INVESTIGATION OF ALKALI SOIL

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The climatic, geologic and hydrologic conditions in our country and in the Carpathian Basin are unfortunately favourable to the development of alkali soils. The climate of the area is semi-arid; evaporation in it is more intensive than leaching. The Great Hungarian Plain is a basin with limited run-off or drainage. The rocks and their eroded debris contain very much sodium and colloidal material. Besides those mentioned, Sigmond (6) speaks of five more soil-forming factors. In a previours paper (4) we dealt with one of these, the anthropogenic factor. A book on the subject, edited by *B. Zhivkovit'*, appeared recently (10).

Material and Methods

We made two soil borings more than 20 m deep and at 700—750 m distance from each other in the NE part of the country between the raiway stations of Kisújszállás and Karcag in the area of section 1530 of the railway line (Tables 1 and 2).

The area which was the object of our investigation lies on the edge of the loess plain of Szolnok. The loess plain is relatively high flat land. Its surface is dissected in places by dry river channels long ago filled up, rivulets, and lowlying fiat stretches of ground (7). From the pedological point of view the parent material, besides the alluvial soils already mentioned, is mainly lowland loess in the higher places and loessial silty clay in the lower. The latter constitutes also the mother rock of the investigated area. Owing to the variety of the hydrological conditions — leaching, alkalinization, gleification — the mother rock is rather varied, and the surface of the area, as is usual on alkali soils, is mosaic-like.

As to the climatic factors, the area lies in the region with the most extreme weather conditions in the country. It is noted as one of the climatically most extreme areas of the Great Plain. Its annual rainfall is 500—530 mm. Most precipitation falls in June, the least in winter. There is a little more rainfall in autumn than in spring.

The area receives an average annual total of 2,000 *sunshine hours*, and occasionally slightly more. Farther north in the region the annual total of sunshine hours is already under 2,000. Thus the average of sunshine hours in the southern parts of the area is higher than the average of the whole country. The average annual *total of solar radiation* in the area is around 100 $Kcal \times cm^{-2}$. The *temperatures* of the region, and within it of the investigated area, are very extreme. The winter is cold, the summer is —except on the northeastern edges of the area — warmer than the nationwide average. In winter severe frosts are frequent here. The mean temperature in January varies between—2.5° and —4 °C, but occasionally temperatures as much as ten degrees lower also occur. The summer is moderately warm. The average mean temperature in July is 20—22 °C. In spite of this, warming up is intense in places, especially in the area investigated, where the average of the annual temperature maxima is around 35 °C.

The wind conditions of the area are very changeable. The prevailing wind is from the NNE, but a SSW wind is also frequent. The annual average wind velocity s 2—3 m/sec. The annual average of windstorm hours varies between 145—180. In the southern parts of the region only 20—25 stormy days can be expected on average.

Fog formation is frequent enough in the region, especially in its NE parts. In the southern parts of it, however, only 20—30 foggy days are likely to occur in a year (2).

The annual average number of rainfall hours is 1300 1500. On the basis of the average of 50 years (1901–1951) – considering the monthly and annual amounts of precipitation – we come to the conclusion that in the annual variation two waves can be observed: the maxima of May–June and October–November on the one hand, and the minima of January–February and August–September on the other. Their regularity does not prevail in every year becausa the distribution of precititation in time and space is unstable, and there is considerable variation in the extreme values.

The *soil temperature* is also very extreme. In winter it is cold, in summer warm. In winter frosts are common. The mean soil temperature in January varies between -3 and 0.1 °C at 2 cm depth. In summer the soil surface is warm. The mean temperature in July at 2 cm depth under the soil surface is between 35.4 and 29.8 °C on average.

The results of the analysis of soil samples are shown in Tables 1 and 2.

On the basis of on-site observations and the results of the analysis we found that the following types of soil are dominant in the area:

Profile 1: *acidic alkali soil.* According to the new genetic classification (1) se-onchaky shallow meadow meadow *solonetz.*

Description of the profile:

Ground water at 270 cm. Next day at 140 cm. In a slightly sloping place near a farm. Characteristic plants of the grassland are: Festuca pseudovina and Achillea millefolium. Dug profile depth: 150 cm. Reaction to hydrochloric acid: weak effervescence from 50 cm on, moderate effervescence from 55 cm on, and very strong formation of CO_2 at 60 cm.

A_1 0–5 cm Light greyish, brownish, dull coloured, strongly structured, crumbly, alkalic heavy loam. Transition to the next lower blurred, moist.

A_2 5–12 cm Dark grey, brownish, strongly structured, crumbly, alkalized heavy loam (layer) with silky shiny appearance. No $CaCO_3$. Large amount of root remnants. Transition to the next lower layer gradual. Moist.

B_1 12–20 cm Dark greyish, brownish, with brownish tinge and silky shine, moderately structured, columnar, alkalized clay. No $CaCO_3$. Root remnants. Iron granules. Transition gradual.

B_2 20–40 cm Brownish-tinged, dark greyish, silkily shiny, prismatically struc.

