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EFFECTS OF LONG-TERM AGRICULTURAL LAND USE ON SOIL PROPERTIES ALONG THE AUSTRIAN-HUNGARIAN BORDER

PART I. SOIL MINERALOGICAL, PHYSICAL AND MICROMORPHOLOGICAL PARAMETERS

N. Rampazzo[1], *K. Rajkai*[2], *W.E.H. Blum*[1], *G. Varallyay*[2], *T. Ubleis*[1]

[1]Institute of Soil Research, University of Agricultural Sciences, Gregor-Mendel-Str. 33, A-1180 Vienna, Austria
[2]Research Institute for Soil Science and Agricultural Chemistry (RISSAC) Hungarian Academy of Sciences, Herman Otto u. 15, H-1020 Budapest, Hungary

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Abstract. The aim of this study was to assess the influence of different long-term agricultural practices on the mineralogical, physical and micromorphological composition of soils along the Austrian-Hungarian border, where Austrian and Hungarian agricultural soils (3 transects with different soil type and cultivation system) were compared with former uncultivated *Iron Curtain* reference soils. The mineralogical results indicated that under undisturbed conditions in the reference zone a higher weathering of illite and formation of smectite occurred. The compacting effects of cultivation were reflected in higher bulk density, decrease of total porosity and soil aggregate stability. Pore size distribution showed a stronger decrease of coarse pores, especially in Hungary, where heavy machines were used, but without affecting hydraulic conductivity. Higher biological activity in topsoils of the untillaged areas was observed in all transects, leading to a more crumby structure, whereas in the tillaged soils a subangular, cracky microstructure had developed.

Keywords: soil degradation, agricultural practices, soil structure

INTRODUCTION

With change of landuse, alterations of soil status can be expected. The influence of cultivation on soil properties has been studied by several scientists. Ehlers [6] compared untillaged and tillaged soils with regard to their total porosity. Tischler and Altermann [28] reported on increased soil microbial activities in green fallows as compared with those of arable soils. Similar conclusions were drawn by Schleuss and Blume [24] and Heilmann and Beese [13]. The effects of different cultivation practices on soil biology were studied by Frank and Malkolmes [8], Kandeler and Murer [16], Linn and Doran [18] and Wolters and Joergensen [30].

After opening of border between Austria and Hungary and following the removal of the so-called *Iron Curtain*, a unique opportunity was given for a pedological comparison between undisturbed soils from the borderland and adjacent agricultural soils of Austria and Hungary, affected by different degradation. Mineralogical, physical and micromorphological soil analyses were carried out at three cross sections (transects), each reaching from the intensive cultivated Austrian site, over the undisturbed *Iron Curtain,* to the extensive cultivated Hungarian site for the purpose of evaluating changes in soil status (degradation) of the arable fields through different agricultural management practices.

MATERIAL AND METHODS

General site description

The Austrian part of the studied fields is located in the *Oberpullendorfer Basin* (formerly Landseer Bay) and turns east into the *Répce Terrace Micro-Region*, where the Hungarian studied sites are located. Important rivers in this area are the Rabnitz (Répce) and the Stoob. All waters drain in a south-eastern and eastern direction. The Oberpullendorfer Basin was created by declination in the Tertiary Age and flooded in the Miocene Age, with different kinds of sediments consisting of block gravel, marine sands, sandy limestone and clay marl. In the Quaternary Age, the tertiary sediments were covered by loess, aeolian sand, glacial loams and alluvials during glacial and interglacial periods. The landscape in the basin is distinguished by gentle hills and terraces with a mean elevation of 167 m a.s.l. The continental climate is predominant all over the investigated region, with an annual average temperature of 9 °C. The long vegetation period of 235 till 250 days between March and November reflects the favourable climate of this area. Typical strong N-NW winds (2-3 m/s) cause high evaporation rates up to 700 mm. The annual mean precipitation reaches 700 mm, 55 % of it occuring during the vegetation period.

Agriculture constitutes, with 74 % of the total area, the predominant landuse in the investigated region. In Austria winter rye, winter wheat, barley and oat are the most common culture, together with maize and sugar beet. On the Hungarian fields a fixed 6-year-cycle of crop rotation is followed (winter wheat - sunflower - winter wheat - rape - winter wheat - sugar peas - winter wheat - sunflower etc.). Viniculture covers 15 % of the arable land in the eastern part of Austria. The majority of the forests in Austria belong to a private estate, the smaller part is controlled by a farmer's co-operative. In Hungary the forests are managed by state-controlled co-operatives. In gullies and troughs, where tillage is not possible, the main landuse is pasture, with decreasing tendency due to the increasing drainage and the transforming of pastures into arable land. A comparison between the crop cover map today and maps from 1759 shows the alterations in the landuse during the past 230 years, expressed in a decrease of the forested area and an increase in agricultural area, respectively. The maps also show that the area along the Rabnitz river was meadow and is now agriculturally utilized. Additionally the course of the Rabnitz river was translocated.

Description of the investigated transects and soils

For the purpose of the study 3 transects were selected, each of them composed of the reference plot (= *Iron Curtain* borderline), which has not been cultivated for the last 50 years, the Austrian cultivated plot, subjected to intensive small scale farming and the Hungarian cultivated plot, subjected to extensive large scale farming, as shown on Fig. 1. In order to get a specific variability, different soil types and cultivation managements were selected between the 3 transects, but identical along each transect.

At a distance of 100 m east and west from the border soil profiles were dug in the adjacent Austrian and Hungarian agricultural areas. For sampling the arable soil, an area of 50 x 50 m on both sides (Austria and Hungary) of the border was marked off. The samples of the undisturbed borderland were taken from a defined area of 10 x 10 m, consequently each transect is composed of 3 investigation plots (Fig. 2) and the samples were designated as shown on Table 1.

Transect I

205 m a.s.l., 9°C annual mean temperature, 700 mm annual mean precipitation, plain, no erosion, loessial deposit, crop and management history as shown on Table 2.

Transect II

197.5 m a.s.l., 9°C annual mean temperature, 700 mm annual mean precipitation, plain, no erosion, alluvial deposit, crop and management history as shown on Table 3.

Transect III

255 m a.s.l., 9 °C annual mean temperature, 700 mm annual mean precipitation, plain, no erosion, carbonated loess material, crop and management history as shown in Table 4.

The classification and description of the soils within the transects were made according to the *World Reference Base for Soil Resources* [7].

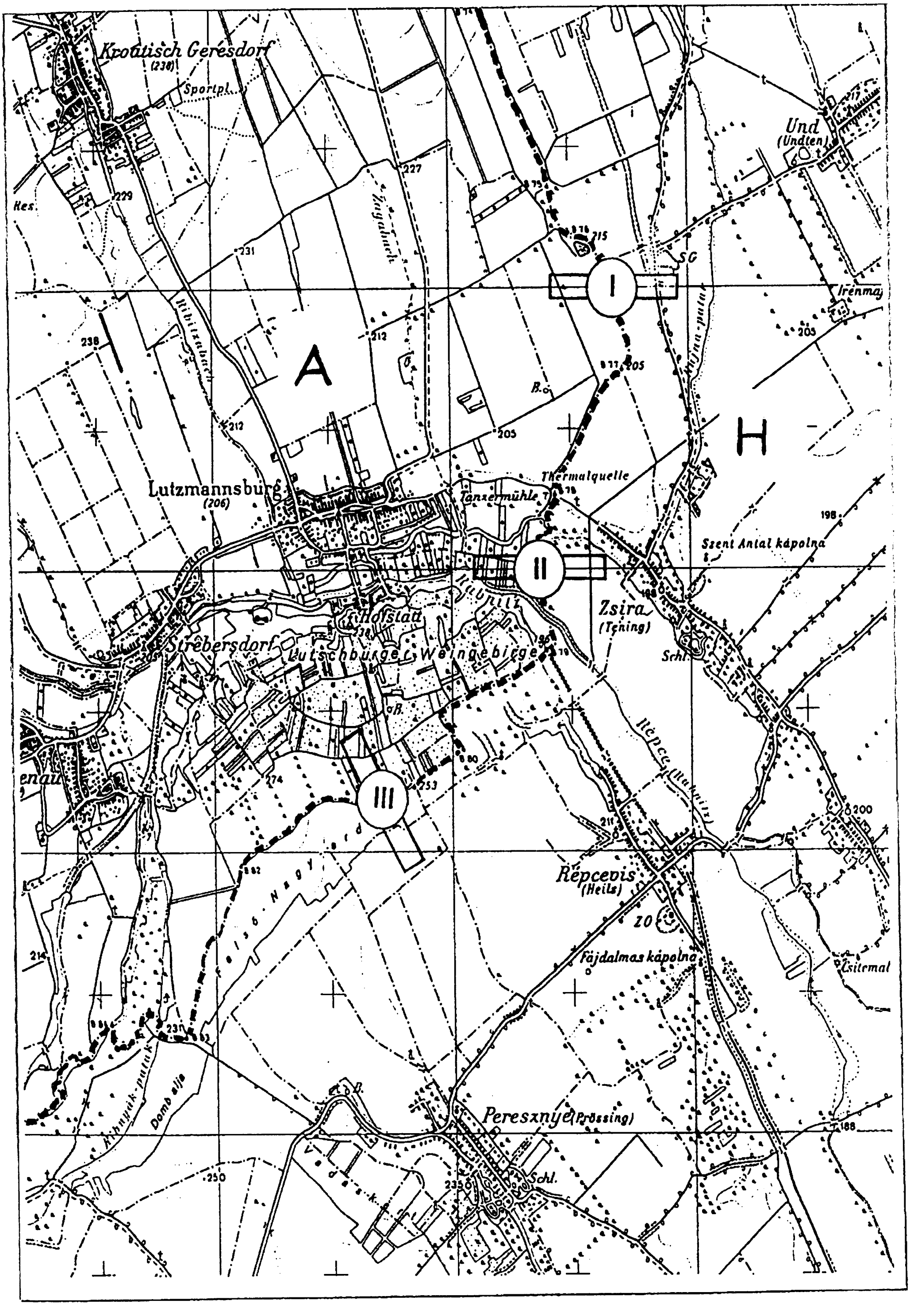

Fig. 1. Localisation of the transects (ÖK 1 : 50000), I = Transect I, II = Transect II, III = Transect III, - · - = border line, A - Austria, H - Hungary.

