Influence of different agricultural landuse on soil properties along the Austrian-Hungarian border

Dedicated to Univ. Prof. Dipl.-Ing. Dr. Dr. h.c. mult. Winfried E. H. Blum, on the occasion of his 60th birthday

N. Rampazzo and A. Mentler

Einfluß unterschiedlicher landwirtschaftlicher Landnutzung auf Bodeneigenschaften entlang der österreichisch-ungarischen Grenze

Herrn o. Univ.-Prof. Dipl.-Ing. Dr. DDDr. h.c. Winfried E. H. Blum zum 60. Geburtstag gewidmet

1. Introduction and definition of the aims

With change of the landuse, alterations of the soil status can be expected. The influence of cultivation on soil properties has been studied by several scientists. EHLERS (1973) compared untillaged and tillaged soils with regard to their total porosity. TISCHLER and ALTERMANN (1992) reported on increased soil microbial activities in green fallows as compared with those of arable soils. Similar conclusions were drawn by SCHLEUS and BLUME (1991) and HEILMANN and BEESE (1991). The effects of different cultivation practices on the soil biology were studied by FRANK and MALKOLMES (1993), KANDELER and MURER (1993), LINN and DORAN (1984), WOLTERS and JOERGENSEN (1992).

After opening of the border between Austria and Hungary and the following 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 to different degradation. Mineralogical, physical, micromorphological, chemical, microbiological and zoological 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, aiming at an evaluation of changes in the soil status (degradation) of the arable fields through different agricultural management.

Zusammenfassung

Österreichische und ungarische landwirtschaftliche Böden (3 Transekte mit unterschiedlichen Bodentypen und Nutzungen) wurden mit früheren unbewirtschafteten Referenzböden des ehemaligen „Eisernen Vorhanges" verglichen. Die maschinelle Bewirtschaftung führte zu Verdichtungseffekten wie höhere Lagerungsdichte, Verlust an Porosität und geringere Aggregatstabilität. Die Referenzböden hatten eine gut entwickelte Krümelstruktur, während die bearbeiteten Böden eine blockig-prismatische Struktur entwickelten. Die bewirtschafteten Böden zeigten einen Verlust an organischer Substanz, an Kationenaustauschkapazität, an Nährelementen, eine Abnahme der mikrobiologischen und zoologischen Aktivität sowie des Wurzelwachstums. Die ungarischen Böden wiesen aufgrund hoher Applikationen an P-Düngemitteln höhere Gehalte an Schwermetallen auf, während auf österreichischer Seite höhere Cd-Gehalte gemessen wurden. Die mikrobiellen Aktivitäten (SIR, Basalrespiration, DRA) zeigten eine hohe positive Korrelation zum Gehalt an organischer Substanz sowie Gesamtstickstoff im Boden. Das Verhältnis Ergosterol/C_{mic} bestätigte die starke Abhängigkeit der pilzlichen Verteilung im Boden vom pH-Wert. Der physiologische Quotient (qCO_2) der Bodenorganismen in den bearbeiteten Böden war stark durch die Zufuhr leicht zersetzbarer organischer Substanz reguliert. Das C_{mic}/C_{org} Verhältnis der Referenzböden zeigte das natürliche Gleichgewicht zwischen Zu- und Abfuhr organischer Substanz. Dieses Gleichgewicht war in den bearbeiteten Böden verändert. Der Effekt unterschiedlicher Bodennutzung auf die Regenwurmpopulation konnte wegen besonderer Trockenheit im Untersuchungszeitraum nicht eindeutig festgestellt werden.

Schlagworte: Bodendegradation, landwirtschaftliche Nutzung, Bodenstruktur, Bodennährstoffe, Bodenbiologie.

Summary

Austrian and Hungarian agricultural soils (3 transects with different soil type and cultivation system) were compared with the former uncultivated "Iron Curtain" reference soils. The compacting effects of cultivation were reflected in the higher bulk density, the decrease of total porosity, soil aggregate stability and of coarse pores. In the uncultivated areas a more crumby structure was observed, whereas in the tilled soils a subangular, cracky microstructure was developed. The cultivated soils showed a decrease of soil organic matter, of CEC_{eff}, a loss of nutrients, a reduced microbial activity, a reduction of root growth and faunal activities in the tillaged horizons. In the Hungarian soil an enhanced content of heavy metals (As, Co, Cr, Cu, Mo, Ni, Sr, Zn) were found due to application of high dosages of P-fertilizers. In Austria a higher Cd-content could be traced. The microbial activities (SIR, basal respiration, DRA) were strongly positive correlated to the amount of soil organic matter and to the N_t content in the soils. The ergosterol/C_{mic}-ratio, showed that the fungal distribution in the soils was mostly influenced by the pH-value. The physiological status (qCO_2) of the soil microorganisms in the arable soils was governed by the input of easily degradable organic materials. The C_{mic}/C_{org}-ratio of the reference soils expressed the natural equilibrium between input and output of organic matter. In the arable soils this equilibrium was disturbed. The effects of different cultivation systems on the earthworm population could not be definitively evaluated because of the very dry conditions during analyses.