Table 1.

Number of soil profile	soil colour	Sample of genetic horizont	Soil depth cm	pH H_2O	KCl	Hidr. acidity	Total salt %	Alkalinity against phenolphtalein as soda %	$CaCo_3$ %	Sticky point	Height of capillary rise durint 5^h	and 20^h
1	light grey	A_1	0—5	6.5	5.3	16.5	0.03	—	—	44	8	25
	dark grey	A_2	5—12	6.9	5.5	11.5	0.05	—	—	45	5	15
	dark grey	B_1	12—20	7.2	6.0	7.8	0.13	—	—	52	0	0
	dark grey	B_2	20—40	7.5	6.2		0.23	—	—	65	0	0
	dark brownish		40—50	8.0	6.8		0.46	—	—	72	0	0
	grey	B_3	50—70	8.5	7.3		0.47	0.04	1.0	78	0	15
	dark yellowish brown	B/	70—90	8.9	7.8		0.44	0.12	12.3	70	0	25
	yellow	C	90—120	9.1	7.8		0.34	0.16	9.4	81	5	20
	yellov		120—200	9.3	7.6		0.30	0.10	2.0	100	0	0
	yellow		200—250	9.3	7.5		0.23	0.08	0.1	100	0	15
	yellow		250—320	9.3	7.4		0.19	0.08	2.3	78	0	13
	yellow		320—400	9.2	7.3		0.14	0.09	2.3	75	0	10
	yellow		400—500	9.3	7.3		0.14	0.09	4.6	80	0	12
	yellow		500—570	9.1	7.2		0.13	0.06	2.3	78	0	10
	yellow		570—670	9.0	7.3		0.08	0.03	0.1	47	0	24
	greyish yellow		670—1390	8.8	7.5		0.07	0.03	4.1	33	13	54
	greyish yellow		1390—1690	8.3	7.4		0.07	0.02	8.1	44	76	170
	yellowish grey		1690—1910	8.7	7.6		0.02	0.04	13.6	42	42	161
	yellowish grey		1910—2000	8.7	7.6		0.05	0.04	2.7	50	20	65
	blue		2000—2200	8.7	7.8		0.02	0.01	0.1	26	175	260

Table 2.

Number of soil profile	Soil colour	Sample of genetic horizont	Soil depth cm	pH H_2O	pH KCl	Hidr. acidity	Total salt %	Alkalinity against phenolphtalein as soda %	$CaCO_3$ %	Sticky point	Height of capillary rise durint 5^h	and 20^h
2	greyish brown	A_{sz}	0—20	6.5	5.2	13.4	0.03	—	—	52	70	140
	dark greyish brown	A_1	20—30	6.9	5.6	9.3	0.03	—	—	59	60	130
	dark greyish brown	B	30—40	8.0	7.0		0.06	—	8.0	67	73	140
	yellowish grey	B/c	40—50	8.3	7.2		0.04	0.04	8.3	62	90	225
	yellow	C_1	50—70	8.4	7.3		0.03	0.04	16.9	60	100	295
	yellow	C_2	70—100	8.5	7.3		0.04	0.04	13.2	61	95	260
	yellow		100—140	8.8	7.4		0.08	0.05	7.5	56	83	210
	yellow		160—260	8.8	7.4		0.14	0.07	10.7	80	14	34
	yellow		260—520	8.8	7.4		0.20	0.04	1.1	76	0	21
	yellow		520—780	8.6	7.1		0.16	0.02	0.4	86	0	11
	yellowish grey		780—1050	8.5	7.4		0.08	0.02	3.4	38	40	109
	yellowish grey		1050—1460	8.5	7.6		0.05	0.02	2.8	32	125	161
	grey		1600—2180	8.4	7.4		0.07	0.02	7.9	45	42	118
	blue		2180—	8.7	7.7		0.02	0.01	0.2	25	312	446

tured, alkalized heavy clay (layer). No $CaCO_3$. Few root remnants. Transition to the next lower layer well discernible.

B_3 40–70 cm Brownish, silkily shiny, moderately structured, finely lumpy alkalized heavy clay. $CaCO_3$ appears at 50 cm. At 55 cm it is moderate, at 60 cm it effervesces strongly with hydrochloric acid. The humus ceases here. Sharp transition.

B/c 70—90 cm Transition layer. Dark yellowish brown. Silkily shiny. Structured, polyhedral alkalized heavy clay. Many lime concretions. Moist. Transition to mother rock sharp.

C_1 90—120 cm Yellow, silkily shiny. $CaCO_3$ concretions, polyhedrally structured, alkalized heavy clay. Moist. Slow transition.

C_2 120—150 cm Yellow, silkily shiny, slightly structured, moist, alkalized heavy clay. $CaCO_3$ concretions.