BC: (40-50 cm), dull yellowish brown (10YR/4/4), earthdry, closed layered medium prismatic structure, loam, weak effervescence, medium content of medium pores, weakly rooted, moderate content of medium debris, boundary clear and straight.

C: (50+ cm), brown (10YR/5/6), earthdry, coherent structure, loam, strong effervescence, no pores, no roots, high content of medium debris.

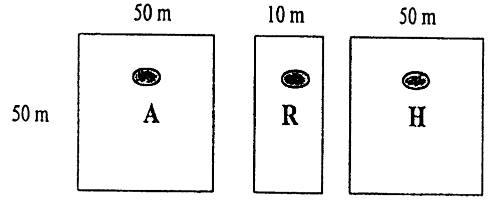

Fig. 2. Situation of the investigated sites (A = Austrian Plot, R = Reference Plot, H = Hungarian Plot.

Table 1. Characterisation of the soil samples among the 3 transects

	Transect I	Transect II	Transect III
Iron Curtain-Borderland	I/R/XX	II/R/XX	III/R/XX
Austrian Plot	I/A/XX	II/A/XX	III/A/XX
Hungarian Plot	I/H/XX	II/H/XX	III/H/XX

R = Reference (*Iron Curtain* Borderland), A = Austria, H = Hungary, XX = Soil horizon.

Table 2. Crop and management history of the Austrian and Hungarian sites on transect I until 1993. Conventional soil management practices consist of tillage involving moldboard plow, followed by disking or harrowing, application of chemical fertilizers and weed control by chemical herbicides.

Country	Year	Crop	Management practices	Wintercover
Austria	1987-1989	maize	conventional	no
	1990	rye	conventional	no
	1991	spring barley	conventional	no
	1992	maize	conventional	no
	1993	sugar peas	conventional	no
Hungary	1982/83	winter wheat	conventional	yes
	1983	sunflower	conventional	no
	1984/85	winter wheat	conventional	yes
	1985/86	rape	conventional	yes
	1986/87	winter wheat	conventional	yes
	1987	sugar peas	conventional	no
	1988/89	winter wheat	conventional	yes
	1990	sunflower	conventional	no
	1991/92	winter wheat	conventional	yes
	1992/93	rape	conventional	yes

Transect I, profile I/R (Reference), calcaric Cambisol:

A: (0-22 cm), dull yellowish brown (10YR/4/3), earthfresh, moderate, very fine crumb structure, silty loam, no effervescence, medium content of medium pores, strongly rooted, low content of medium debris, boundary clear and straight.

B: (22-40 cm), brownish black (10YR/3/3), earthdry, closed layered medium prismatic structure, loam, no effervescence, medium content of medium pores, strongly rooted, moderate content of medium debris, boundary clear and straight.

Transect I, profile I/A (Austria), calcaric Cambisol:

Ap: (0-20 cm), dull yellowish brown (10YR/4/3), friable, moderate, very fine crumb structure, silty loam, no effervescence, few fine tubular pores, moderate content of fine roots, approx. 5 % gravels, plant residues, boundary clear and ondulated.

A_2: (20-32 cm), brown (7.5 YR/4/3), firm, strong, coarse, angular, blocky structure, silty loam, no effervescence, few very fine tubular pores, moderate content of fine roots, approx. 10 % gravel, boundary abrupt and ondulated.

Table 3. Crop and management history of the Austrian and Hungarian sites on transect II until 1993. Conventional soil management practices consist of tillage involving moldboard plow, followed by disking or harrowing, application of chemical fertilizers and weed control by chemical herbicides. No tillage means no soil disturbance, weed control by herbicides.

Country	Year	Crop	Management practices	Wintercover
Austria	till 1983	pasture	no tillage	yes
	1983-88	peach orchard	no tille	yes
	1989	green fallow	no tillage	yes
	1990-93	maize	conventional	no
Hungary	1982/83	winter wheat	conventional	yes
	1983	sunflower	conventional	no
	1984/85	winter wheat	conventional	yes
	1985	maize	conventional	no
	1986	spring barley	conventional	no
	1987	sugar peas	conventional	no
	1988/89	winter wheat	conventional	yes
	1990	sunflower	conventional	no
	1991/92	winter wheat	conventional	yes
	1992/93	rape	conventional	yes

Table 4. Crop and management history of the Austrian and Hungarian sites on transect III until 1993. Conventional soil management practices consist of tillage involving moldboard plow, followed by disking or harrowing, application of chemical fertilizers and weed control by chemical herbicides. No tillage means no soil disturbance, weed control by herbicides.

Country	Year	Crop	Management practices	Wintercover
Austria	till 1983	orchard	no tillage	yes
	1983-88	maize	conventional	no
	1989	sugar peas	conventional	no
	1990-91	winter wheat	conventional	no
	1991	spring barley	conventional	no
	1992/93	winter wheat	conventional	no
Hungary	till 1993	Plantage of Robinia pseudoacacia		

B: (32-80 cm), dull reddish brown (5YR/4/4), air dry, firm, moderate, medium subangular blocky structure, loam, no effervescence, many fine tubular pores, many very fine roots, clay coatings, approx. 25 % gravel, boundary clear and ondulated.

BC: (80+ cm), brown (7.5 YR/6/4), air dry, friable, moderate subangular blocky structure, clay loam, approx. 32 % clay content, slight effervescence, common fine tubular pores, very few very fine roots, approx. 10 % gravel.

C: Becomes dominant from 110 cm on.

Transect I, profile I/H (Hungary), calcaric Cambisol:

Ap: (0-21 cm), dull yellowish brown (10YR/4/3), friable, moderate, very fine crumb structure, clay loam, approx. 35 % clay content, no effervescence, few very fine tubular pores, few very fine roots, approx. 15 % gravel, plant residues, boundary clear and ondulated.

A_2: (21-32 cm), brown (7,5YR/4/3), firm, strong, coarse, angular, blocky structure, clay loam, approx. 30% clay content, no effervescence, few very fine tubular pores, few very fine roots, approx. 10 % gravel, boundary abrupt and ondulated.

B: (32-82 cm), dull reddish brown (5YR/4/4), air dry, firm, moderate, medium subangular blocky structure, loamy clay, approx. 38 % clay content, no effervescence, many fine tubular pores, many very fine roots, clay coatings, approx. 25 % gravel, boundary clear and ondulated.

BC: (82+ cm), brown (7,5YR/6/4), air dry, friable, moderate, medium subangular, blocky structure, clay loam, approx. 32 % clay content, slight effervescence, common fine tubular pores, few very fine roots, approx. 10% gravel, calcium carbonate coatings, snails.

C: Becomes dominant from 130 cm on.

Transect II, profile II/R (Reference), eutric Fluvisol:

A: (0-15 cm), brownish black (10YR/3/2), air dry, slightly hard, weak, medium subangular blocky structure, loam, approx. 25 % clay content, no effervescence, few very fine tubular pores, many very fine and coarse roots, boundary clear and smooth.

B: (15-50 cm), dull yellowish brown (10YR/4/3), air dry, hard, weak, medium subangular blocky structure, loam, approx. 25 % clay content, no effervescence, common, very fine tubular pores, few very fine and common medium roots, organic matter coatings, earth worm casts, few gravels, boundary gradual and ondulated.

Ab: (50-65 cm), brownish grey (10YR/4/2), air dry, hard, weak, medium subangular blocky structure, silty loam, approx. 25 % clay content, no effervescence, common, very fine tubular pores, few very fine and few coarse roots, boundary gradual and ondulated.

Bb: (65-95 cm), yellowish grey (2,5Y/4/2), air dry, slightly hard, weak, medium subangular blocky structure, silty loam, approx. 25 % clay content, no effervescence, common fine tubular pores, few very fine roots and few coarse roots.

Transect II, profile II/A (Austria), eutric Luvisol:

Ap: (0-18 cm), dull yellowish brown (10YR/5/3), air dry, hard, moderate, coarse angular, locky structure, prismatic secondary structure, loam, approx. 25 % clay content, no effervescence, few fine tubular pores, many fine and few coarse roots, boundary clear and smooth.

B: (18-45 cm), dull yellowish brown (10YR/4/3), air dry, hard, moderate, medium subangular, blocky structure, loam, approx. 25 % clay content, no effervescence, few fine tubular pores, many fine roots, organic matter coats, boundary gradual and ondulated.

Ab: (45-60 cm), brownish grey (10YR/4/2), air dry, slightly hard, medium subangular blocky structure, silty loam, approx. 25 % clay content, no effervescence, many very fine tubular pores, few fine roots, few gravels, iron precipitation on peds' surface, boundary gradual and ondulated.

Bb: (65-97 cm), yellowish grey (2,5Y/4/2), air dry, slightly hard, moderate, medium subangular blocky structure, silty loam, approx. 25 % clay content, no effervescence, many fine tubular pores, few fine roots, iron coatings, gley mottles.

Transect II, profile II/H (Hungary), eutric Fluvisol:

Ap: (0-20 cm), dull yellowish brown (10YR/5/3), air dry, slightly hard, moderate, coarse, angular, blocky structure, prismatic secondary structure, loam, approx. 25 % clay content, no effervescence, few very fine tubular pores, many very fine and few coarse roots, boundary clear and smooth.

B: (20-50 cm), dull yellowish brown (10YR 4/3), air dry, hard, moderate medium subangular blocky structure, loam, approx. 25 % clay content, no effervescence, few very fine tubular pores, many very fine roots, organic matter coats, boundary gradual and ondulated.

Ab: (50-65 cm), brownish grey (10YR/4/2), air dry, slightly hard, moderate, medium subangular blocky structure, silty loam, approx. 25 % clay content, no effervescence, many very fine tubular pores, few very fine roots, few gravels, iron precipitation on peds' surface, boundary gradual and ondulated.

Bb: (65-97 cm), yellowish grey (2.5Y/4/2), air dry, slightly hard, moderate, medium subangular blocky structure, silty loam, approx. 25 % clay content, no effervescence, many fine tubular pores, few very fine roots, iron coatings, gley mottles.

Transect III, profile III/R (Reference), calcic Luvisol:

Ah: (0-10 cm), dull yellowish brown (10YR/4/3), loose, weak, fine subangular blocky structure, silty loam, approx. 20 % clay content, no effervescence, many very fine and common medium and coarse roots, boundary clear and smooth.