Keywords: Soil degradation, agricultural practices, soil structure, soil nutrients, CEC, soil biology.

2. Material and methods

2.1 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 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/sec) cause high evaporation rates up to 700 mm.

The annual mean precipitation reaches 700 mm, 55 % of it occuring during the vegetation period.

2.2 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 figure 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. The crop and management history are shown in table 2. The 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.

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 m 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 m x 10 m, consequently each transect is composed of 3 investigation plots and the samples are designated as shown on table 1.

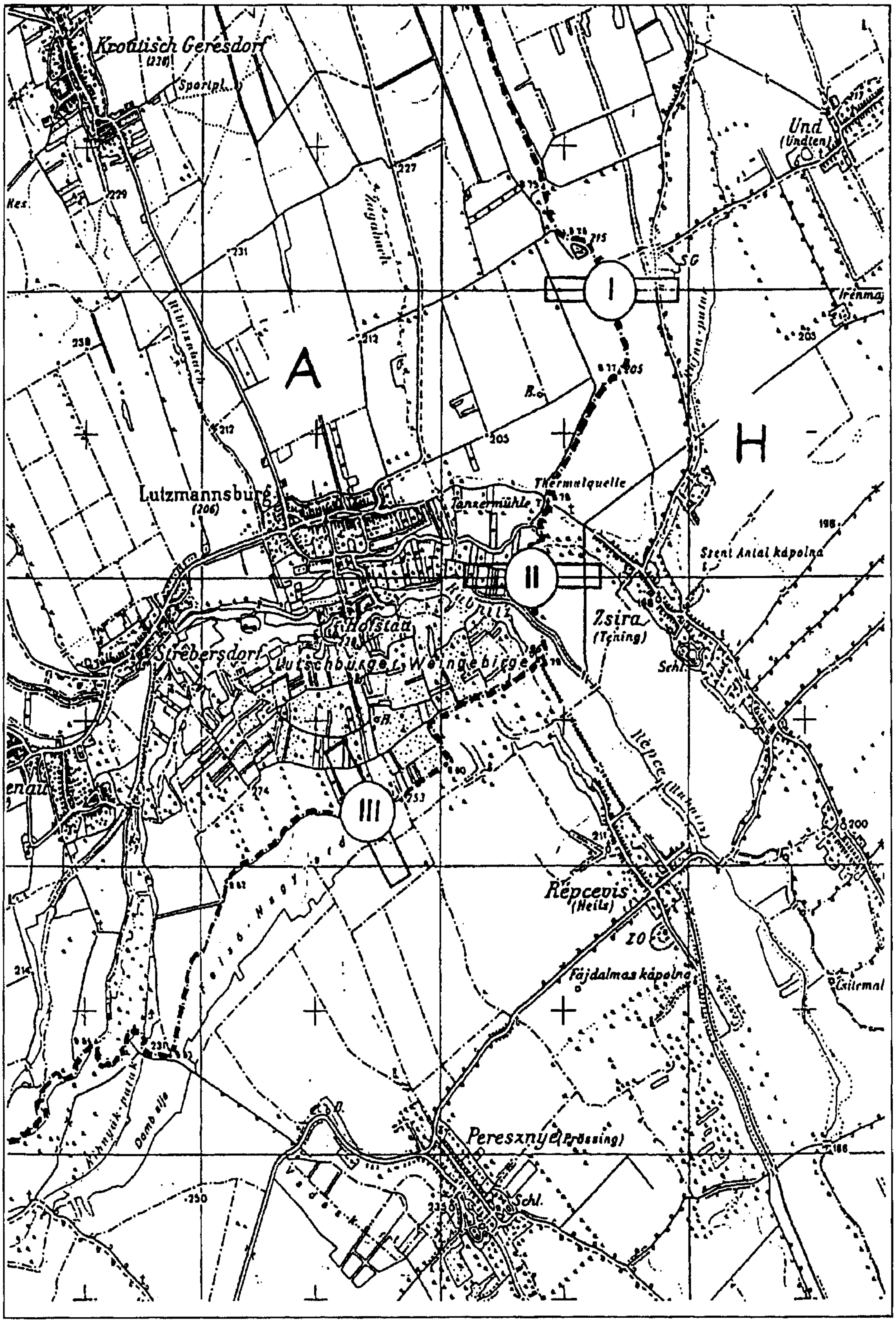

Figure 1: Localisation of the transects (1 : 50000); I = Transect I, II = Transect II, III = Transect III, -------- border line
Abbildung 1: Lageplan der untersuchten Transekte (1 : 50.000); I = Transekt I, II = Transekt II, III = Transekt III, -------- = Staatsgrenze

Table 1: Characterisation of the soil samples among the 3 transects
Tabelle 1: Bezeichnung der Bodenproben in den 3 Transekten

	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, II and III until 1993
Tabelle 2: Fruchtfolge und Bearbeitungsgeschichte der österreichischen und ungarischen Transekte I, II und III

	Year	Crop	Management practices	wintercover
Transect I				
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	sun flower	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	sun flower	conventional	no
	1991/92	winter wheat	conventional	yes
	1992/93	rape	conventional	yes
Transect II				
Austria	till 1983	pasture	no tillage	yes
	1983–1988	peach orchard	no tillage	yes
	1989	green fallow	no tillage	yes
	1990–1993	maize	conventional	no
Hungary	1982/83	winter wheat	conventional	yes
	1983	sun flower	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	sun flower	conventional	no
	1991/92	winter wheat	conventional	yes
	1992/93	rape	conventional	yes
Transect III				
Austria	till 1983	orchard	no tillage	yes
	1983–1988	maize	conventional	no
	1989	sugar peas	conventional	no
	1990/91	winter wheat	conventional	yes
	1991	spring barley	conventional	no
	1992/93	winter wheat	conventional	yes
Hungary	till 1993	Plantage of Robinia pseudoacacia		

Transect I
Latitude 47° 28`45``, longitude 16° 40`10``, 205 m a.s.l., 9° C annual mean temperature, 700 mm annual mean precipitation, plain, no erosion, calcaric loessial deposit.

