Soils of an undulating, cultivated loess plateau in North Mezőföld, Central Hungary

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The study area is located on a lower elevated part of the Mezőföld, one of the largest loess covered plains within the Great Hungarian Plain (Ádám et al., 1959). The elevation of the surface is between 100 and 150 m, and the 15- to 20-m-thick loess layers were deposited mainly during the Saalian and Weichselian glacials (Pécsi, 1995; Horváth, 2001). The typical surface landforms are related to the derasion processes of the loess, and to water erosion. On the slightly undulating, generally cultivated loess plain, erosional and derasional valleys, loess dolines and loess wells can be found (Ádám et al., 1959).

Fig. 1 Localization

Lithology and topography

The parent material of the study area is sandy loess. These aeolian deposits consist mainly of fine sand and silt sized quartz and feldspar grains, having a finely distributed carbonate content up to 8–10 %. The studied catena is located on a gently undulating loess plateau with small elevation differences between 110 and 130 m a.s.l. across a 500-m horizontal distance. On higher elevated slope sections there is visible sheet erosion in lighter coloured soil surfaces. In local depressions the soil surface colour is darker as a result of colluvial accumulation of organic rich topsoil material from the surrounding areas.

Land use

The loess plain and its fertile soils offer advantageous conditions for agriculture, especially cereal production. Therefore, the area has been cultivated since very early times, probably since the Neolithic age. Currently the study area is an experimental field of the Centre for Agricultural Research of the Hungarian Academy of Science where annual crops like corn, wheat, rapeseed and sunflower are cultivated (Kádár, 2015).

Soil conditions

The texture of the soils is slightly variable in topsoil layers, being silty loam, sandy loam or clay loam. In deeper layers it is quite homogeneous and dominantly silty loam. pH is neutral to slightly alkaline (7–8) at the surface. Carbonate content starts in some cases directly on the surface, where it already reaches 13–15%, but mostly it appears only below the organic rich horizons (at a depth of 30–60 cm). The depth of the humus layer varies between 25 and 60 cm, with >1.5% organic carbon on average. According the Hungarian classification they belong to the Chernozems and Chernozems with forest remains (Árendás & Csathó, 2002; Árendás et al., 2004).

Climate

The climate of investigated area is slightly more dry and continental than the surrounding hilly areas. According to Kottek et al. (2006) it is located in the humid zone with warm summer. The average annual temperature is 10.6°C, the average amount of annual precipitation about 560 mm (Ádám et al. 1959).

Profile 1 – Anocalcic **Kastanozem** (Aric, Epiloamic, Katosiltic)
Localization: Loess plateau, summit - upper slope, inclination 4°, arable land, elevation 128 m a.s.l.
N 47°19'56.9" **E** 18°47'36.3"

Morphology:

Apk – 0–30 cm, *mollic* horizon, *calcic* horizon, loam, very dark grayish brown (10YR 5/2, 10YR 3/2), slightly moist, moderate medium and coarse subangular blocky, very strongly calcareous, hard carbonate concretions, very fine and common roots, abrupt and smooth boundary;

Ck – 30–(50) cm, *calcic* horizon, colluvic material, sandy loam, light yellowish brown (2.5YR 7/3, 2.5YR 6/3), dry, medium moderate subangular blocky structure, extremly strongly calcareous, hard carbonate concretions, fine few roots.

Table 1. Texture

Horizon	Depth [cm]	Percentage share of fractions, size of fractions in mm										Textural class
		> 2.0	2.0-1.0	1.0-0.5	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.02	0.02-0.005	0.005-0.002	< 0.002	
Apk	0–30	2.3	0.4	1	1.2	7.4	18	18	16	13	25	L
Ck	30–50	0	0	0.3	0.5	4.2	20	26	16	14	19	SiL

Table 2. Chemical and physicochemical properties

Horizon	Depth [cm]	OC [$g \cdot kg^{-1}$]	Nt [$g \cdot kg^{-1}$]	C/N	pH		$CaCO_3$ [$g \cdot kg^{-1}$]
					H_2O	KCl	
Apk	0–30	16.4	0.87	19	8	7.3	218
Ck	30–50	na.	na.	na.	8.3	7.6	310