A(E): (10-32 cm), brown (10YR/5/3), air dry, weakly cemented, weak, very fine angular, blocky structure, loam, approx. 30 % clay content, no effervescence, few very fine and few coarse roots, organic matter coatings, boundary clear and smooth.

Bt: (32-48 cm), brown (7,5YR/4/4), extremely firm, moderate, fine angular, blocky structure, clay loam, approx. 40 % clay content, no effervescence, common fine irregular pores, few fine and medium roots, organic matter coatings, slightly developed clay coatings, iron precipitation, boundary gradual and smooth.

BtC: (48-70 cm), brown (10YR/4/4), field capacity, extremely firm, weak, fine angular blocky structure, clay loam, approx. 35 % clay content, no effervescence, common fine irregular pores, few very fine and few coarse roots, earthworm casts, organic matter coatings, slightly developed clay coatings, boundary gradual and smooth.

C: (70-95 cm), dull reddish brown (2,5YR/5/4), air dry, slightly hard structureless, silty loam, approx. 25 % clay content, strong effervescence, many fine tubular pores, few coarse roots, carbonate coatings, slightly developed clay coatings, organic matter coatings.

Transect III, profile III/A (Austria), calcic Luvisol:

Ap: (0-15 cm), dull yellowish brown (10YR/05/4), loose, moderate, very fine angular, blocky structure, loam, approx. 25 % clay content, no effervescence, many very fine roots, boundary gradual and smooth.

A(he): (15-32 cm), dull yellowish brown (10YR/5/4), firm, moderate, very fine angular, blocky structure, loam, approx. 30% clay content, no effervescence, many very fine roots, boundary abrupt and smooth.

Bt: (32-50 cm), brown (7.5YR/4/4), very firm, moderate fine angular, blocky structure, clay loam, approx. 40 % clay content, no effervescence, common fine irregular pores, few fine roots, slightly developed clay coatings, boundary abrupt and smooth.

BtC: (50-80 cm), dull reddish brown (2.5YR/5/4), very hard, structureless, silty loam, approx. 25 % clay content, strong effervescence; fine tubular pores, carbonate coatings.

Transect III, profile III/H (Hungary), calcic Luvisol:

Ah: (0-18 cm), dull yellowish brown (10YR/5/3), loose, moderate, very fine angular, blocky structure, loam, approx. 30 % clay content, no effervescence, many very fine and many coarse roots, boundary gradual and smooth.

A(E): (18-30 cm), dull yellowish brown (10YR/5/3), firm, moderate, very fine angular, blocky structure, loam, approx. 30 % clay content, no effervescence, many very fine and coarse roots, organic matter coatings, boundary abrupt and smooth.

Bt: (30-49 cm), brown (7,5YR/4/4), very firm, moderate, fine angular blocky structure, clay loam, approx. 40 % clay content, no effervescence, common fine irregular pores, few very fine and coarse roots, organic matter coatings, slightly developed clay coatings, boundary abrupt and smooth.

BtC: (49-75cm), dull reddish brown (2,5YR/5/4), friable, structureless, silty loam, approx. 25 % clay content, strong effervescence, many very fine tubular pores, carbonate coatings.

MATERIAL AND METHODS

Soil sampling

Sampling for mineralogical analyses

For the determination of mineralogical analyses bulk samples were taken from each horizon of the reference profiles (R) and randomly from the two soil depths (0-15 cm, 15-30 cm) of the Austrian and Hungarian sites.

Sampling for physical analyses

For the determination of particle size distribution and soil aggregate stability bulk samples were taken from each horizon of the reference profiles (R) and randomly from the two soil depths (0-15cm, 15-30 cm) of the Austrian and Hungarian sites.

For the determination of the pF-curve 3 cylinders (200 cm^3) were taken from each horizon of the reference profiles (R) and from the A-horizon (0-15 cm) of the Austrian and Hungarian sites.

For the determination of the saturated hydraulic conductivity 5 cylinders (200 cm^3) were taken from each horizon of the reference profiles (R) and from the A-horizon (0-15 cm) of the Austrian and Hungarian sites.

For the determination of the unsaturated hydraulic conductivity one cylinder was taken from each horizon of the reference profiles (R) and from the A-horizon (0-15 cm) of the Austrian and Hungarian site.

The C-horizon of the reference profile in transect I (I/R/C) could not be sampled because of its extreme hardness.

Sampling for micromorphological analyses

For the preparation and analyses of soil thin sections of undisturbed samples were taken by Kubiena-boxes (6,5 x 8 x 4 cm = 208 cm^3) from each horizon of the reference profiles (R), except from I/R/C because of its hardness, and from the A-horizon of the Austrian and Hungarian sites.

Analytical methods

Soil mineralogical analyses

- Total mineral content by X-ray diffraction, using Cukα-radiation, according to Schultz [25].
- Clay mineral content by X-ray diffraction, using Cukα-radiation, according to Brindley and Brown [4], and Garcia and Camazano [10].
- Na-dithionite-citrate-bicarbonate (DCB) soluble Fe-, Al- and Mn-oxides, according to Schwertmann [26].
- NH_4-oxalate soluble Fe-, Al- and Mn-oxides according to Schwertmann [27].
- Na-pyrophosphate soluble, organically bounded Fe-, Al- and Mn-oxides according to Hermann and Gerke [14].

Soil physical analyses·

- Bulk density (dB) using 200 cm^3 cylinders.
- Total porosity (TP) calculated from density values.·
- Soil aggregate stability (SAS), according to Murer *et al.* [19].
- Particle size distribution by wet sieving and sedimentation technique.
- Water retention curve (pF-curve) and pore size distribution using pressure chambers according to Hartge and Horn [11,12] and Klute [17].
- Saturated hydraulic conductivity (K_{sat}) according to Klute [17].
- Unsaturated hydraulic conductivity (Ku) using an *Instantaneous Profile Method* according to Plagge [20], and Wind [29].

Soil micromorphological analyses

Thin sections were prepared from the undisturbed soil by fixation of the samples with polyester resine (CHS-polyester 109), diluted in acetone under vacuum, according to Curlik [5], and Jongerius [15].

RESULTS AND DISCUSSION

Mineralogical data

The mineralogical data of the investigated soils are shown in Tables 5-7.

Transect I:

The reference profile I/R shows the features of a moderate weathered Cambisol, where layer silicates accumulate on the top, whereas quartz and chlorite increase with soil depth (see Table 5). The clay mineral distribution corresponds to this features and shows an accumulation of illite on the top, and few kaolinite through the whole profile. The relatively high amount of smectite, which is an expandable 2:1-clay mineral, explains the subangular blocky structure and the extreme hardness of the B-horizon. No illuviated clay, Fe, Al and organic matter occurs (see Tables 7 and 9). The increasing amount of oxalate-soluble Fe (Fe_0) in the cambic horizon also explains the moderate weathering process in this soil (see Table 7).

The comparison of the three investigated areas over transect I (Austria, Hungary, reference) shows the uniformity of this soil between Austria and the reference, whereas the Hungarian site shows a contrarily distribution in the contents of quartz, chlorite and layer

Table 5. Semiquantitative primary mineral content in the fine earth of the investigated soils in weight %

Transect	Quartz	Chlorite	Micas	Felspars	Calcite	Dolomite
Transect I						
I/R/A	74	4	20	2	tr.	tr.
I/R/B	75	11	13	1	-	-
I/R/BC	81	15	4	tr	-	-
I/R/C	80	17	2	tr.	1	-
I/A/Ap	68	10	20	2	tr.	-
I/A/A2	82	16	2	tr.	-	-
I/H/Ap	83	14	12	1	-	-
I/H/A2	66	7	24	3	-	-
Transect II						
II/R/A	62	11	19	7	1	-
II/R/B	44	24	26	6	-	-
II/R/Ab	63	15	17	5	-	-
II/R/Bb	82	6	10	2	-	-
II/A/Ap	50	17	27	6	-	-
II/A/B	35	25	30	6	1	-
II/H/Ap	33	35	23	8	1	-
II/H/B	50	17	29	4	-	-
Transect III						
III/R/Ah	39	14	37	8	2	-
III/R/(A)E	85	12	3	tr.	-	-
III/R/Bt	71	19	9	1	-	-
III/R/BtC	60	14	16	4	3	3
III/A/Ap	88	10	1.5	0.5	-	-
III/A/A(he)	87	7	5	1	-	-
III/H/Ah	66	14	16	4	-	-
III/H/A(E)	69	15	12	4	-	-

silicates (see Table 5) which could have been caused by deeper tillage practices like ploughing. Moreover, the clay mineral distribution indicates that the undisturbed conditions in the reference-profile led to a higher weathering of illite and formation of smectite than in the cultivated Austrian and Hungarian sites.

Transect II:

The reference profile II/R shows the typical stratification phenomena of a Fluvisol, concerning the primary minerals quartz, chlorite and layer silicates (see Table 5). The same tendency is given by the distribution of smectite and kaolinite (see Table 6). The distribution of the "free" oxides confirms the stratification and the presence of buried horizons within this profile, with accumulation of the dithionite- and oxalate-soluble Fe in the II/R/Ab-horizon (50-65 cm) and the high accumulation of organic-bounded (pyrophosphate-soluble) Mn in the II/R/Bb-horizon (69-95 cm) (see Table 7). As in transect I, the mineralogical distribution probable as a consequence of deep tillage practices, in the tillaged horizons of the Hungarian site, behaves contrarily to the Austrian and the reference sites.

