Properties of Calcareous Sandy Soils and Their Reclamation

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9% of Hungary's agricultural land is covered by sandy soils, some of which are acidic and others calcareous.

Hungarian researchers have made complex studies on the properties of sandy soils and on how they can be ameliorated. The location of sandy soils was illustrated by STEFANOVITS & SZÜCS (1961), while they were classifed by SZABOLCS et al. (1966) and mapped in more detail (on a 1:100,000 scale) by VÁRALLYAY et al. (1979). The physical, chemical and mineralogical properties of sandy soils were examined by PÉCSI et al. (1982).

Many authors have also dealt with the amelioration of sandy soils. EGERSZEGI (1953, 1957) elaborated a stratified sand amelioration method, which successfully utilized the distribution of ameliorants in separate horizons. Several authors discussed the amelioration of sandy soils together with their fertilization. ANTAL (1956); HEPP (1968); BAUER (1984); LÁNG & GÁTI (1958) and LÁNG (1961) studied the effect of stratified sand amelioration on crops. One of the main aims of amelioration on calcareous sandy soils is to improve their ability to retain water and nutrients. In general the authors thus recommend to carry out investigations on colloid-containing materials (e.g. clay, peats, powdered lignite, etc.) with high adsorption capacities (FERENCZ & ZVADA, 1984; FÖLDI et al., 1984; STEFANOVITS & FEKETE, 1984).

Materials and Methods

The authors studied calcareous sandy soils in the region between the Rivers Danube and Tisza. These sandy soils occur on higher-lying areas.

The lime content was determined using Scheibler's method and the humus content by means of the potassium bichromate method. The pH values were measured electrically. The mechanical analysis was carried out after preliminary sodium pyrophosphate treatment, using a pipette. The mineral composition was analyzed on the whole soil and on the fraction smaller than 2 microns with the aid of an X-ray diffractometer and derivatograph.

Results and Discussion

Twenty-five soil profiles were studied in the region between the Danube and the Tisza. Two series of sections, each consisting of nine soil profiles, were taken parallel to each other and perpendicular to the Danube and the Tisza, while the third series was located in a NE-SW direction, intersecting the other two.

On the area examined the parent rock consisted of sand and sandy loess.

In situ studies led to the following findings:

- Blown sand soil could only be found in its original state on a fairly small area, since long-term cultivation had created humous horizons in the majority of cases.

- In many places cover sand, containing no humus, had been deposited on the humous horizons.

- Humous horizons had arisen in the upper layers of most sandy soils, improving the water and nutrient management of the soil.

- Sandy soils with several humous horizons had the most favourable properties, since these humous horizons have an extremely beneficial effect on the water and nutrient retention of sandy soils.

- The location and thickness of the humous horizons had a decisive influence on the soil characteristics.

Due to the chemical properties of the Danube alluvium, the vast majority of the sandy soils are calcareous (Table 1). In general, due to the carbonate content, the pH was alkaline, usually over 8. The carbonate content tended to increase with depth. The physical and chemical analyses of five characteristic profiles are presented in Table 1. Meadow soil with a clayey mechanical composition was chosen for comparison, while the other soil profiles consisted of blown-sand, cover sand, humous sand and stratified humous sand. There was a very considerable difference in mechanical composition between the clayey meadow soil and the sandy soils. While the clay fractions made up 10-30% of the clayey meadow soil, this figure ranged from 0.1 to 3.4% for sandy soils. At the same time the sand fraction was (with the exception of one sample) over 90% for all the sandy soils. If the mechanical composition of the blown sand and cover sand is compared with that of sandy soils with one or more humous horizons, it can be seen that the clay fraction made up 0.1-1.5% of the former and 1.1-3.4% of the latter. This seemingly insignificant difference in the clay fractions is nevertheless of great importance, as it causes a substantial change in fertility.

