedric structure. There are lots of roots. Transition is gradual in structure.
B_2 25—42 cm:	Yellowish-grey (10Y 6/1), nearly saturated with water, compacted sandy loam with fine polyhedric structure. Transition is sharp.
C_1 42—70 cm:	Grey (7.5Y 5/2) with yellowish patches, compacted silty sand without structure. Sparsely rooted. There are lots of hydromorphic marks. Transition is sharp.
C_2 70— cm:	Yellowish-blueish-grey (5Y 5/3), saturated with water, compacted sandy silt without structure. There are lots of hydromorphic marks.

Soil type: Peaty meadow soil

From the results of the soil survey it can be concluded that the soil forming processes take place under the effect of a highly alkaline groundwater situated close to the surface. However, these salt affected soils were formed under various geographical conditions, resulting in a heterogeneous soil cover of the territory. Generally, the following can be stated about the soils:

1. Salt affected soils: the groundwater table continuously feeds the evapotranspiration taking place from the soil surface and salts accumulate in the surface layers. Of the leaching—accumulation processes, accumulation is dominant.

2. Peaty or peaty meadow soils: there is no salt accumulation in the soil profile because of stagnant water which disappears only for short periods. The accumulation of organic matter is characteristic.

3. Meadow soils: the groundwater table is below the "critical level", so there is no salt transport and accumulation in the profile.

The relevant analytical data of the soils are given in Tables 1 and 2.

In the present case the problem is to interpret the relationship between an alkali soil complex and the vegetation pattern existing on it. More exactly, to give a possible explanation for the existence of a spot of meadow soil in the middle of a salt affected soil complex and for the location of a halotolerant plant association on this non-salty biotope. An outline of the problem is given in Fig. 2.

The site on which attention was focused is situated in the middle of a salt affected soil complex at the relatively "highest" level topographically. The saline groundwater can be found about 30 cm deeper here than in the surrounding area, in a coarse sand material with low capillarity. The influence of the soluble salts is slight and the soil profile (K II) has the characteristics of a meadow soil with a well-structured surface layer resistant to micro-erosion. Consequently, the microbulge on the surface may be the result of soil formation. Some metres from this place the texture of the alluvial parent material is finer because of the high heterogeneity discussed earlier. The capillary rise from the same groundwater level is higher, salts can accumulate and the soil profile shows the characteristics of an alkali soil (namely, solonetz).

In this case the heterogeneity of the parent material may be the primary cause of different types of soil formation, resulting in a mosaic-like structure of the soil cover.