Transect III:

The reference profile III/R shows the typical mineralogical features of a Luvisol, with a significant eluviated horizon (E) and illuviated horizon (Bt and BtC). The loss of clay from E-horizon and its accumulation in the Bt-horizon are visible from the particle size distribution (see Table 9). This process leads to loss of mobile minerals (layer silicates and chlorite) and the relative accumulation of quartz in the eluviated horizon (see Table 5), respectively in the accumulation of illite and transport downwards of chlorite and smectite (see Table 6). Fe- and Al-oxides are also affected by this process and accumulate in the Bt-horizon, as shown in Table 7. The formation of a Luvisol

Table 6. Semiquantitative clay mineral content in the fine earth of the investigated soils in weight %

Transect	Illite	Chlorite	Smectite	Vermiculite	Kaolinite
Transect I					
I/R/BC	63	14	21	-	2
I/R/C	55	13	27	-	5
I/A/Ap	58	12	26	-	2
I/A/A2	45	14	39	-	2
I/H/Ap	73	14	8	-	5
I/H/A2	80	15	-	-	5
	81	10	-	-	9
	72	10	11	-	7
Transect II					
II/R/A	60	20	18	-	2
II/R/B	56	13	21	-	10
II/R/Ab	40	14	41	-	5
II/R/Bb	45	8	43	-	4
II/A/Ap	58	12	25	-	5
II/A/B	42	13	38	-	7
II/H/Ap	43	13	40	-	4
II/H/B	37	23	27	-	13
Transect III					
III/R/Ah	79	14	-	-	7
III/R/(A)E	86	7	7	-	-
III/R/Bt	81	17	-	-	2
III/R/BtC	44	16	36	-	4
III/A/Ap	76	11	13	-	-
III/A/A(he)	72	15	10	-	3
III/H/Ah	51	11	38	-	tr.
III/H/A(E)	64	16	16	-	4

is also manifested in other soil features like soil colours (10YR/5/3 in the E-horizon and 7.5YR/4/4 in the Bt-horizon), CEC (108 med/kg in the E-horizon and 142 med/kg in the Bt-horizon, [22]) and clay coatings in the Bt-horizon.

Physical data

Bulk density (dB) and total porosity (TP)

The bulk density and the total porosity are two descriptive structure parameters. With their help it is possible to deduce the water balance and aeration of soils, but they give no information about the geometry and continuity of the pore system. At the reference sites (R) the bulk density becomes higher with soil depth (see Table 8), except for transect I, where the upper horizons (I/R/A, I/R/B) have the same density as the I/R/BC-horizon. Ehlers [6] indicated a maximum of 1.55 g/cm^3 for bulk density as the critical level for plant growth, which is not reached in any horizon of the investigated soils. On the other hand, Beckmann and Altermüller [2], showed, that bulk density of topsoils of tillaged sites can vary from 1.3 to 1.6 g/cm^3. These values are reached in all A-horizons of the tillaged soils. By comparing all A-horizons in Table 8, it can be seen that the bulk densities of the reference sites are much lower than at the tillaged sites (H and A), with the exception, again, of transect I (I/R/A). This is a consequence of their undisturbed development, higher organic matter and the highly developed rooting system. The total porosity of the reference sites (R) (Table 8), calculated from density values, show the decreasing tendency of the total porosity with the depth. This is in accordance with the values of water content at 1 hPa (see Table 10).

Particle size distribution

The particle size distribution of the investigated soils is shown on Table 9 and reflects a

Table 7. Dithionite- (d), oxalate- (o) and pyrophosphate- (p) soluble Fe-, Al- and Mn-oxides of the investigated soils in mg/kg fine earth (ppm)

Transect	Fe_d	Fe_o	Fe_p	Fe_o/Fe_d	Al_d	Al_o	Al_p	Mn_d	Mn_o	Mn_p
Transect I										
I/R/A	11080	1290	277	0.12	1236	1225	377	576	525	241
I/R/B	15250	1320	10	0.09	583	1300	190	535	490	103
I/R/BC	11970	1145	533	0.10	1208	1250	164	579	490	53
I/A/Ap	12560	1400	233	0.11	1325	1322	414	620	520	160
I/A/A2	12800	1370	237	0.11	1560	1222	414	712	548	158
I/H/Ap	13630	1728	150	0.13	1519	1250	275	609	470	94
I/H/A2	13990	1690	126	0.12	1630	1338	283	695	560	126
Transect II										
II/R/A	10150	3090	596	0.30	1008	1018	394	565	505	177
II/R/B	10660	3760	487	0.35	1036	912	325	665	568	87
II/R/Ab	11660	5050	490	0.43	993	910	210	779	770	82
II/R/Bb	9860	4975	385	0.50	597	675	199	839	943	616
II/A/Ap	6390	4550	650	0.71	660	1253	424	470	490	110
II/A/B	11460	4450	634	0.39	1046	1173	421	570	515	95
II/H/Ap	11540	4275	652	0.37	1539	1368	475	852	595	128
II/H/B	11560	4200	568	0.36	1308	1263	448	704	580	143
Transect III										
III/R/Ah	8200	1928	494	0.24	1353	1123	502	598	548	270
III/R/(A)E	8830	1788	402	0.20	1231	963	384	629	540	240
III/R/Bt	14810	1160	213	0.08	1920	1048	368	388	261	45
III/R/BtC	10630	825	38	0.08	1192	798	58	403	313	13
III/A/Ap	8540	2178	412	0.26	1344	1278	486	620	538	204
III/A/A(he)	7580	1918	391	0.25	1255	1025	446	613	510	182
III/H/Ah	11840	1468	337	0.12	1690	1275	519	417	345	165
III/H/A(E)	11390	1645	278	0.14	1535	1145	404	447	418	143

relative high soil homogenity between tillaged (A and H) and reference soils within each transect. The effect of clay illuviation in the Bt-horizon of the Luvisol of transect III is evident. The content of fine pores and the bulk density are also increasing in the Bt-horizon of transect III, as shown in Table 11 and Table 8, thus confirming the illuviation process and the formation of a Luvisol.

The amount of silt is high in each horizon, except in the I/R/C-horizon, therefore most horizons are loams or silty loams, as shown in Table 9. The texture class can be used for estimating the productivity of a soil. Loamy soils and silty soils with a medium amount of clay have sufficient aeration and storage capacity for available water if their bulk density is not too high [23]. Moreover, silty soils with less than 17 % clay tend to sludge in the crumb and erode [23].

Soil aggregate stability (SAS)

The stability of soil aggregates in water is affected by various biotic and abiotic factors and landuse practices. The concept of soil aggregate stability reflects many soil structural parameters [3,21,22], but is also a function of whether the cohesive forces between particles resist the applied disruptive force of water. Table 8 shows a general decrease of SAS with soil depth at the reference sites (R), which can be explained by differences in root density and microbiological activity [1]. SAS decreases in Austrian and Hungarian soils as a consequence of tillaging, lower organic carbon content, mostly uncovered soil surface and microbiological activity, see also [22]. Lower SAS can also be caused by using chemical fertilizers [19].

Water retention characteristic

The soil water retention characteristic of the investigated soils, often used to characterize the

Table 8. Bulk density (dB), total porosity (TP), and soil aggregate stability (SAS) of the investigated soils

Transect	dB (g/cm^3)	TP (vol %)	SAS (%)
Transect I			
I/R/A	1.43	46	90
I/R/B	1.42	47	78
I/R/BC	1.40	47	82
I/R/C	not sampled	-	64
I/A/Ap	1.27	52	68
I/A/B	-	-	56
I/H/Ap	1.32	50	61
I/H/A2	-	-	60
Transect II			
II/R/A	1.06	60	75
II/R/B	1.34	49	56
II/R/Ab	1.33	50	53
II/R/Bb	1.45	45	22
II/A/Ap	1.35	57	67
II/A/B	-	-	64
II/H/Ap	1.30	51	56
II/H/A2	-	-	49
Transect III			
III/R/Ah	1.11	58	81
III/R/(A)E	1.30	51	63
III/R/Bt	1.47	45	63
III/R/BtC	1.49	44	38
III/A/Ap	1.41	47	27
III/A/A(he)	-	-	33
III/H/Ah	1.31	50	76
III/H/A(E)	-	-	66

soil aeration and the water balance, is shown on Table 10.

The water content at 300 hPa is equivalent to the field capacity. From Table 10 it can be seen that all values of the A-horizons within each transect are almost equal. The tension of 15000 hPa is equivalent to the permanent wilting point (pF 4.2). Comparing the cultivated sites with the undisturbed reference soils, a higher water content in the tillaged A-horizons of Austria and Hungary becomes evident, which is explainable by the higher bulk density. An exception is the I/R/A-horizons which show a similar value as the corresponding A-horizons of Austria and Hungary in transect I.

Pore size distribution

Table 11 shows the distribution of pore sizes calculated from the values of the different water contents.

The results show that in all the top soils of each transect water availibility, expressed by the content of medium pores, is guaranteed and comparable. The weathering B-horizons in the undisturbed reference site of transect I (I/R/B) and transect II (II/R/B) show, on the contrary, a significant decrease of medium pores. Moreover, the results show that the amount of medium pores in the A-horizons is not so much affected by tillage practices. The coarse pores, responsible for aeration, water and solute transport can also be considered as sufficient. In transect I there is a decrease of medium pores in the I/R/B-horizon (in comparison to the I/R/A-horizon), with an increase of coarse and fine pores at the same time. This is typical for the weathering-horizon of a Cambisol with shrinking cracks. A similar tendency is occuring in the II/R/B-horizon of transect II, in favour of the fine pores. The coarse pores decreased. The reference soil of transect III (Luvisol) shows a rapid decrease of coarse pores with soil depth till the III/R/Bt-horizon, where the content of coarse pores is very low, accompanied with a strong increase of fine pores with the highest content in the illuvial-horizon (III/R/Bt).

The tillaged A-horizons (I/H/Ap and I/A/Ap) show a higher content of coarse pores than the reference horizon (I/R/A), and is in agreement with bulk density and total porosity. The medium and fine pore contents are as high as in the reference site. The higher content of total porosity in the Austrian A-horizon than in the Hungarian A-horizon points to the use of light-weight machines in Austria, which may be the contrary at the Hungarian site, where heavy machines are mostly used, leading to a higher decrease of coarse pores.

The III/R/Ah-horizon has a high content of coarse pores, which can be explained by the strongly developed rooting system of bushes and grasses. The strong decrease of coarse pores and lower total porosity in the tillaged sites of transect III can only be explained for the Austrian site (III/A/Ap), where conventional landuse over years has probably caused a compaction of the soil. Additionally a decrease of total porosity is given by a natural compaction after tillaging a soil (the samples were taken in June, just before harvesting).