It is also obvious from the quantities of clay fractions that more intensive weathering has taken place in sandy soils with one or more humous horizons than in the blown sand and cover sand soils. The comparison of the total min-

Table 1

Physical and chemical properties of the sandy soils examined

Depth, cm	Horizon	$CaCO_3$ %	H %	pH	Mechanical composition, %			
					Clay	Silt	Loess	Sand
A. Soil with clay mechanical composition								
0-11	A	8	3.2	8.2	30.0	18.7	20.4	30.3
11-24	B	7	3.2	8.3	29.6	20.4	20.8	28.1
24-46	B-C	26	1.1	8.6	36.2	23.5	16.7	22.2
46-65	C_1	31	-	8.6	22.4	21.7	28.5	26.7
65-110	C_2	21	-	8.4	10.6	9.4	31.5	48.0
B. Blown sand soil								
0-8	I	12	0.2	8.1	0.1	1.4	1.0	96.5
8-110	II_1	10	-	8.3	0.3	0.9	-	98.3
8-110	II_2	14	-	8.4	0.8	0.4	-	97.8
C. Cover sand soil								
0-8	A_o	7	0.2	8.5	0.7	0.5	0.6	97.4
8-28	A_1	6	-	8.5	1.1	0.6	0.2	95.7
28-49	B	10	-	8.4	0.6	0.2	0.4	98.3
49-55	CA	8	-	8.4	1.5	0.4	0.4	97.6
55-105	CC	13	-	8.5	0.4	0.1	0.3	98.1
D. Humous sandy soil								
0-14	A_p	2	0.7	8.0	2.3	0.8	0.5	94.7
14-28	A	2	0.6	8.2	1.9	0.8	0.6	96.0
28-41	B	4	-	8.4	1.1	3.8	1.2	93.2
41-56	B-C	5	-	8.3	3.1	1.7	0.7	93.8
56-120	C	13	-	8.5	3.4	3.0	1.4	91.7
E. Stratified humous sandy soil								
0-25	A	3	0.5	8.3	1.2	0.6	0.6	97.1
25-39	B	2	0.2	8.3	2.2	1.0	0.4	95.3
39-51	CA_1	1	0.6	8.2	1.8	0.8	1.2	95.8
51-99	CB_1	5	-	8.5	2.1	1.3	0.4	93.5
99-130	CA_2	8	0.6	8.3	2.9	3.3	4.1	87.5
130-145	CC_1	6	-	8.4	2.4	1.3	0.2	96.5

eral composition of meadow soil and of the sandy soils indicates (Table 2) that the quantity of quartz in the sandy soils is generally considerably higher, ranging from 14 to 38% in meadow soil and from 45 to 88% in sand. There is a particularly great difference between clayey meadow soil and sandy soils with respect to mica, which makes up 27-40% of clayey meadow soil, but is com-

Table 2

Mineral composition of the sandy soils examined

Horizon	Quartz	Mica	Feldspars		Calcite	Dolomite	Chlorite	Montmorillonite
			K	PL				
A. Soil with clay mechanical composition								
A	38	40	-	8	3	3	8	-
B	30	27	-	24	6	5	8	-
B-C	26	32	-	12	20	5	5	-
C_1	14	40	-	2	18	6	20	-
C_2	20	40	4	6	4	20	6	-
B. Blown sand soil								
I	76	-	-	20	2	2	-	-
II_1	77	-	-	8	11	4	-	-
II_2	60	-	-	32	6	2	-	-
C. Cover sand soil								
A_o	65	5	5	10	6	4	5	-
A_i	61	10	-	17	5	3	4	-
B	75	5	4	8	4	4	-	-
CA	62	4	-	22	8	4	-	-
CC	51	5	19	8	10	7	-	-
D. Humous sandy soil								
A_p	59	6	-	29	4	2	-	-
A	74	6	-	13	2	2	3	-
B	45	12	3	25	7	4	4	-
B-C	48	10	9	22	7	4	-	-
C	47	9	6	13	8	12	5	-
E. Stratified humous sandy soil								
A	68	-	15	7	5	-	5	-
B	63	6	8	15	4	-	4	-
CA_1	88	7	-	5	-	-	-	-
CB_1	64	4	-	26	4	2	-	-
CA_2	53	12	5	8	6	5	7	4
CC_1	60	5	-	23	5	3	4	1

pletely absent from blown sand and makes up only 4-12% of the other sandy soils. In stratified humous sand, no mica was found in the A horizon. Calcite and dolomite were generally found in all horizons of all soils, with the exception of the CA_1 horizon of stratified humous sand, where neither calcite nor dolomite could be demonstrated, and the A and B horizons of this same soil, which contained no dolomite.