Transect II
Latitude 47° 27`40``, longitude 16° 39`40``, 197.5 m a.s.l., 9° C annual mean temperature, 700 mm annual mean precipitation, plain, no erosion, alluvial deposit.

Transect III
Latitude 47° 26`45``, longitude 16° 38`10``, 255 m a.s.l., 9° C annual mean temperature, 700 mm annual mean precipitation, plain, no erosion, calcaric loessial deposit.

The classification and description of the soils within the transects were made according to the "*World Reference Base for Soil Resources*" (FAO-ISRIC-ISSS, 1994).

Transect I, profile I/R (Reference), calcaric Cambisol from loessial deposits (June 1993):
Ah (0–30 cm): Brown (10YR/4/3), approximately 10 % gravels, moderate very, fine crumbstructure, silty loam, moderate content of organic matter, weakly acid, no effervescence, strongly rooted, low content of medium debris, clear and straight boundary to:
Bv (30–80 cm): Reddish brownish black (5YR/4/4), approximately 25 % gravel, prismatic structure, loam, low content of organic matter, neutral pH, no effervescence, strongly rooted, moderate content of medium debris, clear and straight boundary to:
BvCv (80–110 cm): Light brown (7,5YR/6/4), approximately 10 % gravel, prismatic structure, loam, no organic matter, neutral pH, weak effervescence, weakly rooted, moderate content of medium debris, clear and straight boundary to:
Cv (110 + cm): Yellowish brown (10YR/5/6), coherent structure, loam, free of humus, alkaline, strong effervescence, no roots, high content of medium debris.

Transect I, profile I/A (Austria), calcaric Cambisol from loessial deposits (June 1993):
Ap (0–20 cm): Brown (10YR/4/3), approx. 5 % gravels moderate very fine crumb structure, silty loam, no effervescence, moderate content of fine roots, plant residues, clear and ondulated boundary to:
Ah (20–32 cm): Brown (7,5YR/4/3), approx. 10 % gravel, angular blocky structure, silty loam, no effervescence, moderate content of fine roots, abrupt and ondulated boundary to:
Bv (32–80 cm): Reddish brown (5YR/4/4), approx. 25% gravel, subangular blocky structure, loam, no effervescence, many very fine roots, clay coatings, clear and ondulated boundary to:
BvCv (80–110 cm): Light brown (7,5YR/6/4), approx. 10 % gravel, subangular blocky structure, loam, slight effervescence, very few very fine roots, clear boundary to:
Cv (110+ cm): Yellowish brown (10YR/5/6), coherent structure, loam, strong effervescence, no roots, high content of medium debris.