Table 9. Particle size distribution (weight %) and texture class of the investigated soils. (cS = coarse sand, mS = medium sand, fS = fine sand, cU = coarse silt, mU = medium silt, fU = fine silt, c = clay)

Transect	cS	mS	fS	ΣS	cU	mU	fU	ΣU	C	Texture class
Transect I										
I/R/A	2.6	2.6	8.9	14.1	32.9	18.6	3.3	54.8	31.0	uL
I/R/B	5.5	3.0	9.2	17.7	31.9	11.2	9.1	52.2	30.1	L
I/R/BC	5.4	2.9	10.4	18.8	30.2	8.0	16.5	54.7	26.5	L
I/R/C	5.7	4.8	12.8	23.2	20.8	16.5	5.5	42.8	34.0	L
I/A/Ap	0.3	2.3	7.0	9.5	34.7	11.2	12.0	57.9	32.5	uL
I/A/A2	1.5	1.9	6.8	10.2	31.0	21.9	6.4	59.3	30.5	uL
I/H/Ap	2.7	1.9	7.1	11.7	32.0	11.7	8.5	52.2	36.1	L
I/H/A2	2.3	2.5	6.8	11.6	30.7	19.4	5.7	55.8	32.6	uL
Transect II										
II/R/A	0.2	0.9	12.6	13.8	32.0	18.7	7.5	58.2	28.0	uL
II/R/B	0.2	1.6	16.9	18.7	40.2	12.7	5.4	58.4	22.9	lU
II/R/Ab	0.1	1.8	14.0	15.9	30.1	15.0	14.0	59.1	25.0	uL
II/R/Bb	0.5	3.8	20.3	24.6	28.9	14.0	12.0	54.9	20.5	sL
II/A/Ap	0.1	1.9	12.8	14.8	23.3	20.3	11.1	54.7	30.5	L
II/A/B	0.1	1.1	8.7	10.0	24.8	22.0	1.6	58.3	31.7	uL
II/H/Ap	0.2	1.2	9.6	11.0	31.3	17.5	8.3	57.1	32.0	uL
II/H/B	0.2	1.4	11.5	13.1	28.1	19.0	10.5	57.6	29.3	uL
Transect III										
III/R/Ah	0.2	2.4	11.7	14.3	32.2	22.0	5.8	60.0	25.6	lU
III/R/(A)E	0.3	1.8	10.9	13.0	28.9	24.0	9.1	62.0	25.0	lU
III/R/Bt	2.3	1.7	9.6	13.6	26.5	15.0	8.4	49.9	36.5	L
III/R/BtC	1.3	3.8	12.9	18.0	31.0	17.5	8.5	57.0	25.0	lU
III/A/Ap	0.5	2.4	10.6	13.5	33.3	20.4	8.8	62.5	23.9	lU
III/A/A(he)	0.4	2.0	11.3	13.7	32.5	20.8	9.2	62.5	23.9	lU
III/H/Ah	0.3	2.6	12.0	14.9	34.8	14.0	1.7	50.4	34.7	L
III/H/A(E)	0.4	2.8	12.3	15.5	31.8	15.8	7.5	55.0	29.5	L

Table 10. Soil water retention characteristic of the A-horizons of the investigated soils in vol.% at different water tension in hPa

Transect	1hPa	300 hPa	15000 hPa
Transect I			
I/R/A	50	35	17
I/A/Ap	55	36	17
I/H/Ap	51	34	16
Transect II			
II/R/A	55	33	13
II/A/Ap	56	31	16
II/H/Ap	50	32	15
Transect III			
III/R/Ah	50	26	11
III/A/Ap	49	32	18
III/H/Ah	48	33	18

Saturated hydraulic conductivity (K_{sat})

The hydraulic conductivity under water saturated conditions plays an important role in matters of drainage, irrigation, etc., and is a very sensitive soil structure parameter which sometimes may give better information about the status of soil structure than the pore size distribution [11,12]. Table 12 shows the K_{sat}-values of the investigated soils in m/d and cm/s. Due to the influence of different pore size systems (the 'primary' pore system as a result of particle size distribution and the 'secondary' pore system as a result of aggregation), the variability of this parameter can be very high, with differences in the same horizon of one order of magnitude. Therefore 5 cylinders per horizon were measured three times, so 18 repetitions were done for each horizon. Since the saturated hydraulic conductivity is not a normal distributed parameter, it is not convenient to calculate its arithmetic

Table 11. Pore size distribution of the investigated soils in vol. %

Transect	Coarse pores (>10 μm)	Medium pores (10-0.2 μm)	Fine pores (< 0.2 μm)
Transect I			
I/R/A	11.4	17.6	17.1
I/R/B	16.0	9.4	21.1
I/R/BC	13.4	11.8	22.0
I/R/C	not sampled	not sampled	not sampled
I/Ap	16.3	18.4	17.2
I/H/Ap	16.3	18.0	16.0
Transect II			
II/R/A	27.4	19.2	13.4
II/R/B	21.8	9.8	17.7
II/R/Ab	20.3	11.4	18.0
II/R/Bb	14.6	12.9	17.7
II/A/Ap	25.6	15.0	16.1
II/H/Ap	19.0	17.0	15.0
Transect III			
III/R/Ah	32.2	14.8	11.1
III/R(A)E	18.8	16.1	15.9
III/R/Bt	9.2	13.7	21.8
III/R/BtC	12.9	10.7	20.1
III/A/Ap	15.1	13.4	18.5
III/H/Ah	17.6	15.2	17.7

average but the geometric average [12], as shown in Table 12.

Hydraulic conductivity is primarily influenced by soil texture. Soil aggregation, the genesis of the 'secondary' pore system and the pricking of pores through illuviation of fine particles cause a deviation of K_{sat} [12]. In the case of the investigated topsoils, the influence of aggregation-induced 'secondary' pores is evident. Hartge and Horn [12] found that silty soils and soils with a considerable amount of silt had a saturated hydraulic conductivity of about 10^{-3} to 10^{-4} cm/s (at water tension 1 hPa), which is also given for the investigated soils. Richard and Lüscher [after 9] showed a classification of water conductivities of soils. Most of the upper horizons are classified as 'overabundant conductive' (K_{sat}>1.0 m/d) and the others as 'normally conductive' (K_{sat} 0.1-1.0 m/d).

Unsaturated hydraulic conductivity (Ku)

In Fig. 3 the curves calculated from conductivity and water tension show that the values of the three top soils in transect I behave almost equally. With a logarithmical scale it is possible to interpret the values only when they exhibit a minimum difference of one order of magnitude. The similarity of the hydraulic function in transect I is also confirmed by the data of the particle size distribution which are almost equal as well. All three curves show an almost steady course. Between 30-40 hPa and 110-130 hPa the function is decreasing by about three orders of magnitude. The course of the I/A/Ap-curve in the lower range cannot be caused by different clay content or the content of fine pores because these values are almost equal in the three described horizons. So it must be caused by a different evaporation conditioned of a different texture.

The curves in Fig. 4 are less steady than those in Fig. 3. Only the II/R/A- and II/A/Ap are almost steady in the range from 60 to 105 respectively 130 hPa. It can be seen that the values of the II/H/Ap horizon are only given for the section from 110 to 160 hPa and that the course of this curve is much flater than the other ones.

Table 12. Saturated hydraulic conductivity (K_{sat}) of the investigated soils in m/d and cm/s

Transect	cm/s	m/d
Transect I		
I/R/A	7.35×10^{-4}	0.6
I/R/B	5.05×10^{-4}	0.4
I/R/BC	4.51×10^{-3}	3.9
I/R/C	not sampled	not sampled
I/Ap	7.23×10^{-3}	6.2
I/H/Ap	4.62×10^{-3}	4.0
Transect II		
II/R/A	1.49×10^{-3}	1.3
II/R/B	4.97×10^{-4}	0.4
II/R/Ab	1.71×10^{-3}	1.5
II/R/Bb	4.88×10^{-4}	0.4
II/A/Ap	2.82×10^{-3}	2.4
II/H/Ap	1.01×10^{-4}	0.1
Transect III		
III/R/Ah	4.07×10^{-3}	4.1
III/R(A)E	2.12×10^{-3}	1.8
III/R/Bt	3.33×10^{-3}	2.9
III/R/BtC	5.71×10^{-4}	0.5
III/A/Ap	2.97×10^{-4}	0.3
III/H/Ah	6.11×10^{-3}	5.3

Figure 5 shows that the curve of the III/H/A2-horizon, (forest) has a lower unsaturated hydraulic conductivity than the III/A/A1-horizon (arable land). These two curves have the III/R/Ah curve (meadow) in their middle. So no tendency can be observed which could be deduced from the values of conductivity of disturbed horizons. An almost equal decrease of the curves as in the other curves of transect I and II is occurring, the course is almost steady.

Micromorphological data

The calcaric Cambisol in transect I was formed on calcified, later decalcified alluvial deposits. There are the signs of the primary (clastogene) and secondary (authigene) calcites etching (depletion features). Some signs of clay translocation are visible but not well pronounced as to speak about a diagnostic "argillic" horizon, see Figs 6 and 7.

The euthric Fluvisol in transect II has the signs of former hydromorphic influence. This is clear from the bleached colour and from iron spots, nodules and concretions. A rusty appearence is a typical feature for this development. Very high biological activity was also confirmed by the high C_{org}-content (= 2.17) and in the extreme high value of the analysis of DMS-activity, [22], see Figs 8-11.

The soil in transect III is confirmed as a Luvisol. This can be proved from the micromorphological features, which show the presence of an "argillic" horizon. The red colour of the clay coating gives the impression that this is an old horizon formed under warm and more humid conditions, see Figs 12 and 13.

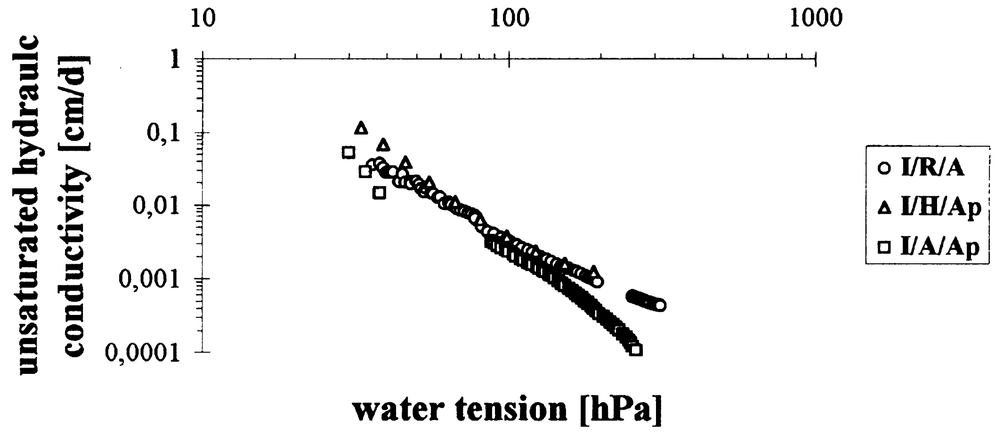

Fig. 3. Unsaturated hydraulic conductivity (*Ku*) as function of the water tension of the three A-horizons of transect I.

