Culti–sequence of village garden soils on the Great Hungarian Plain

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The study area comprises the Nagy-Sárrét microregion (620 km^2) in Eastern Hungary, which is a recent alluvial plain interspersed with alkaline lands and flood-free areas (Fig. 1). The characteristic landforms (natural levees, abandoned river beds) of the microregion have fluvio-aeolian origin (Dövényi 2010).

Fig. 1. Location

Lithology and topography

The average elevation of the Nagy-Sárrét is typically 84–100 m a.s.l. and the region can be classified as a flat plain, the mean relative relief is < 1.5 m·km^{-2}. Most of the surface is covered with fluvial silt and clay mixed with aeolian dust at higher elevated locations. The source of fluvial material is predominantly the catchment of the Berettyó river. In addition to the silt and sand layers, we can often find clay layers in the upper 10 m sequence, which leads to stagnic conditions in many places (Dövényi 2010). The groundwater level is close to the surface, with a typical seasonal variation in depth between 1 and 2 m; consequently, the soils frequently show the influence of shallow groundwater (Michéli et al. 2006). In the study area, the most common soils are Solonetzs, Vertisols, Kastenozems, and Chernozems, and in residential areas – accumulation of artefacts and human transported materials is observed as a result of soil sealing – Technosols and Anthrosols (Novák &Tóth 2016, Balla et al. 2017).

Land use

The microregion has been significantly altered by anthropogenic effects, starting from their cultivation in the Neolithic. Over the time, not only the cultivated areas have been expanded, but there has also been an increase in the intensification of cultivation. In 75% of the microregion area, predominantly wheat, corn and sunflower are cultivated, with an increase in rape in the recent years. The deeper areas, which are influenced by shallow groundwater or stagnic conditions because of the low permeability of soils, are typically used as pastures and meadows, accounting for 16% of the area. The objective of our study was to describe and classify the soils of intensively used gardens covering 3.6% of the microregion, located partially around settlements, partially interspersed between residential areas around houses and other buildings. Since the first agricultural settlement, the pattern of residential and garden areas has been repeatedly reorganized in space, recently the built-up areas constitute 4% of the microregion area (Dövényi 2010).

Climate

The microregion has moderately warm and dry climate. The annual average of sunshine duration is between 1960 and 2000 hours, the annual mean temperature is 10.2°C and the mean temperature of the growing season is 17.3°C. The mean temperature of the coldest and the warmest month is –1.6°C and 20.7°C. The total annual amount of precipitation is 530 mm, its distribution is uneven with frequent periods of draught. Of the annual amount, 310–320 mm falls during the growing season (Dövényi 2010).

Profile 1 – Luvic Calcic **Chernozem** (Aric, Epiloamic, Clayic, Pachic)
Localization: fluvial silt, infusion loess, inclination < 3° garden: annual crops, vegetables, 91 m a.s.l.,
N 47°17'29.3" **E** 21°15'01.1"

Morphology:

Ap – 0–20 cm, black (10YR 2/1), loam, fine granular structure, many fine roots, ploughed horizon, artefacts (fine brick fragments, <2%);

Ah – 20–35 cm, Very dark gray (10YR 2/1), clay loam, lenticular, strongly compacted structure, many fine roots, humus coatings;

2ABt – 35–55 cm, Very dark grayish brown (10YR 2/1), fine to medium size strong prismatic structure, clay, strong humus coatings;

2Btg – 55–70 cm, Very dark gray (2.5Y 3/1), clay, prismatic structure, moderately carbonates, very fine soft iron concentrations, clay accumulation;

2BCk – 70–110 cm, Very dark grayish brown (2.5Y 3/2), weak structure, clay, strongly carbonated, weak humus–clay coatings;

2BCk2 – 110–130 cm, Light olive brown (2.5Y 4/3), weak structure, clay, strongly carbonated, hard calcretes;

2Ck – 130–160 cm, Light olive brown (2.5Y 5/4) clay loam, strongly carbonated, very fine iron–manganese concentrations;

2C – 160– (180) cm, Light olive brown (2.5Y 5/4) clay loam, weakly carbonated;

Table 1. Texture

Horizon	Depth [cm]	Percentage share of fraction [mm]			Textural class
		> 0.05	0.05–0.002	< 0.002	
Ap	0–20	29.1	34.6	26.3	L
Ah	20–35	27.2	34.5	38.3	CL
2ABt	35–55	22.8	32.5	44.7	C
2Btg	55–70	20.5	34.3	45.2	C
2BCk	70–110	20.6	34.2	45.2	C
2BCk2	110–130	20.1	38.8	41.1	C
2Ck	130–160	24.5	35.8	39.7	CL
2C	160–(180)	26.0	38.4	35.6	CL