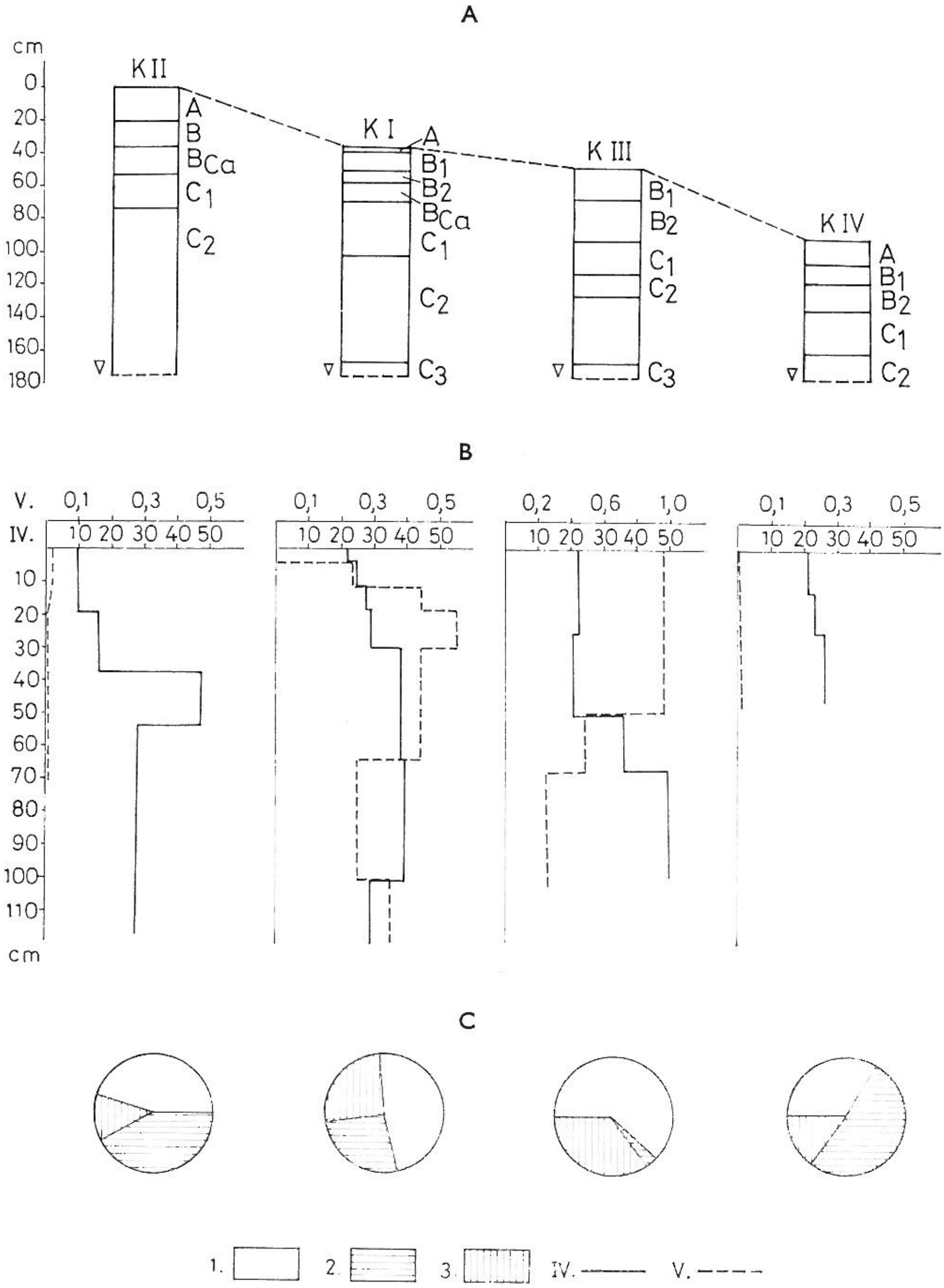

Fig. 1
The topological situation and some soil properties of the soil profiles investigated. A = the relative toposequence; B = salt % (V.) and $CaCO_3$ % (IV.) profiles; C = texture of the soil layer at the groundwater level; 1. sand, 2. silt, 3. clay

Table 1

Physical and chemical characteristics of the soils investigated

No. of soil profile	Genetic horizons		pH		$CaCO_3$ %	Saturation percentage (according to Arany)	Total salt %	Organic matter %
	Symbol	Depth, cm	H_2O	nKCl				
K I	*A*	0–2	7.8	7.4	23.0	65	0.06	5.5
	B_1	2–12	9.9	8.7	25.0	29	0.25	2.4
	B_2	12–20	10.0	9.1	28.0	26	0.45	1.7
	B_{Ca}	20–33	10.1	9.3	29.0	27	0.55	0.6
	C_1	33–65	10.2	9.5	39.0	37	0.45	
	C_2	65–110	10.2	9.5	41.0	34	0.22	
	C_3	110–	10.0	9.1	28.0	41	0.23	
K II	*A*	0–18	7.6	7.3	10.0	45	0.02	4.5
	B	18–34	8.7	7.9	15.0	38	0.03	3.1
	B_{Ca}	34–53	9.8	8.8	49.0	25	0.08	0.3
	C_1	53–75	9.7	9.0				
	C_2	75–110	9.7	9.1	27.0	30	0.07	
K III	B_1	0–25	10.3	9.9	22.0	33	0.96	0.7
	B_2	25–50	10.5	9.9	10.0	35	0.98	0.4
	C_1	50–70			36.0	37	0.45	
	C_2	70–			49.0	34	0.22	
K IV	*A*	0–14	8.3	8.0	22.0	21	0.03	5.4
	B_1	14–25	8.4	8.1	24.0	34	0.06	3.2
	B_2	25–42	8.4	8.1	27.0	30	0.07	1.1