Transect I, profile I/H (Hungary), calcaric Cambisol from loessial deposits (June 1993):
Ap (0–21 cm): Brown (10YR/4/3), approx. 5% gravel, moderate very fine crumb structure, loam, no effervescence, few very fine roots, plant residues, clear and ondulated boundary to:
Ah (21–32 cm): Brown (7,5YR/4/3), approx. 10% gravel, coarse angular blocky structure, loam, no effervescence, few very fine roots, abrupt and ondulated boundary to:
Bv (32–82 cm): Reddish brown (5YR/4/4), approx. 25% gravel, subangular blocky structure, loam, no effervescence, many very fine roots, clay coatings, clear and ondulated boundary to:
BvCv (82–130 cm): Light brown (7,5YR/6/4), approx. 10% gravel, subangular blocky structure, loam, slight effervescence, few very fine roots, calcium carbonate coatings, snails, clear boundary to:
Cv (130 + cm): Yellowish brown (10YR/5/6), coherent structure, loam, strong effervescence, no roots, high content of medium debris.

Transect II, profile II/R (Reference), eutric Fluvisol from alluvial deposits (June 1993):
Ah (0–15 cm): Brown (10YR/5/3), crumby structure, silty loam, medium content of organic matter, weakly acid, no effervescence, many very fine and coarse roots, clear and smooth boundary to:
Bv (15–50 cm): Brown (10YR/4/3), weak subangular blocky structure, loamy silt, low content of organic matter, weakly acid to neutral pH, no effervescence, few very fine and common medium roots, organic matter coatings, earth worm casts, few gravels, gradual and ondulated boundary to:
Abur (50–65 cm): Dark grayish brown (10YR/4/2), weak subangular blocky structure, silty loam, medium content of organic matter, weakly acid, no effervescence, few very fine and few coarse roots, gradual and ondulated boundary to:
Bbur (65–95 cm): Dusky red (2,5Y/4/2), weak subangular blocky structure, silty loam, low content of organic matter, weakly acid, no effervescence, few very fine roots and few coarse roots.
Cv (95+ cm): Yellowish brown (10YR/5/6), coherent structure, silty loam, no humus, weakly acid to neutral pH, no effervescence, no roots.

Transect II, profile II/A (Austria), eutric Luvisol from alluvial deposits (June 1993):

Ap (0–18 cm): Brown (10YR/5/3), coarse angular blocky structure, loam, low content of organic matter, weakly acid, no effervescence, many fine and few coarse roots, clear and smooth boundary to:

Bv (18–45 cm): Brown (10YR/4/3), subangular blocky structure, silty loam, medium content of organic matter, weakly acid, no effervescence, many fine roots, organic matter coats, gradual and ondulated boundary to:

Abur (45–60 cm): Dark grayish brown (10YR/4/2), subangular blocky structure, silty loam, medium content of organic matter, weakly acid, no effervescence, few fine roots, few gravels, iron precipitation on peds' surface, gradual and ondulated boundary to:

Bbur (65–97 cm): Dusky red (2,5Y/4/2), medium subangular blocky structure, silty loam, very low content of organic matter, weakly acid, no effervescence, few fine roots, iron coatings, gley mottles.

Cv (97+ cm): Yellowish brown (10YR/5/6), coherent structure, silty loam, no humus, weakly acid to neutral pH, no effervescence, no roots.

Transect II, profile II/H (Hungary), eutric Fluvisol from alluvial deposits (June 1993):

Ap (0–20 cm): Brown (10YR/5/3), coarse angular blocky structure, silty loam, medium content of organic matter, weakly acid, no effervescence, many very fine and few coarse roots, clear and smooth boundary to:

Bv (20–50 cm): Brown (10YR 4/3), medium subangular blocky structure, silty loam, medium content of organic matter, weakly acid, no effervescence, many very fine roots, organic matter coats, gradual and ondulated boundary to:

Abur (50–65 cm): Dark grayish brown (10YR/4/2), medium subangular blocky structure, silty loam, medium content of organic matter, weakly acid, no effervescence, few very fine roots, few gravels, iron precipitation on peds' surface, gradual and ondulated boundary to:

Bbur (65–97 cm): Dusky red (2,5Y/4/2), medium subangular blocky structure, silty loam, low content of organic matter, weakly acid, no effervescence, few very fine roots, iron coatings, gley mottles.