Table 2. Chemical and physicochemical properties

Horizon	Depth [cm]	OC [g·kg^{-1}]	EC_{SE} [dS/m]	pH [H_2O]	Exchangeable cations [cmol(+)·kg^{-1}]		$CaCO_3$ [g·kg^{-1}]
					Ca^+	Na^+	
Ap	0–20	17	0.97	6.94	6.94	<0.02	1
Ah	20–35	15	0.75	7.63	7.63	<0.02	6
2ABt	35–55	11	1.22	7.74	7.74	<0.02	1
2Btg	55–70	7	0.93	8.10	8.10	<0.02	11
2BCk	70–110	3	0.42	8.58	8.58	<0.02	174
2BCk2	110–130	2	0.39	8.76	8.76	<0.02	161
2Ck	130–160	2	0.39	8.75	8.75	0.1	117
2C	160–	2	0.42	8.74	8.74	0.34	85

Profile 2 – Hortic **Chernozem** (Protoclacic, Loamic, Pachic, Prototechnic)
Localization: fluvial silt, infusion loess, inclination < 3°, garden, orchard, 92 m a.s.l.,
N 47°28'74.4" **E** 21°23'89.9"

Morphology:

Ah1 – 0–40 cm, *hortic horizon, part of chernic horizon,* accumulation of organic matter, silt loam, very dark brown (10YR 2/2), slightly moist, medium moderate granular structure, very fine and common roots, animal pores <25%, gradual and smooth boundary; artefacts < 5%

Ah2 – 40–80 cm, *chernic horizon*, accumulation of organic matter, silt clay loam, brownish black (10YR 3/2), slightly moist, fine subangular blocky structure, fine and few roots, artefacts 2–5%, gradual and smooth boundary;

ABh – 80–100 cm, clay loam, black (10YR 2/1), slightly moist, subangular blocky structure, fine and common roots, artefacts 2–5%, gradual and smooth boundary;

B – 100–120 cm, silt loam, very dark gray (10 YR 3/1), subangular blocky structure, fine and few roots, artefacts < 2%;

BCk – 120–(140) cm, *protocalcic properties* grayish brown (10 YR 5/2), silt loam;

Table 3. Texture

Horizon	Depth [cm]	Percentage share of fraction [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	
Ah1	0–40	–	–	–	–	1	4	25	35	15	20	SL
Ah2	40–80	–	–	–	–	1	3	24	29	12	31	SiCL
ABh	80–100	–	–	–	–	2	3	25	28	12	30	SiCL
B	100– 120	–	–	–	–	1	4	24	30	14	27	SL
BCk	120–(140)	–	–	–	–	2	5	22	29	13	29	SL

Table 4. Chemical and physicochemical properties

Horizon	Depth [cm]	OC [g·kg^{-1}]	P_2O_5 [g·kg^{-1}]	NO_3^- [g·kg^{-1}]	EC_{SE} µS/cm	pH		$CaCO_3$ [g·kg^{-1}]
						H_2O	KCl	
Ah1	0–40	25	0.1825	0.0088	192	7.8	7.5	70
Ah2	40–80	18	0.0707	0.0087	138	8.0	7.5	56
ABh	80–100	13	0.0377	0.0062	2250	7.9	7.7	50
B	100– 120	9	0.0150	0.0085	1563	8.1	7.9	124
BCk	120–(140)	9	0.0149	0.0062	2820	8.3	8.0	182

Profile 3 – Hortic **Anthrosol** (Loamic, Protocalcic)

Localization: fluvial loess (uf), inclination < 3°, residential area, kitchen garden, 92 m a.s.l., **N** 47°28'19.5" **E** 21°23'94.2"

Morphology:

Ap1 – 0–20 cm, plough *mollic* horizon, *hortic* horizon, silt loam, very dark grayish brown (10YR 3/2), subangular blocky structure, animal pores >25%, artefacts (fine brick fragments, <2%), gradual and smooth boundary;

Ap2 – 20–55 cm, plough *mollic* horizon, *hortic* horizon, silt loam, black (10YR 2/1), subangular blocky structure, animal pores >25%, artefacts <2%, bones, gradual and irregular boundary;

Ah1 – 55–85 cm, silt loam, black (10YR 2/1), granular structure, common soft concretions and pseudomycelium of secondary carbonates, animal pores <25%;

Ah2 – 85–120 cm, black (10YR 2/1), granular structure, common soft concretions and pseudomycelium of secondary carbonates;