The plant cover "follows" this mosaic-like pattern, sharply indicating the differences in soil properties, except on the soil in question (K II). On the "island" of meadow soil there is a halotolerant plant community *(Festucetum pseudovinae)*, but *Thymus* plant species are frequent in the community and indicate different ecological conditions from those in the neighbourhood.

There is no contradiction in a non-salty soil covered by halotolerant vege-

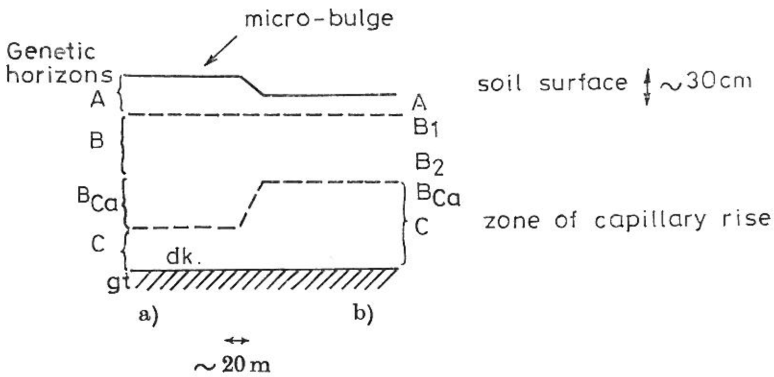

Fig. 2

An outline of the problem.

dk = saturated capillary zone; gt = water table.

a) coarse sand – meadow soil; b) sandy loam – shallow meadow solonetz

Table 2

The mechanical composition of the soils investigated

No. of soil profile	Depth of sampling (cm)	Mechanical fraction %						
		>0.25	0.25—0.05	0.05—0.02	0.02—0.01	0.01—0.005	0.005—0.002	<0.002
		mm						
K I	0—2	9.6	4.4	19.0	20.1	15.7	13.7	17.5
	2—12	0.8	5.2	13.7	10.8	18.1	12.1	39.3
	12—20	0.8	6.4	11.7	8.1	12.5	17.3	43.2
	20—33	—	7.6	6.8	10.0	12.9	18.1	44.6
	33—65	—	0.4	17.7	16.1	16.1	16.1	33.6
	65—110	2.4	0.4	9.3	16.1	19.4	17.7	34.7
	110—140	4.4	23.8	12.1	8.8	12.1	12.5	26.3
K II	0—18	5.2	22.2	22.2	18.1	9.2	6.8	16.3
	34—53	2.4	18.1	21.0	12.1	11.3	7.6	27.3
	53—75	—	16.1	17.3	11.3	8.4	10.0	36.9
	75—90	—	41.1	25.8	9.2	6.4	5.6	11.9
K III	0—25	0.8	8.1	24.2	16.1	15.3	9.6	25.9
	25—50	—	3.6	22.2	14.1	16.9	10.0	33.2
	50—82	—	0.4	17.7	16.1	16.1	16.1	33.6
	82—127	2.4	0.4	9.3	16.1	19.4	17.7	34.7
	127—157	4.4	23.8	12.1	8.8	12.1	12.5	26.3
K IV	0—14	6.4	43.9	13.7	6.0	8.1	6.0	15.9
	14—25	—	49.6	18.5	5.6	4.8	4.8	16.7
	25—42	—	51.2	19.4	6.2	4.1	4.3	14.8

tation if we consider these as systems having different dynamics in their development. Generally, where the vegetation is not the generator in soil formation, the plant system follows the changes taking place in the soil, but only with some delay. The cause of the delay can be derived from the stable tendency of fairly highly developed plant communities. The occurrence of a halotolerant plant association on a meadow soil can also be explained by the population genetic background. This means that this non-saline spot was populated by the plant species living in the neighbourhood.