Illite was the dominant mineral in all horizons of all soils in the fraction measuring less than 2 microns (Table 3). In clayey meadow soil quartz was

Table 3

Mineral composition of the < 0.002 mm fractions of the sandy soils examined

Horizon	Quartz	Feldspars	Illite	Montmorillonite	Chlorite	Illite-Montmorillonite	Illite-Chlorite	Kaolinite
A. Soil with clay mechanical composition								
A	2	3	71	3	10	8	-	3
B	3	-	60	5	17	5	6	4
B-C	3	-	60	5	18	-	10	4
C_1	2	2	32	7	37	12	-	8
C_2	3	3	30	16	28	16	-	4
B. Blown sand soil								
I	8	3	17	15	24	15	13	5
II_1	10	4	30	8	24	12	4	8
II_2	10	3	30	8	24	12	5	8
C. Cover sand soil								
A_o	6	3	60	-	10	8	9	4
A_1	5	3	44	8	17	11	8	4
B	5	2	45	8	14	14	8	4
CA	6	4	45	8	18	7	9	3
CC	8	3	46	-	22	8	10	3
D. Humous sandy soil								
A_p	16	4	32	15	13	10	10	-
A	7	3	39	15	10	12	9	5
B	7	4	34	13	16	11	11	4
B-C	4	3	28	14	21	17	8	5
C	5	3	38	11	13	10	13	7
E. Stratified humous sandy soil								
A	5	4	46	-	12	10	18	5
B	5	4	26	10	10	20	20	5
CA_1	5	4	29	-	22	15	20	5
CB_1	4	4	29	10	18	14	14	7
CA_2	8	5	27	15	15	13	13	4
CC_1	7	2	37	11	18	10	10	5

found in a ratio of 2-3%, this figure was 4-16% for sandy soils. The sandy nature was thus also detectable in the clay fractions. In all the soils chlorite and, in places, montmorillonite were also present in large quantities. It is probable that both the illite-montmorillonite interstratified mineral and montmorillonite itself were not formed in situ, but originate from the Danube alluvium, since in these soils the reduction processes are not intensive enough to lead to the formation of montmorillonite.

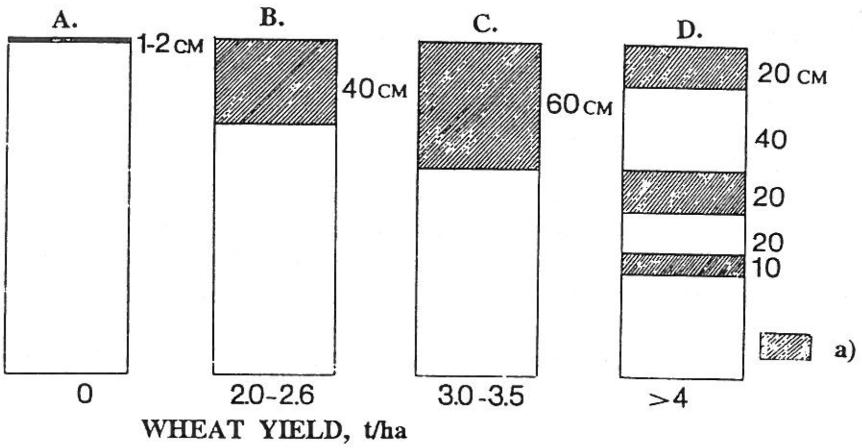

Figure 1

Correlation between the types and subtypes of calcareous sandy soils and their fertility. A. Blown sand soil. B. Humous sandy soil. C. Humous sandy soil. D. Stratified humous sandy soil. a) Humous horizon

Studies were made on the correlation between various sandy soil types and subtypes and their fertility (Fig. 1). On the basis of 15 years' production experience, the fields of a cooperative farm were classified as areas with poor, medium and good fertility.