Cv (97+ cm): Yellowish brown (10YR/5/6), coherent structure, silty loam, no humus, weakly acid to neutral pH, no effervescence, no roots.

Transect III, profile III/R (Reference), calcic Luvisol from calcaric loessial deposits (June 1993):

Ah (0–10 cm): Brown (10YR/4/3), fine subangular blocky structure, loamy silt, high content of organic matter, acid, no effervescence, medium and coarse roots, clear and smooth boundary to:

A(E) (10–32 cm): Brown (10YR/5/3), weakly cemented, very fine angular blocky structure, loamy silt, medium content of organic matter, acid, no effervescence, few very fine and few coarse roots, organic matter coatings, clear and smooth boundary to:

Bt (32–48 cm): Brown (7,5YR/4/4), moderate fine angular blocky structure, clay loam, low content of organic matter, acid, no effervescence, few fine and medium roots, organic matter coatings, slightly developed clay coatings, iron precipitation, gradual and smooth boundary to:

BtCv (48–70cm): Dark yellowish brown (10YR/4/4), weak fine angular blocky structure, clay loam, no humus, weakly acid, no effervescence, few very fine and few coarse roots, earthworm casts, organic matter coatings, slightly developed clay coatings, gradual and smooth boundary to:

Cv (70+ cm): Very pale brown (10YR/7/4), coherent hard structure, silty loam, no humus, alkaline pH, strong effervescence, few coarse roots, carbonate coatings, slightly developed clay coatings, organic matter coatings.

Transect III, profile III/A (Austria), calcic Luvisol from calcaric loessial deposits (June 1993):

Ap (0–15 cm): Brown (10YR/4/3), very fine angular blocky structure, loamy silt, low content of organic matter, acid, no effervescence, many very fine roots, gradual and smooth boundary to:

A(E) (15–32 cm): Brown (10YR/5/3), very fine angular blocky structure, loamy silt, low content of organic matter, acid, no effervescence, many very fine roots, abrupt and smooth boundary to:

Bt (32–50 cm): Brown (7,5YR/4/4), fine angular blocky structure, clay loam, no humus, acid, no effervescence, few fine roots, slightly developed clay coatings, abrupt and smooth boundary to:

BtCv (50–80 cm): Dark yellowish brown (10YR/4/4), hard coherent structure, silty loam, no humus, alkaline pH, strong effervescence, carbonate coatings, smooth boundary to:

Cv (80+ cm): Very pale brown (10YR/7/4), coherent hard structure, silty loam, no humus, alkaline pH, strong effervescence, few coarse roots, carbonate coatings, slightly developed clay coatings, organic matter coatings.

Transect III, profile III/H (Hungary), calcic Luvisol from calcaric loessial deposits (June 1993):

Ah (0–18 cm): Brown (10YR/4/3), very fine angular blocky structure, loam, medium content of organic matter, acid, no effervescence, many very fine and many coarse roots, gradual and smooth boundary to:

A(E) (18–30 cm): Brown (10YR/5/3), very fine angular blocky structure, loam, low content of organic matter, acid, no effervescence, many very fine and coarse roots, organic matter coatings, abrupt and smooth boundary to:

Bt (30–49cm): Brown (7,5YR/4/4), fine angular blocky structure, clay loam, no humus, acid, no effervescence, few very fine and coarse roots, organic matter coatings, slightly developed clay coatings, abrupt and smooth boundary to:

BtCv (49–75cm): Dark yellowish brown (10YR/4/4), coherent structure, silty loam, no humus, alkaline pH, strong effervescence, carbonate coatings, smooth boundary to:

Cv (75+ cm): Very pale brown (10YR/7/4), coherent hard structure, silty loam, no humus, alkaline pH, strong effervescence, few coarse roots, carbonate coatings, slightly developed clay coatings, organic matter coatings.

2.3 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 (30 drill points from each plot) from two soil depths (0–15 cm, 15–30 cm) of the Austrian and Hungarian plots.