This approach may serve as a good basis for carrying out more detailed, quantitative investigations on the problem by using the system aspect. In this way more information can be obtained about some basic functions of the environment, which will help to predict and prevent unfavourable processes in soil—water—plant systems. With such an approach human activity in both natural and agricultural ecosystems can be planned.

Summary

On a protected territory of the Kiskunság National Park in the Great Hungarian Plain the relationship between soil properties and vegetation cover in a mosaic-like salt affected area was studied. The cause of the existence of a meadow soil covered by a halotolerant plant community in a salt affected environment was analysed. The explanation was found in the heterogeneity of the parent material, mainly in its texture. The different texture of the parent material results in different types of water regime within the soil profile and in different soil types. The unusual character of the plant cover is a consequence of the special dynamics of the plant system and the population genetic background of its origin.

References

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Discussion

Girdhar, I. K.
You observed two different textures within 20 m distance, please explain why and how are you going to manage this heterogeneity of the soil in such a short distance?
Molnár, E.
As I have already mentioned the quaternary and holocen geology of the area is very heterogeneous. The eolian and fluviatil sediments change very often vertically in the soil profiles. The texture of the eolian sediments is mainly sand — loamy sand and the fluviatil sediments have clay-loam texture. The management of these soils is very difficult because due to the heterogeneous soil cover, there is no general method for amelioration. That is why we leave them as meadows and pastures.
Szabolcs, I.
In alluvial plains and even in deltas the stratification of sediments is evident, because year by year new alluvium covers the surface resulting in a complex soil cover.
Bhattacharyya, A. K.
What are the pH, organic carbon % and predominant clay minerals in sediments of the river Danube? What is the pH of the water of Danube?
Molnár, E.
The Danube sediments are calcareous, the pH of the sediments is slightly alkaline (7.6—7.8), the predominant clay minerals are the following: dominantly illite and chlorite smectite and interstratifications (mainly illite-smectite). About the organic carbon content of the river sediments at the moment I cannot give you a correct answer. The pH of the river Danube is around 7.6 on the average.
Singh, N. T.
What is the exchange complex composition in solonetzic meadow situations?
Molnár, E.
In the A_1 and B_1 horizons of solonetzic meadow soils Ca^{2+} and Mg^{2+} are the dominant exchangeable cations, and their amounts decrease with depth. At a depth of 50—70 cm one can find a solonetzic horizon, in which the ESP value is between 5—25. This means that in this horizon the sodium has an important and characteristic role. The difference between a meadow solonetz and a solonetzic meadow soil is in the depth of solonetzic horizons and in ESP value, mainly.
Várallyay, G.
I wish to emphasize the particular significance of analyses similar to the one presented in the paper of Rajkai and Molnár. Pattern-analysis, using modern techniques (particularly dense sampling, analyses and computerized data-processing), provides an important new tool for micro-heterogeneity studies and for the evaluation of groundwater—moisture—soil—plant relationships on micro-scale. The mosaic-like cover of salt affected soils with special native plant communities, having well-expressed horizontal and vertical contures, provides good possibilities for such analyses.
Based on the results of such investigations, some general conclusions can be drawn on the interactions between the moisture regime, mass and energy transport and transformation, botanical composition and biomass production of the natural vegetation. These findings can also be applied for agricultural ecosystems and the optimum ecological conditions for the various crops can be determined and created. The authors' presentation gives a good starting point for the positive and negative record yield analyses in the future, too.