Areas of blown sand were practically infertile. Humous sandy soils with a humus horizon of around 40 cm produced a wheat grain yield of 2.0-2.6 t/ha, those with a humus horizon deeper than 60 cm yielded 3.0-3.5 t/ha, while stratified humous sandy soils were capable of producing more than 4 t/ha. The fertility of sandy soils was thus characterized by the following order:

1. Soils with high fertility
   a) stratified humous sandy soils
   b) sandy chernozem meadow soils
2. Soils with medium fertility
   a) humous sandy soils

3. Soils with poor fertility
   a) blown sand soils
   b) cover sand soils.

In some places soil acidity and a high groundwater level also had an unfavourable effect on soil fertility.

Effect of locally available ameliorants with a clay mineral content on calcareous sandy soils

The authors examined the reclamation of hydromorphic, stratified humous sandy soils. Two types of amelioration were compared (Table 4):

a) the application of 750 q/ha peat, or

b) 600 m³/ha local ameliorants.

The following conclusions were reached:

1. The quantity of clay in the A_p horizon was 3.1% on non-ameliorated areas; around 7% on area treated with peat; and 17.3% on stratified humous sandy soil treated with local ameliorants. Therefore, more than five times as much clay was present in the A_p horizon of soil treated with high clay content ameliorants than in the same horizon of untreated areas (Table 4).

2. The adsorption capacity of A_p horizon was 2.84, 3.65 and 4.25 meq/100 g soil, respectively, for the control plot and for areas treated with peat and local ameliorants.

Table 4

Changes in the clay content and adsorption capacity of calcareous sandy soils ameliorated with peat or local materials

Stratified calcareous humous sandy soils and soil ameliorants	Horizon depth, cm	Humus %	Clay % < 5 microns	Adsorption capacity, meq/100 g
1. Control plot, Code 6/0	A_p 0-27	0.65	3.11	2.84
	A 27-50	0.21	2.44	4.25
2. Treated with peat, Code 5/L	A_p 0-24	0.43	6.99	3.65
	A 24-53	0.21	3.20	4.96
3. Treated with local ameliorants, Code 4P	$A_{amel.}$	0.43	17.30	4.25
4. Local ameliorant (drilled profile) Code P_1	0-30	5.6	64.84	49.64
	30-60	5.6	65.97	43.97
5. Local ameliorant (drilled profile) Code P_2	0-30	2.05	48.1	26.95
	30-60	1.08	43.64	19.86
6. Local ameliorant (drilled profile)Code P_3	0-30	3.01	45.82	24.82
	30-60	0.86	39.28	20.57

3. While the clay content of untreated soil profiles was 2.4-3.1%, that of ameliorated profiles ranged from 39-65%.

4. While the T values of the soils ranged from 2.84-4.96 meq/100 g, those of locally available ameliorants were in the region of 20-50 meq/100 g soil.

5. These facts indicate that local materials with a high clay content are suitable for the amelioration of calcareous sandy soils, since their high clay content increases the adsorption capacity of the sandy soils, thus improving their water and nutrient retention.

Summary

1. Calcareous sandy soils were studied in the region between the Danube and the Tisza Rivers. It was found that the fertility of blown sand and cover sand soils differed considerably from that of humous sand and stratified humous sandy soils.

2. The position and thickness of the humous horizons in sandy soils have a decisive influence on the properties and fertility of the soils.

3. The effect of groundwater could be observed in some of the sandy soils.

4. Even a slight increase in the relatively small clay fraction has a substantial influence on the fertility of sandy soils and on their water and nutrient retention.

5. The mineral composition of the parent rock has a decisive effect on the mineral composition of sandy soils.

6. Many sandy areas are situated 1-2 metres higher than the surrounding areas, which often consist of peaty soils with a high clay content, suitable for the amelioration of the sandy soils. These low-lying wet soils are practically infertile. These local materials improve the water and nutrient retention of the sandy soils and also have the advantage that their use does not incur transportation costs.

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