ACl – 120–150, grayish brown (10 YR 5/2), transitional horizon, silt loam, fine to medium subangular blocky structure, common soft concretions and pseudomycelium of secondary carbonates protocalcic properties;

Clk – 150–(160) cm, silt loam, grayish brown (10 YR 5/2), common secondary carbonates;

Table 5. Texture

Horizon	Depth [cm]	Percentage share of fraction [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	
Ap1	0–20	–	–	–	–	4	7	21	34	15	20	SL
Ap2	20–55	–	–	–	–	4	5	25	32	14	20	SL
Ah1	55–85	–	–	–	–	2	5	26	34	13	21	SL
Ah2	85– 120	–	–	–	–	4	5	20	32	13	26	SL
ABl	150–(160)	–	–	–	–	–	4	24	29	14	29	SL

Table 6. Chemical and physicochemical properties

Horizon	Depth [cm]	OC [g·kg^{-1}]	P_2O_5 [g·kg^{-1}]	NO_3^- [g·kg^{-1}]	EC_{SE} µS/cm	pH		$CaCO_3$ [g·kg^{-1}]
						H_2O	KCl	
Ap1	0–20	24	0.2163	0.0233	216	8.1	7.6	105
Ap2	20–55	23	0.1971	0.0194	249	8.0	7.5	89
Ah1	55–85	21	0.1671	0.0292	215	8.0	7.4	53
Ah2	85– 120	18	0.0713	0.1857	599	8.1	7.5	51
ABl	150–(160)	12	0.0328	0.1345	1105	8.2	7.8	128