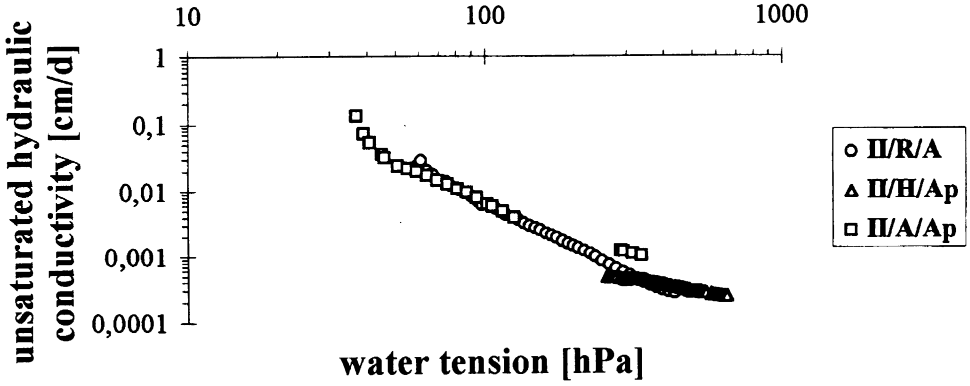

Fig. 4. Unsaturated hydraulic conductivity (*Ku*) as function of the water tension of the three A-horizons of transect II.

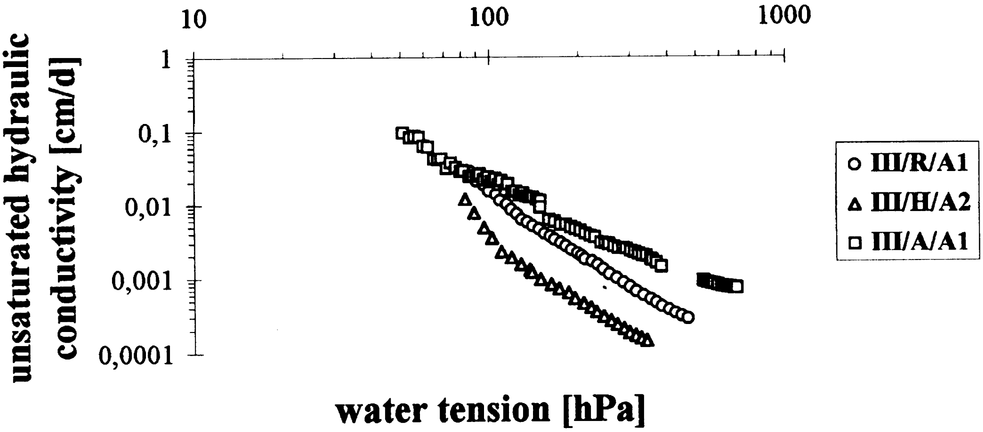

Fig. 5. Unsaturated hydraulic conductivity as function of the water tension of the three A-horizons of transect III.

The main difference between the uncultivated reference soils and the adjacent Hungarian and Austrian soils of all transects lies in the higher biological activity in the A-horizons of the reference soils. This leads to differences in the microstructure, with mostly a crumby microstructure in the undisturbed reference soils, whereas the tillaged soils tend to form subangular, cracky microstructure, as shown in Figs 14-16.

CONCLUSIONS

In Austria and Hungary soil management practices have been different in the last 50 years. Different types and dosages of fertilizers were used and the size of agricultural fields also differed. Large plots, high inputs of mineral fertilizers, intensive tillage activities were characteristic for Hungary. In Austria small scale farming was performed, especially in the neighbourhood of the border. The question was, how these differences were reflected in soil mineralogical, physical and especially micromorphological characteristics analyzed in the two countries, and how these would differ from a non agriculturally utilized reference site.

The mineralogical results indicated that under undisturbed conditions in the reference zone a higher weathering of illite and formation of smectite occured than in the cultivated Austrian and Hungarian sites. This showed also some influence on the genesis of the

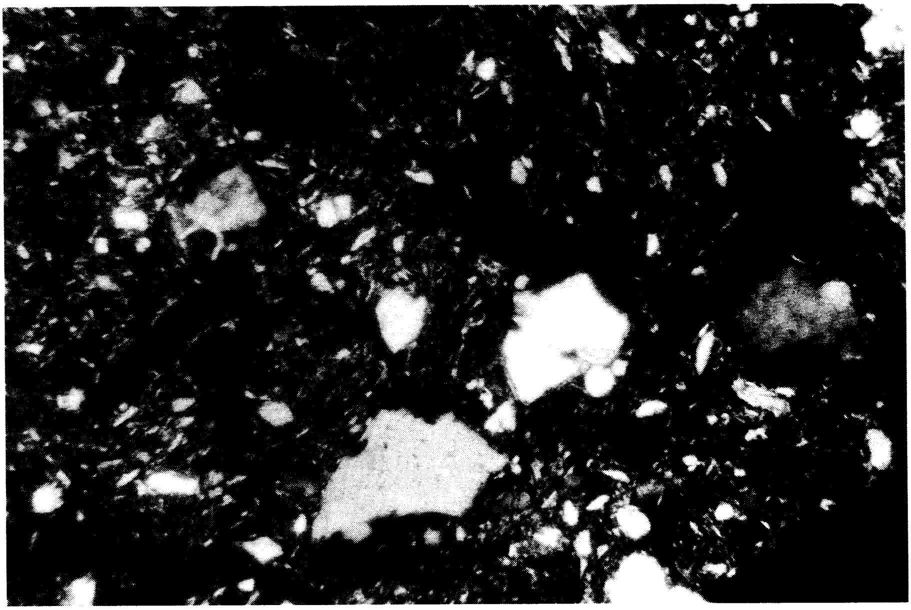

Fig. 6. Ca-oxalate crystalls in the pores of the reference A-horizon (transect I, I/R/A, 0-22 cm) of the calcaric Cambisol, 86 x magnification, XPL.

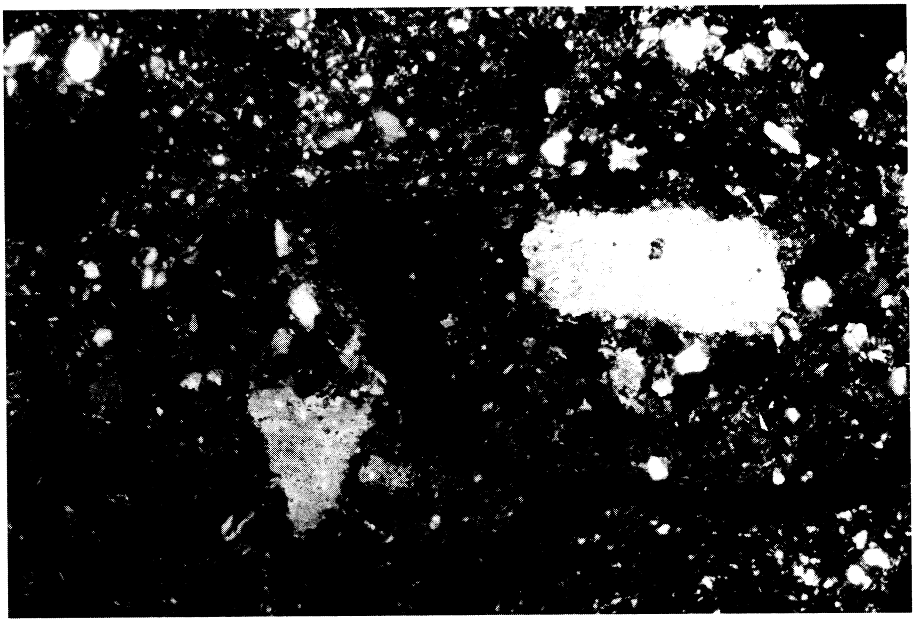

Fig. 7. Calcite, partially weathered, in the reference BC-horizon (transect I, I/R/BC, 40-50 cm) of the calcaric Cambisol, 27 x magnification, XPL.

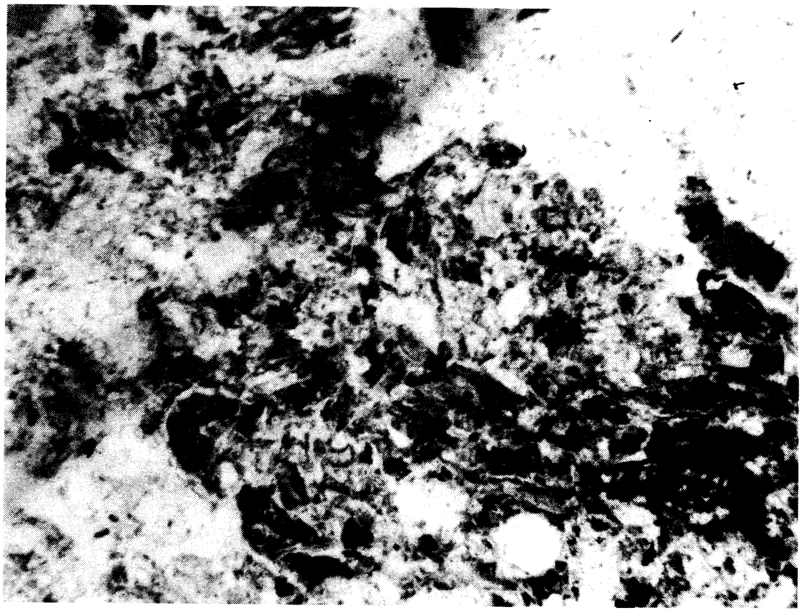

Fig. 8. Organic debris in the reference A-horizon (transect I, I/R/A, 0-22 cm) of the calcaric Cambisol, 86 x magnification, PPL.