Profile 2 – Endocalcic **Chernozem** (Aric, Pachic, Anoloamic, Endosiltic, Bathystagnic)
Localization: Loess plateau, local depression, flat, slope inclination 0°, arable land, elevation 119 m a.s.l.
N 53°09'17.8" **E** 17°39'40.1"

Morphology:

Ap – 0–28 cm, *chernic* horizon, clay loam, black (10YR 2/1), slightly moist, medium to fine strong granular and subangular blocky structure, fine and common roots, earthworm channels, clear and smooth boundary;

Ah1 – 28–50 cm, *chernic* horizon, clay loam, black (10YR 2/1), slightly moist, medium-fine strong granular and subangular blocky structure, fine few roots, gradual and smooth boundary;

Ah2 – 50–80 cm, *mollic* horizon, clay loam, very dark grayish brown (10YR 3/2), slightly moist, medium strong subangular blocky structure, fine and medium very few roots, gradual and wavy boundary;

ACk – 80–110 cm, *calcic* horizon, silty loam, light olive brown (2.5Y 5/3), medium moderte subangular blocky structure, strongly calcareous, soft and hard secondary carbonate concretions, pseudomycelia, krotovinas, gradual and smooth boundary;

Ck – 110–135 cm, *calcic* horizon, colluvic material, silty loam, light yellowish brown (2.5Y 6/4), medium moderate subangular blocky structure, strongly calcareous, soft and hard secondary carbonate concretions, clear and smooth boundary;

Cgk – 135–(150) cm, *calcic* horizon, silty loam, light yellowish brown (2.5Y 6/3), *stagnic* colour pattern (5Y 8/1; 10YR 6/8), strongly calcareous.

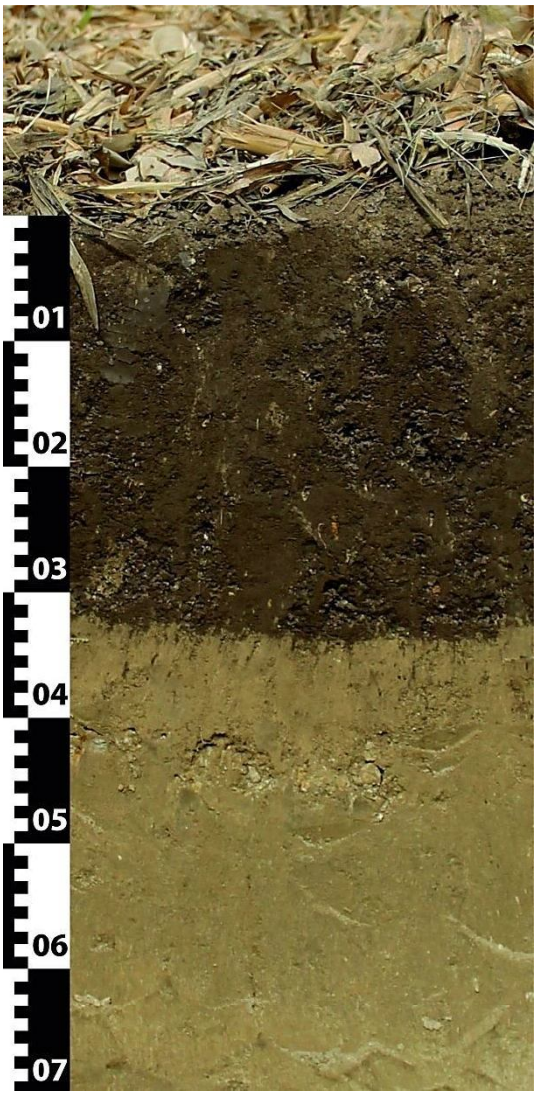
Table 3. Texture

Horizon	Depth [cm]	Percentage share of fractions, size of fractions in mm										Textural class
		> 2.0	2.0-1.0	1.0-0.5	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.02	0.02-0.005	0.005-0.002	< 0.002	
Ap	0–28	0.2	0.1	0.2	1.7	10	15	18	14	9	32	CL
Ah1	28–50	0.1	0	0.3	1.5	7.2	14	19	14	10	34	CL
Ah2	50–80	0.1	0.2	0	1.5	9.3	13	19	14	10	33	CL
ACk	80–110	0	0.1	0.5	1.5	7.9	14	21	16	13	26	SiL
Ck	110–135	0.6	0.2	0.2	1	5.6	13	21	19	16	24	SiL
Cgk	135–(150)	0	0	0	0.5	1.5	16	22	24	18	18	SiL