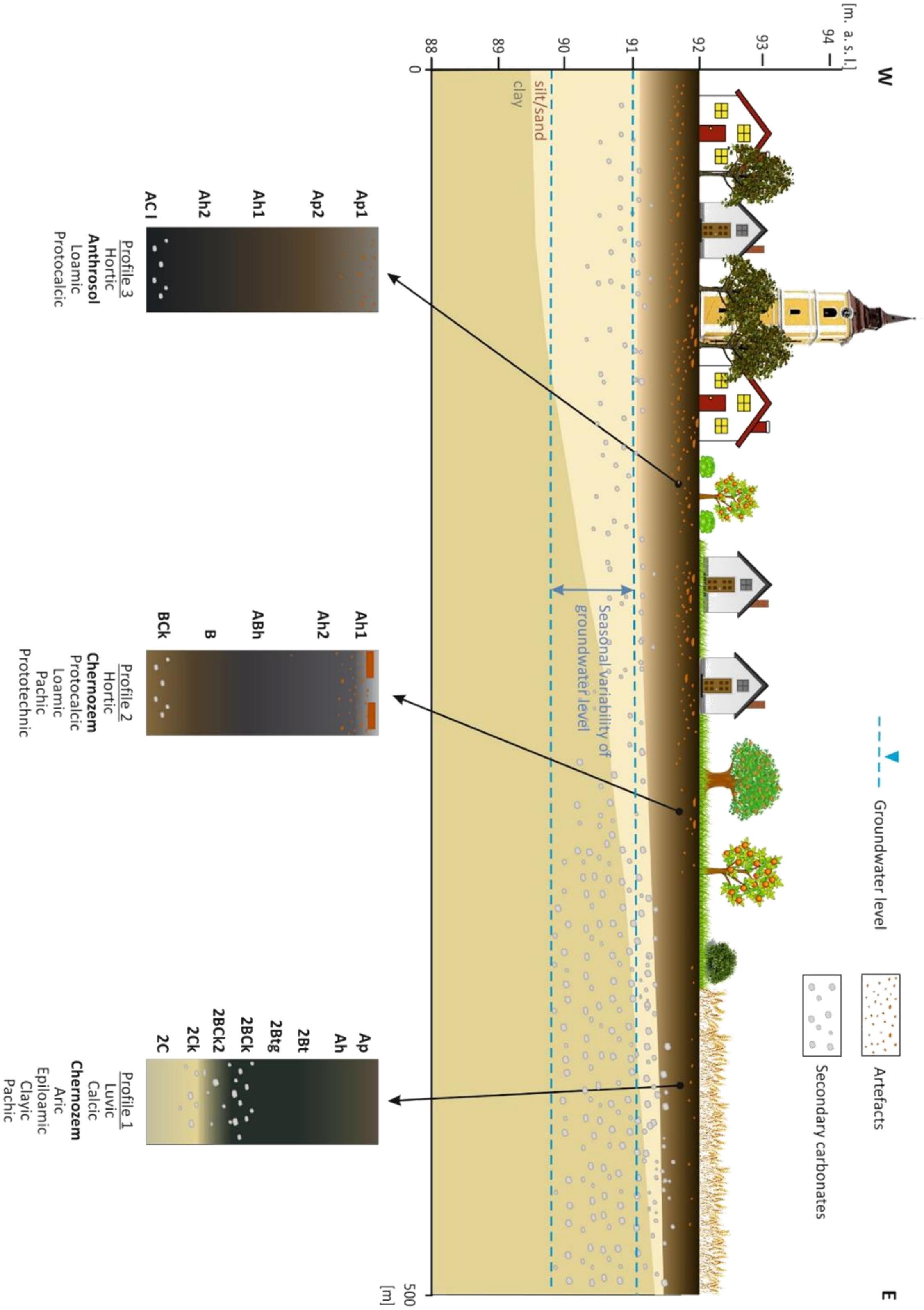

Fig. 2. Culti-sequence of village garden soils on the Great Hungarian Plain

Soil genesis and systematic position

Garden and urban soils are considered as young soils, they can develop ex situ and are often created by anthropogenic activity (Lehmann & Stahr 2007, Bulgariu et al. 2012). Garden soils are located close to inhabited areas and residential buildings, so they are exposed to strong and various anthropogenic effects (Dudal et al. 2002, Marcinek & Komisarek 2004, Hagan et al 2012). These effects are extremely mosaic and hence very large differences can occur over small areas (Greinert 2015, Charzyński et al. 2017). In this soil profile sequence, we classified soil profiles typical of rural areas on the Hungarian Great Plain, developed from natural soils during several thousand years of agricultural influence and constant human residence. The intensity and duration of anthropogenic soil transformation increases from the outskirts of villages toward the village center. Therefore, we called this sequence a culti-sequence, expressing the increasing grade of soil transformation by cultivation.

Profile 1 was classified into **Chernozem** (IUSS Working Group WRB, 2015), where the occurrence of the *calcic* horizon starting at a depth of 70 cm was highlighted by applying the ***Endocalcic*** qualifier. To express the presence of the *argic* Bt horizon, the ***Luvic*** qualifier was added to the RSG. The thickness of the A horizon was expressed by the ***Pachic*** qualifier. The place is used as an arable field, which is manifested in the ploughing character of the A horizon (***Aric***). From 35–130 cm, the texture class is clay; the ***Clayic*** qualifier was added to the RSG. The topsoil of the investigated soil profiles has developed on infusion loess with silt-rich loamy texture, therefore the ***Epiloamic*** qualifier is assigned to the profile. In each of the profiles, secondary carbonates can also be found in various amounts and at different depths (Fig. 2).

Profile 2 was classified as **Chernozem** (IUSS Working Group WRB, 2015), because the structure, the colour, the base saturation and the amount of organic carbon of the A horizon meet the criteria of the *chernic* horizon and there are *protocalcic properties* present in a soil layer starting ≤ 50 cm below the lower limit of this horizon (***Protocalcic*** suplementery qualifier). The significant thickness of the A horizon is expressed by the ***Pachic*** qualifier (≥50 cm). Because of the human influence (fertilization, application of wastes and other organic residues), the 0.5 M $NaHCO_3$ extractable P_2O_5 content in the upper 40 cm of the profile is ≥ 100 mg kg^{-1} (Table 4), therefore it is suitable to classify it as a *hortic* horizon. The presence of this horizon is the reason of adding the ***Hortic*** principal qualifier. The amount of artefacts was ≥ 5% in the upper 100 cm from the soil surface, which was expressed by adding the ***Prototechnic*** qualifier.

Profile 3 is located in the village center in a kitchen garden, impacted by anthropogenic effects to the point where it is observable at the level of Reference Soil Groups (**Anthrosol**) as it contains a *hortic* horizon >50 cm thick. The *Hortic* horizon has high content of organic matter and phosphorous, high animal activity in the form of mole burrows (≥ 25% of animal pores, coprolites), high base saturation (Table 6), resulting from long-term cultivation, fertilization and application of organic residues (*hortic* horizon). This horizon was diagnosed by adding the ***Hortic*** principal qualifier. Loess parent material occurs directly under the transitional ABl horizon. It contains primary and secondary carbonates in the form of soft concretions, which is expressed by using the ***Protocalcic*** qualifier.