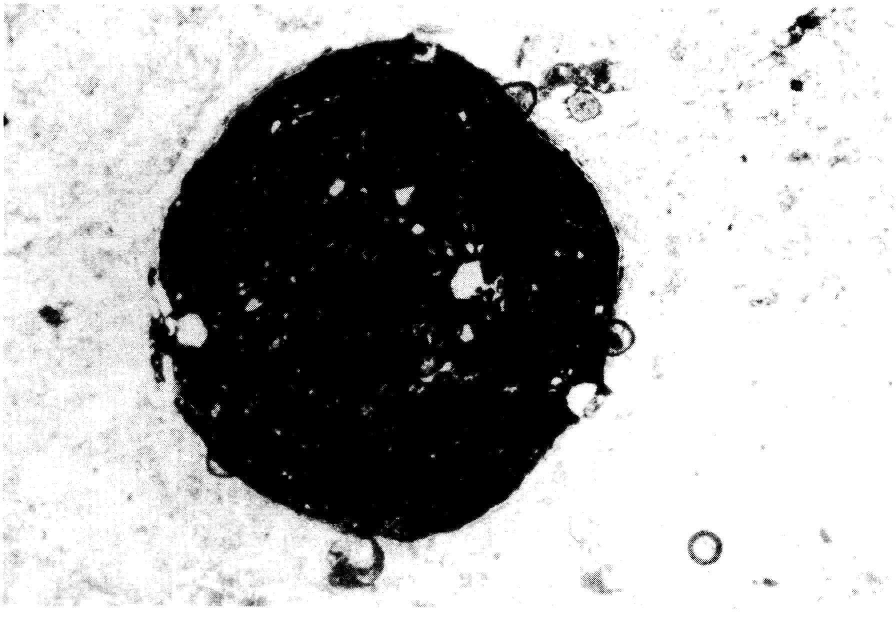

Fig. 9. Concentric iron nodule in the reference B-horizon (transect I, I/R/B, 22-40 cm) of the calcaric Cambisol, 27 x magnification, PPL.

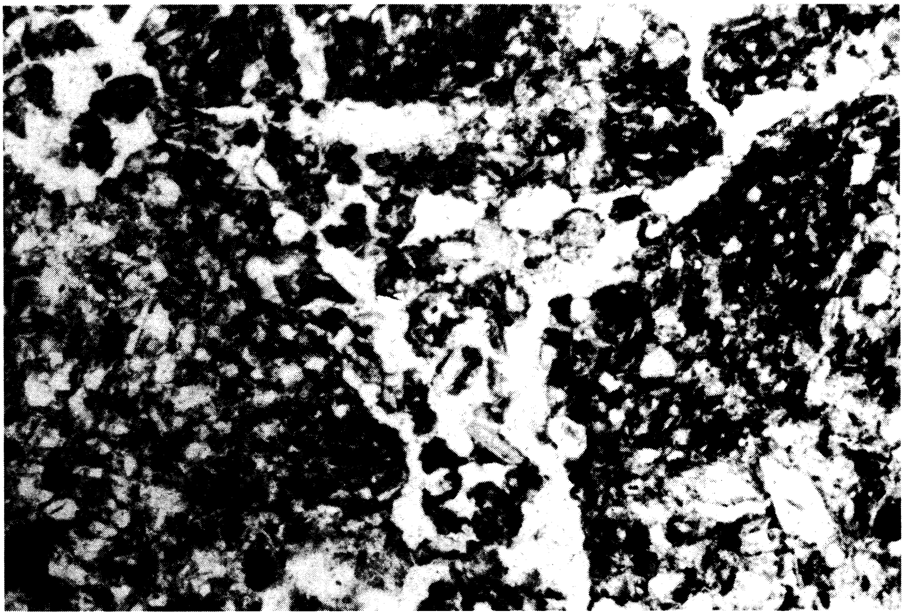

Fig. 10. Pedotubes with organic debris and loose excremental infillings in the reference horizon (transect II, II/R/A, 0-20 cm) of the Eutric Fluvisol, 45 x magnification, PPL.

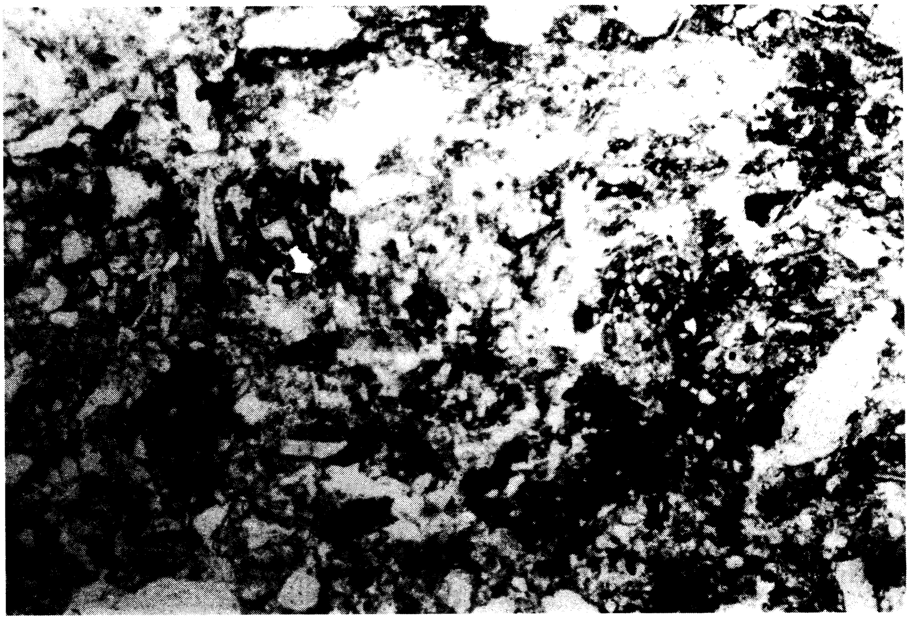

Fig. 11. Secondary Fe-mottles in the reference Bb-horizon (transect II, II/R/Bb, 65-95 cm) of the Eutric Fluvisol, 27 x magnification, PPL.

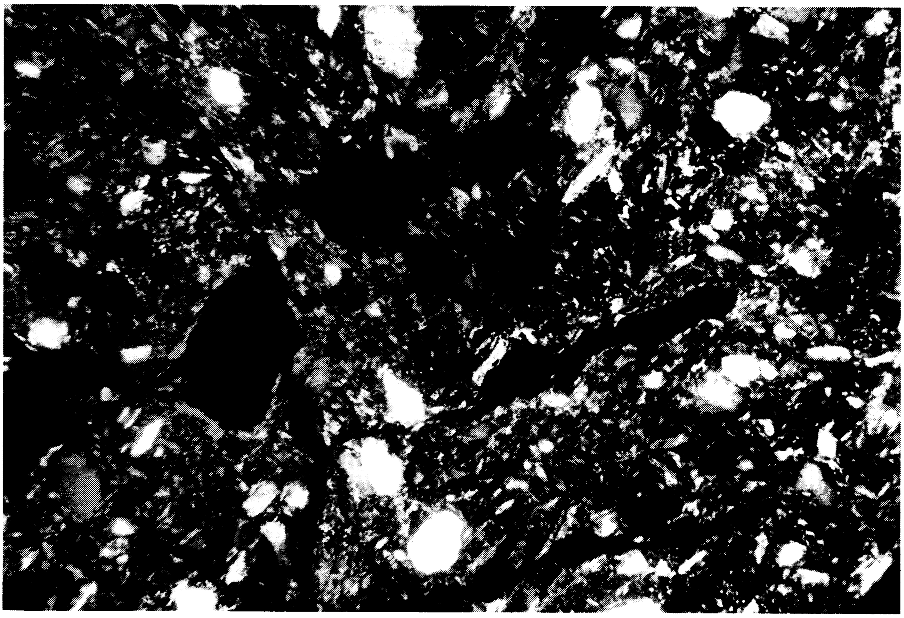

Fig. 12. Clay coatings in the reference Bt-horizon (transect III, III/R/Bt, 32-48 cm) of the Calcic Luvisol, 86 x magnification, XPL.

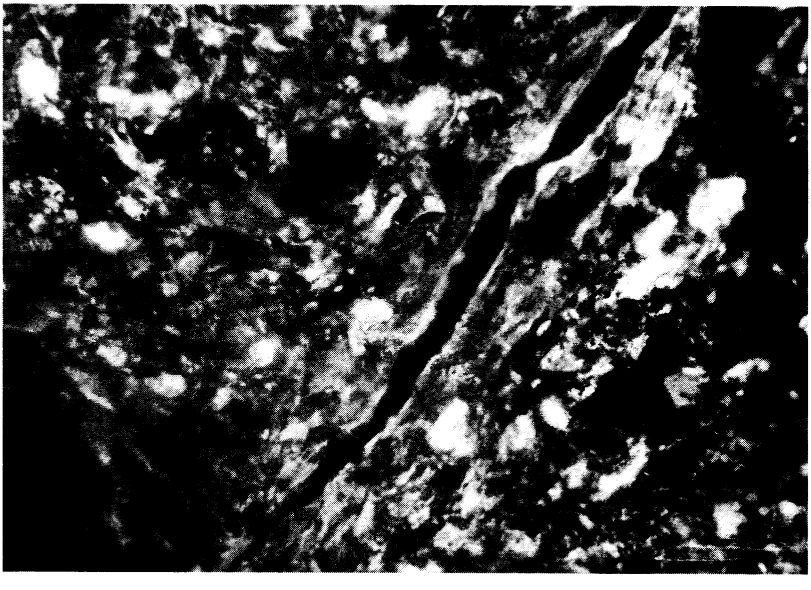

Fig. 13. Clay coatings in the reference C-horizon (transect III, III/R/C, 70-95 cm) of the Calcic Luvisol, 170 x magnification, XPL.