Table 4. Chemical and physicochemical properties

Horizon	Depth [cm]	OC [$g \cdot kg^{-1}$]	Nt [$g \cdot kg^{-1}$]	C/N	pH		$CaCO_3$ [$g \cdot kg^{-1}$]
					H_2O	KCl	
Ap	0–28	16.5	0.102	16	7	6.1	1.13
Ah1	28–50	16.5	0.086	19	7.3	6.1	1.46
Ah2	50–80	13.5	0.072	19	8.2	7.1	1.78
ACk	80–110	6.67	0.037	18	8.4	7.8	26.9
Ck	110–135	na.	na.	na.	8.6	7.9	28.1
Cgk	135–(150)	na.	na.	na.	8.9	8.1	31.7

Profile 3 – Endocalcic **Chernozem** (Aric, Pantoloamic)
Localization: Loess plateau, lower slope positon – slope inclination 2°, arable land, elevation 113 m a.s.l.
N 47°19'45.3" **E** 18°47'31.5"



Morphology:

Ap – 0–35 cm, *chernic* horizon, clay loam, very dark grayish brown (2.5Y 5/2, 2.5Y 3/2), slightly moist, medium moderate granular –subangular blocky structure, fine and very few roots, abrupt and smooth boundary;

BCk2 – 35–60 cm, *protocalcic* properties, loam, light olive brown (2.5Y 5/3), dry, medium-coarse weak subangular blocky structure, moderately calcareous, soft and hard secondary carbonate concretions, pseudomycelia, disperse powdery lime, fine few roots, gradual and smooth boundary;

Ck – 60–(80) cm, *calcic* horizon, colluvic material, sandy loam, light yellowish brown (2.5Y 6/4), slightly moist, medium-coarse weak subangular blocky structure, strongly calcareous, soft and hard secondary carbonate concretions, pseudomycelia, disperse powdery lime.

Table 5. Texture

Horizon	Depth [cm]	Percentage share of fractions, size of fractions in mm										Textural class
		> 2.0	2.0-1.0	1.0-0.5	0.5-0.25	0.25-0.1	0.1-0.05	0.05-0.02	0.02-0.005	0.005-0.002	< 0.002	
Ap	0–35	5	0.6	1.5	4	13.9	11	15	14	13	27	CL
BCk	35–60	1.6	0.1	1.7	7.5	29.7	12	9	9	12	19	L
Ck	60–(80)	0	0.1	0.5	5.2	38.2	16	8	7	7	18	SL

Table 6. Chemical and physicochemical properties

Horizon	Depth [cm]	OC [g·kg^{-1}]	Nt [g·kg^{-1}]	C/N	pH		$CaCO_3$ [g·kg^{-1}]
					H_2O	KCl	
Ap	0–35	12.1	0.8	15	8	7.6	136
BCk	35–60	na.	na.	na.	8.6	7.8	222
Ck	60–80	na.	na.	na.	8.7	7.9	208