Profile 2: Brown chernozem. According to the new genetic classification: *meadow chernozem with moderately thick humus layer, and with carbonates in the deeper layers.*

Description of the profile

Ground water at 400 cm depth, the next day at 200 cm. Four-year-old sparse alfalfa stand. 700–750 m away from the first profile in the direction of Kisújszállás. Weeds: Taraxacum officinalis, Bursa pastoris, Cikoria intibus. Depth of dug profile: 140 cm. Reaction to hydrochloric acid: slight formation of CO2 at 30 cm, moderate at 35 cm, and strong effervescence at 40 cm.

A_a 0–20 cm Dark greyish brown, pale-coloured clay with crumbly structure. Layer thickly interwoven with roots. Contains na $CaCO_3$. Moist, non-alkalized. Transition gradual.

A_1 20–30 cm Dark brownish black, dull-coloured clay with crumbly structure. Contains no lime. Layer interwoven with roots. Moist, nonalkalized. Transition to the next lower layer distinguishable.

B 30–40 cm Dark greyish brown, crumbly, non-alkalized heavy clay of silky shiny appearance. $CaCO_3$ appears in this layer. At 40 cm strong effervescence. Streaks of lime at the bottom of the layer. Interwoven with roots. Moist. Transition discernible.

B/c 40–50 cm Yellowish, greyish brown, non-alkalized clay having silky shine and polyhedral structure. The humus gradually disappears in this layer. $CaCO_3$ in the form of veins. The layer is streaked like marble. There are thick roots in it. Slightly moist. Transition distinguishable.

C_1 50–70 cm Dark yellow non-alkalized clay of silky shiny appearance and compact structure. $CaCO_3$ concretions. Layer with patches of iron. Slightly moist. Transition indistinct.

C_2 70–140 cm Dark yellow non-alkalized clay of silky shiny appearance and compactly porous structure. Finely distributed lime. Slightly moist.

The analysis of the soil samples was made according to your book on methods (9).

Experimental

One approach to the problem is the analysis of especially deep soil profiles and the drawing of conclusions from these. In this paper we have followed this method.

Ballenegger, R (3) says that the climate of our country has changed several times since the last glaciation. In the period of glaciation light-coloured semi-desert soils evolved. The sodium salts formed in the course of weathering remained in the soil profile, they did not sink down into the deeplying subsoil water. This period was the time of the accumulation of salt. Later the semi-arid chraacter of the climate changed. The amount of rainfall increased. There came a transition period such as prevails now on the Russian steppe. Our chernozem soils covering the loess plains are products of this period. On the other hand, the rise of the subsoil water in deeper-lying places brought to the surface the salts formed also as products of the previous period. This period, differently from the former one, was the period of the rising of the salts. As an effect of the salts that had risen to the surface – if the conditions were favourable – alkali soils evolved in the Great Plain. According to the author, the soils have changed only their form since then, and solonchaks, solonetzes and solods have evolved.

According to the *J. Sümeghy* (8) the stable ground water supplying layer is blue sand of fluvial origin formed at the end of the Pleistocene. Its thickness under the Great Plain is generally 50–70 m. It is this layer that collects and conveys the water from rainfall and from the surrounding mountains. This layer is pedologically important also because owing to the fact that it is under pressure, if the conditions are favourable, the waters near the surface are fed from it.

Over the stratum of blue sand up to surface of the soil there are alluvial loess, ppond clay, and other deposits, among them the above-mentioned soil salts. Where and in what amounts the soil salts occur between the blue sand and the surface in the profile depends on the chemical and physical properties of the afore-mentioned sediments. *E. Sigmond* (5) says that the salts and their accumulations depend on the impermeability or permeability of the subsoil layers and their location in depth. The impermeable pond clay sometimes lies immediately under the alkalized layers, sometimes a permeable sandy layer is interposed. The latter – if it is not drainageless, shaped like a lensworks as a drain. The nearer this draining layer is to the surface, the less salt remains in the soil. The situation is reversed when the imperme-able layer, the pond clay, is near the surface, and there is no draining layer. I this case the salts accumulate in the profile, and alkali soils evolve. Therefore in good soils the salts are in the deeper layers, and in bad soils near the surface.

We have seen in the description of the profile that Profile 1 is acid alkali soil, while Profile 2 is chernozem. This is proved also by the data of capillary rise and total salt percentage in Tables 1 and 2. The accumulation of salt is above 120 cm in Profile 1, and below 160 cm in Profile 2. The water-retaining lens-shaped pond clay layer is at the depth first named. This is what sticky point 100 means (Table 1). The salts have accumulated above this layer and have formed the alkali soil. At the depth of 160 cm there is also clay, but the accumulation of salts only begins there and continues in the 520–780 cm deep water-impermeable layers of the alkalized clay. Thus the accumulation occurred owing to the (520–780 cm) deep-lying alkalized layer containing 27.5% adsorbed sodium. Accordingly the soil salts could accumulate only in the deep layers of the profile, and so chernozem evolved and not alkali soil as in the former case, owing to the much higher-lying (120 cm) water-retaining layer. At the bottom of the profiles examined the upper edge of the blue sand layer constantly containing subsoil water – which is characteristic of the Great Plain – can be found below 20–21 m; this is proved by the sticky points 25, 26.

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