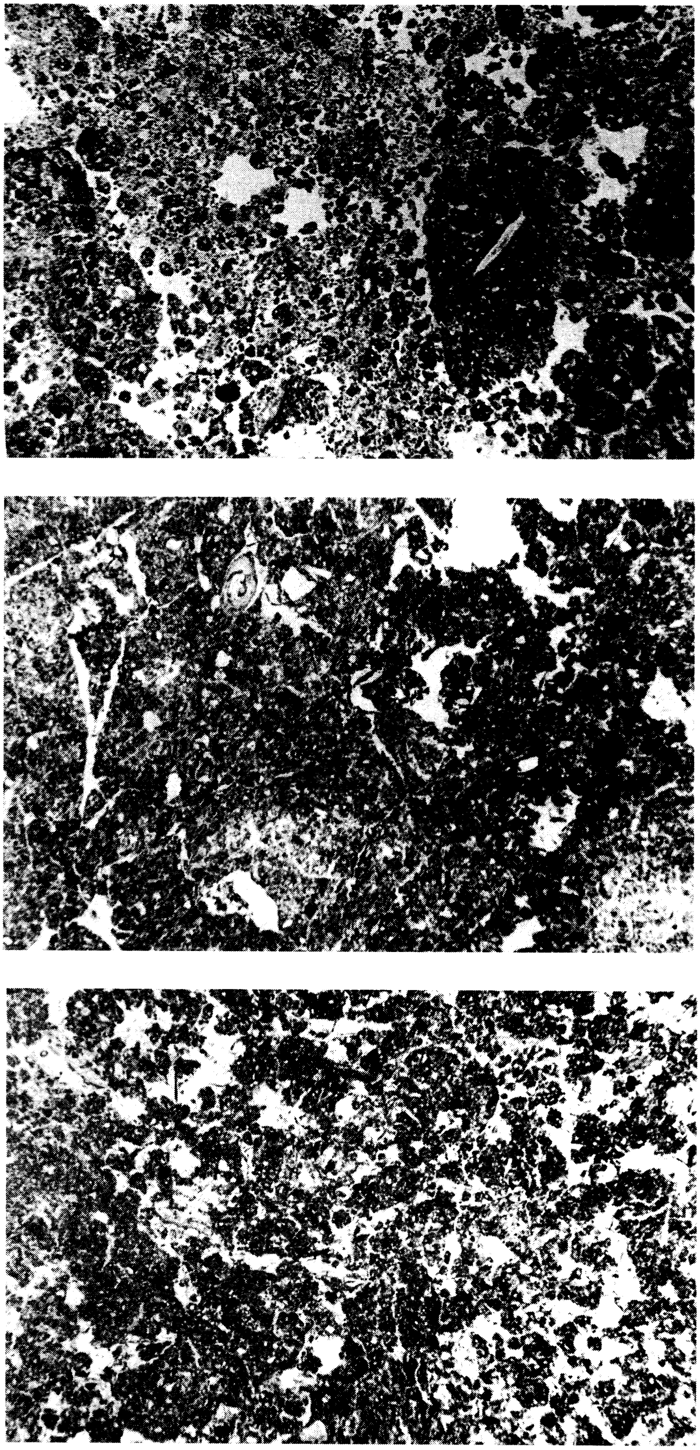

Fig. 14. Microstructure of the topsoils of transect I (Reference above, Austria middle, Hungary below), 4 x magnification, PPL.

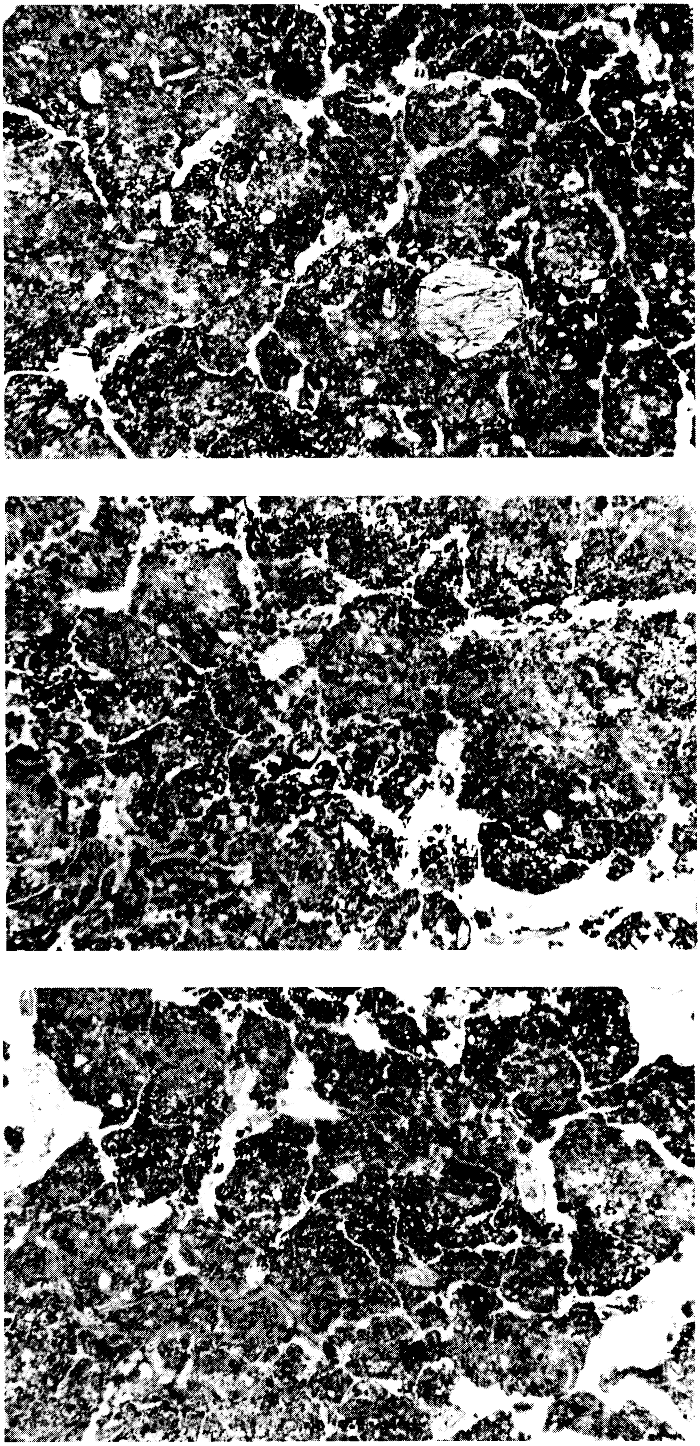

Fig. 15. Microstructure of the topsoils of transect II (Reference above, Austria middle, Hungary below), 4 x magnification, PPL.

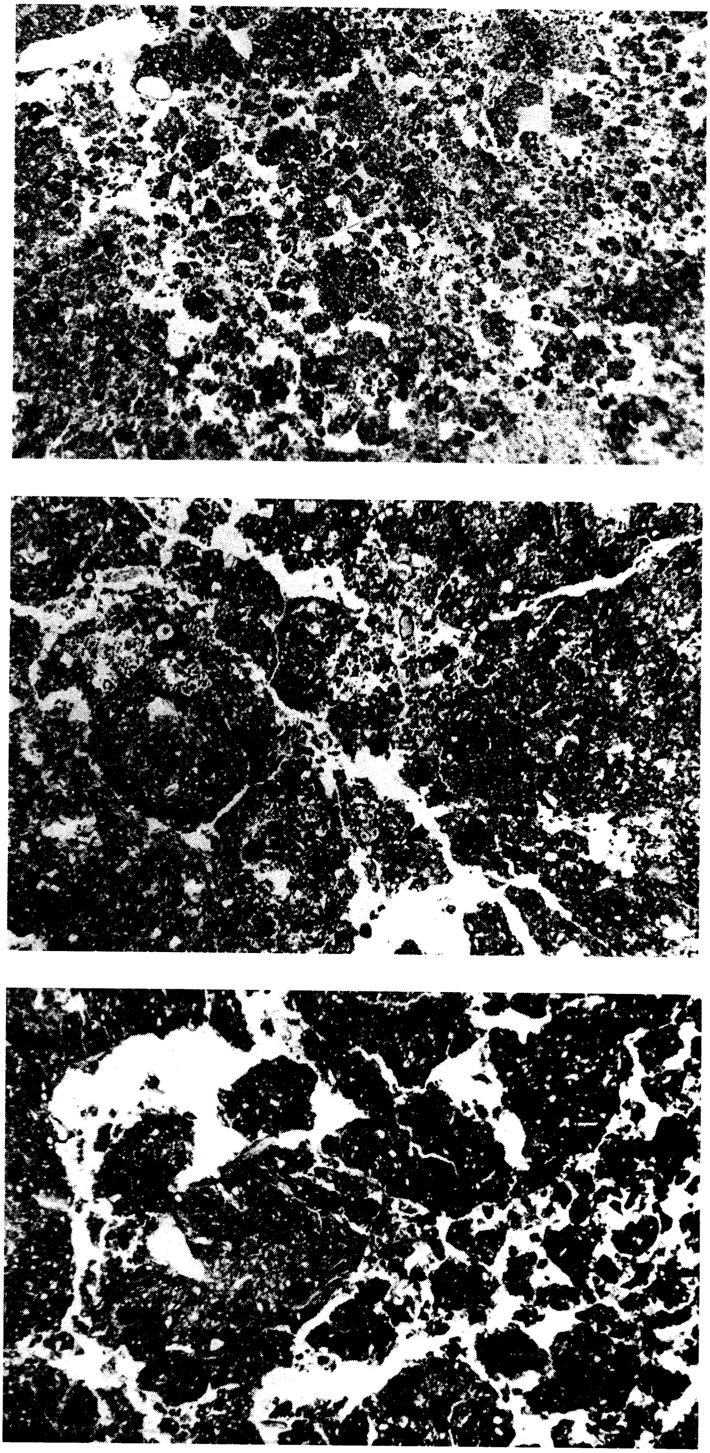

Fig. 16. Microstructure of the topsoils of transect III (Reference above, Austria middle, Hungary below), 4 x magnification, PPL.

microstructure, leading to a more angular structured type in the tillaged areas and to a more crumby structured type in the reference profile. By comparing the mineral contents of the Austrian, Hungarian and reference soils it can be presumed that in Hungary more intensive and deeper tillage practices were used.

The negative effects of cultivation were reflected in an higher bulk density and a decrease of total porosity. A general decrease of aggregate stability with soil depth could be observed at the reference sites (R), this is normally due to differences in root density and microbiological activity. Aggregate stability decreased in Austrian and Hungarian soils as a consequence of tillaging, lower organic carbon content, mostly uncovered soil surface and microbiological activity. The pore size distri-bution showed a stronger decrease of coarse pores (instead of an increase due to tillaging), especially in Hungary, where heavy machines were used. For each horizon it was found that the saturated hydraulic conductivity of the cultivated sites was "normally conductive" or better, so there should be no problem in aeration or water drainage.

By comparing the Austrian, Hungarian and reference sites with respect to the micromorphological results, the occurance of higher biological activity in the A-horizons of the untillaged areas (in all transects), as shown by Rampazzo *et al.* [22], was confirmed, leading to a more crumby structure, whereas in the tillaged soils a subangular, cracky microstructure was developed.

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