Profile 1 was established east of Báránd, in an arable land where the recent land use has led to anthropogenic transformation of the topsoil manifested by a cultivated layer (***Aric*** supplementary qualifier). Profile 2 was established in a plum plantation within a settlement which is used as a garden and orchard since several hundred years. The increase of anthropogenic effects can be observed in the high density of artefacts (***Prototechnic*** supplementary qualifier) and the alteration of chemical parameters of the profile (***Hortic*** principal qualifier). In the case of three profiles, we could observe increasing anthropogenic influences from the outskirts toward the center of the settlement.

Human-made soils were often younger and shallower and contained many artefacts, higher content of coarse fraction, sand and $CaCO_3$ compared to other soils (Amossé et al. 2015). The performed laboratory test showed the transformation in the diagnostic soil properties, which were caused by anthropogenic activities. In the case of the described soil profiles the alteration of the carbonate profile could be explained by calcareous material present in Profile 3. In natural soils, with the appearance of the original soil horizons, carbonate content gradually increases toward the bedrock, or an accumulation level is formed under the influence of water (*calcic, protocalcic* horizons). This natural pattern of carbonates can be significantly modified due to anthropogenic effects, like soil improvement through calcification, mixing artefacts with the soil leading to an increase in $CaCO_3$ concentration in the cultivated layer of the topsoil. In the case of soil profile 3, it is characteristic that the $CaCO_3$ content artificially increased until the depth of cultivation, and increases again only in the deeper horizons, as a result of the influence of seasonally fluctuating groundwater rich in carbonates. The continuous cultivation (disturbance, ploughing, mixing of construction waste) of the upper layers in these garden soils leads to greater porosity, which causes increased decomposition of organic matter. The value of organic C is slightly above 2% in the case of the Ah1 horizon in Profile 2 and the Ap horizon in Profile 3, which is typical of cultivated soils. The nitrogen content of the heavily fertilized soils is typically above 60 mg/kg. In the case of values above 100 mg kg^{-1}, the possibility of wash-out significantly increases. Based on the N content in the soil profiles, it can be concluded that Profile 3, classified as **Anthrosol,** has been heavily fertilized for a longer period (Figure 5). The maximum of the N content in this soil profile (185.7 mg kg^{-1}) was measured in the Ah2 horizon, ranging from 85 to 120 cm, which indicates a significant degree of wash-out.

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References

Amossé, J., Le Bayon, R. C., & Gobat, J. M., 2015. Are urban soils similar to natural soils of river valleys? Journal of soils and sediments, 15(8), 1716–1724.

Balla, D., Novák, T. & Zichar, M., 2017. Approximation of the WRB reference group with the reapplication of archive soil databases. Acta Universitatis Sapientiae, Agriculture and Environment, 8(1), pp. 27–38

Bulgariu, D., Filipov, F., Rusu, C., & Bulgariu, L., 2012. Pedogeochemistry of hortic anthrosol from copou greenhouse–Iasi (I). Agronomy Series of Scientific Research/Lucrari Stiintifice Seria Agronomie, 55(2).

Charzyński, P., Galbraith, J. M., Kabała, C., Kuhn, D., Prokofeva, T. V., & Vasenev, V., 2017. Classification of Urban Soils.

Dövényi, Z., 2010. Inventory of microregions in Hungary. Geographical Research Institute, Budapest.

Dudal, R., F.O. Nachtergaele, M.F. Purnell., 2002. The human factor of soil formation. Transactions of the 17th World Congress of Soil Science, Bangkok, Thailand.

Greinert A. 2015. The heterogeneity of urban soils in the light of their properties, Journal of Soils and Sediments Vol. 15(No. 8):1725–1737

Hagan, D., Dobbs, C., Timilsina, N., Escobedo, F., Toor, G. S., Andreu, M. 2012. Anthropogenic effects on the physical and chemical properties of subtropical coastal urban soils Soil Use and Management, Volume 28, Issue 1, pages 78–88

IUSS Working Group WRB, 2015. World Reference Base for soil resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Report No. 106. FAO, Rome.

Lehmann A., & Stahr K., 2007. Nature and significance of anthropogenic urban soils. J Soils Sediments 7(4):247–260

Marcinek, J., & Komisarek, J., 2004. Anthropogenic transformations of soils of Poznań Lakeland as a results of intensive agricultural farming. AR, Poznań.

Michéli, E., Fuchs, M., Hegymegi, P. and Stefanovits, P., 2006. Classification of the Major Soils of Hungary and their Correlation with the World Reference Base for Soil Resources (WRB). Agrochemistry and Soil Science, 55 (1), 19–28.

Novák, T. J. & Tóth, Cs. A., 2016. Development of erosional microforms and soils on semi–natural and anthropogenic influenced solonetzic grasslands. Geomorphology 254: 121–129.