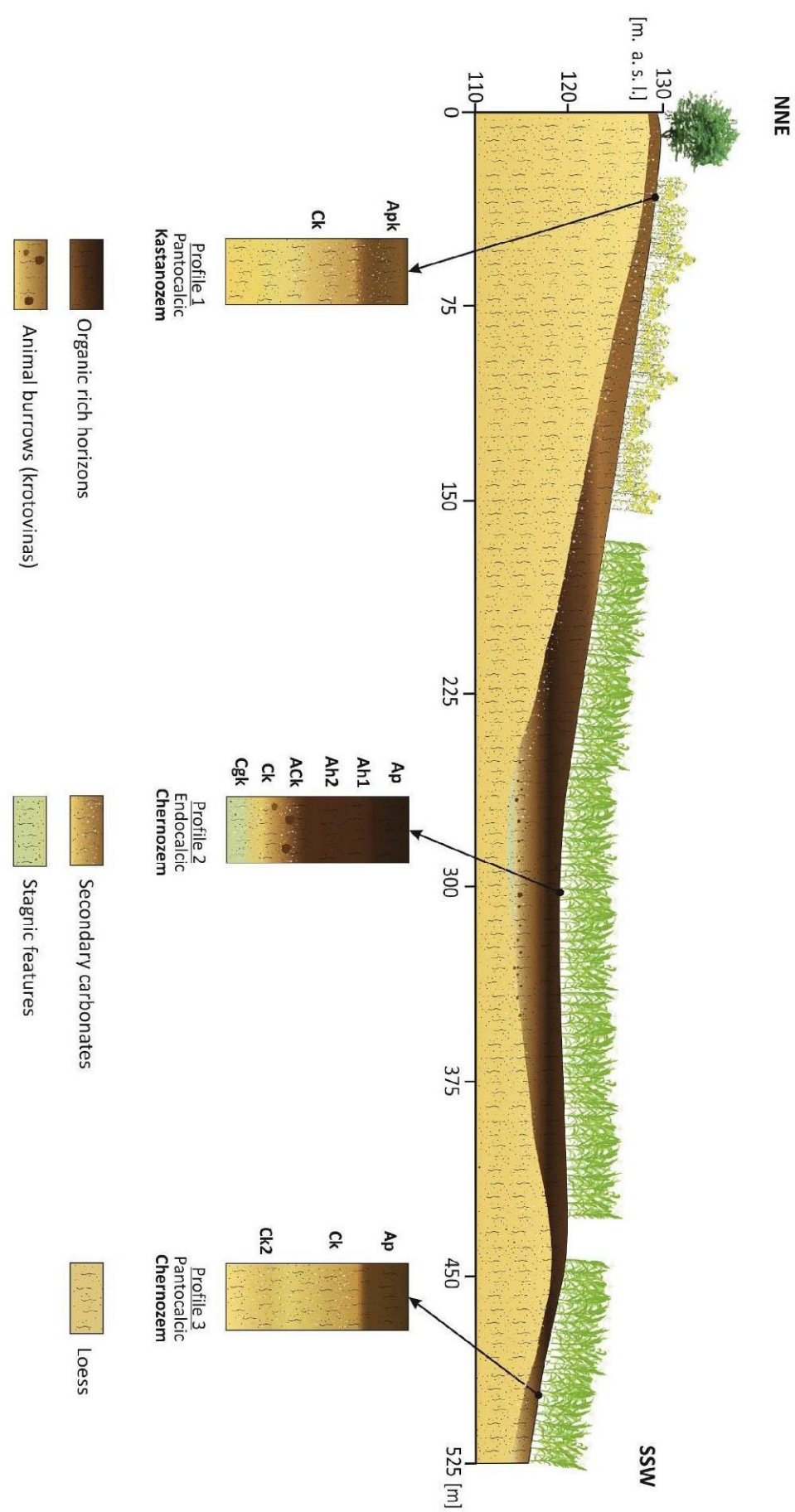


Fig. 2. Toposequence of soils of undulating, cultivated loess plateau in North Mezőföld, Hungary

Soil genesis and systematic position

Profile 1 was classified as **Kastanozem**, since it has *mollic* horizon, and also *calcic* horizon within the required depth below the lower boundary of the *mollic*, but the surface horizon does not fulfil the structure-related criteria for *chernic*. Since the calcic horizon appears not below the *mollic*, but in combination with it, starting directly from the surface, the principal qualifier ***Calcic*** was added, with the ***Panto***- specifier, i.e. ***Pantocalcic***. As the soil, similarly to the other two profiles, is ploughed, the ***Aric*** supplementary qualifier applies. The topsoil has loamic texture in a 30 cm layer, and below 30 cm it changes to silty loam. Therefore the ***Epiloamic*** and ***Katosiltic*** supplementary qualifiers describe the textural character of the profile.

Profile 2 has a very dark and deep *mollic* horizon, with well-developed granular and fine subangular blocky structure, and therefore in this case it also fulfils the criteria for *chernic*. *Calcic* horizon also appears, and directly underlying the *chernic*. Therefore the profile was classified as a ***Chernozem***. Since the *calcic* horizon is not overlapping the *mollic*, i.e. *chernic*, but starting just below that, at a depth of 80 cm, the ***Endocalcic*** principal qualifier was applied. As the profile is cultivated to a depth of 28 cm, the ***Aric*** supplementary qualifier was added, and the ***Pachic*** remains for the very thick (80 cm) *chernic* horizon. The textural characteristics of the profile describe the ***Anoloamic*** and ***Endosiltic*** supplementary qualifiers, being clay loam over 80 cm, and silty loam throughout below that depth. In the deepest described part of the profile a stagnic colour pattern was also recognisable, but because of its deep position within the profile, this qualifier was added with the *bathy* specifier, described with the ***Bathystagnic*** supplementary qualifier.

Profile 3 has also *mollic* horizon, which at the same time fulfils the criteria for *chernic*. It also has *calcic* horizon, starting within 50 cm below the lower boundary of the *chernic*, and therefore this profile is classified as ***Chernozem***. The *protocalcic* properties appear directly below the *chernic* but the *calcic* horizon itself starts at 60 cm depth, and therefore the principal qualifier ***Katocalcic*** applies. Because of the 35-cm-deep ploughed *chernic* horizon, the ***Aric*** supplementary qualifier was also added. The main texture class of the soil profile is loam throughout, but changing from clay loam to sandy loam, and it is described by the ***Pantoloamic*** supplementary qualifier.

Soil sequence

The catena represents a topographic section starting from a locally highest elevated place (Profile 1), crossing a shallow local depression (Profile 2) and ending in a slightly sloping surface. In spite of the small elevation differences (15 m) over a larger distance (ca. 500 m), and the relative low slope gradient (2–4°), the effects of erosion processes are clearly visible comparing the 3 profiles. It is recognisable in the difference of the depth of humus horizon, which is restricted to the ploughed horizon (***Aric***) in the case of the two eroded profiles (Profiles 1 and 3). The erosion was stronger, i.e. more effective in Profile 1, where the material of the underlying parent material was mixed with the topsoil, that its colour becomes lighter than in the other 2 profiles, and the structure has been destroyed to such an extent that it no longer fulfils the criteria for *chernic*, but only for *mollic*. That is why Profile 1 was classified as **Kastanozem**, but Profile 3 – with a very similar eroded profile configuration – was classified as **Chernozem**. In the local depression (Profile 2), where erosion was not even visible, but organic rich material eroded elsewhere was deposited, the **Chernozem** even acquired the ***Pachic*** qualifier, having a >50-cm-thick *mollic* horizon (which is also *chernic* at the same time).

Erosion also affected the vertical position of the *calcic* horizon, or horizons with *protocalcic* properties.It is supposed that it was originally present below the humus horizons, because organic

matter accumulation slightly acidifies soil and facilitates the leaching of carbonates, and this process stops below the humus layer. In the case of strongly eroded profiles (Profile 1) the carbonates, which were originally located below the mollic horizon, were mixed due to ploughing into the whole mollic, and therefore the calcic horizon starts from the surface (***Pantocalcic***). In the other eroded profile, *calcic* horizon, or *protocalcic* properties, starts at the depth of 35 cm, which is below the depth of regular ploughing. Therefore it is still not mixed into the cultivated layer, but starts directly below the humus horizon. For this profile the ***Katocalcic*** qualifier applies. In the local depression the calcic horizon lies below the very deep chernic, and it is described with the ***Endocalcic*** qualifier.

The profile in the local depression functions not only as a sink for organic rich topsoil that was eroded elsewhere, but it also acquires some additional moisture from surface or subsurface runoff, which might be periodically faster than the infiltration. This supposed process is recognisable in the *stagnic properties* appearing in a deeper position (>100 cm) of the Profile 2, for which the ***Bathystagnic*** qualifier is used.

The soil sequence is a typical example for soils of the slightly undulating chernozemic landscapes of Central Hungary, which are affected by erosion triggered by long-time agriculture and machinery cultivation, which has changed not only the soil surface characteristics, but also the taxonomic position of the soils.

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