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 (30 drill points from each plot) from the two soil depths (0–15 cm, 15–30 cm) of the Austrian and Hungarian plots. For the determination of the pore size distribution 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 plots. 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 plots. For the determination of the unsaturated hydraulic conductivity 5 cylinders were taken from each horizon of the reference profiles (R) and from the A-horizon (0–15 cm) of the Austrian and Hungarian plots.

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

Sampling for micromorphological analyses

For the preparation and analyses of soil thin sections, 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 plots.

Sampling for chemical analyses

For the determination of chemical analyses bulk samples were randomly taken (30 drill points from each plot) from two soil depths (0–15 cm, 15–30 cm) of the reference profiles (R) and from the Austrian and Hungarian plots.

Sampling for microbiological analyses

Bulk samples from the A-horizon of each plot were randomly taken (30 drill points from each plot). After sampling and during transportation the soil samples were cooled at 4 °C. In the laboratory the bulk samples were frozen at -20 °C.

Sampling for zoological analyses

8 soil samples were taken from each investigation plot. For each sample a soil spot of 50 x 50 cm and a depth of 30 cm were digged out.

2.4 Analytical methods

Soil mineralogical analyses

- Total mineral content by X-ray diffraction, using Cuka-radiation, according to SCHULTZ (1964).
- Clay mineral content by X-ray diffraction, using Cuka-radiation, according to BRINDLEY and BROWN (1980) and GARCIA and CAMAZANO (1968).
- Na-dithionite-citrate-bicarbonate (DCB) soluble Fe-oxides, according to SCHWERTMANN (1959).
- NH_4-oxalate soluble Fe-oxides according to SCHWERTMANN (1964).
- Na-pyrophosphate soluble, organically bounded Fe-oxides according to HERMANN and GERKE (1992).

Soil physical analyses
- Bulk density (d_B) using 200 cm^3 cylinders.
- Total porosity (TP) calculated from density values.
- Soil aggregate stability (SAS), according to MURER et al. (1993).
- Particle size distribution by wet sieving and sedimentation technique.
- Pore size distribution using pressure chambers according to KLUTE (1986), HARTGE and HORN (1991), HARTGE and HORN (1992).
- Saturated hydraulic conductivity (K_{sat}) according to KLUTE (1986).
- Unsaturated hydraulic conductivity (K_u) using an "Instantaneous Profile Method" according to WIND (1966), PLAGGE (1991).

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 JONGERIUS (1973) and CURLIK (1977).

Soil chemical analyses
Prior to chemical analyses the collected soil samples (0–15 cm, 15–30 cm) were air dried and passed through a 2 mm sieve (fine earth). The chemical data are means of 5 replicates for each soil sample and quoted on an oven-dry basis (105 °C for 24 h). Correlation analysis (Spearman rang correlation) is used to combine the chemical, physical and microbiological data. One way Anova (modified LSD-test) with a significance level 0.05 is used to distinguish differences between the Austrian, Hungarian and Reference fields. The normal distribution of the data is tested with the Kolmogorov-Smirnov Goodness of Fit test.

- pH-value in H_2O and 1 M KCl potentiometrically.
- Electrical conductivity (EC) in a water-saturated extract.
- Organic carbon (C_{org}) content , Tyulin-method, according to SSSA (1996).
- $CaCO_3$ content (Scheibler-method).
- Soluble nitrogen fractions (NH_4^+, NO_3^-, N_{min}) contents, Bremner-method according to SSSA (1965).
- Total nitrogen (N_t) content, regular macro-Kijeldahl-method, according to SSSA (1965).
- Effective cation exchange capacity (CEC_{eff}) and exchangeable Ca, Mg, K, Na, Fe, Al, Mn in unbuffered 0.1 M $BaCl_2$-extract.
- P and K the Ammonium-lactate-extract.
- Heavy metal (As, Co, Cr, Cu, Mo, Ni, Pb, Sr, Zn, Cd) contents in aqua regia-extract.

Soil microbiological analyses
- Microbial nitrogen (N_{mic}) by fumigation-extraction, according to BROOKES et al. (1985), VANCE et al. (1987), JENKINSON and POWLSON (1976).
- Substrate-induced-respiration-rate (SIR) and microbial carbon (C_{mic}) according to HEILMANN and BEESE (1992), JENKINSON and POWLSON (1976), ANDERSON and DOMSCH (1978).
- Basal respiration, according to HEILMANN and BEESE (1992).
- Dimethylsulfoxide-reductase-activity (DRA) according to ALEF and KLEINER (1989).
- Ergosterol content, according to DJAJAKIRANA et al. (1993).
- Metabolic quotient (qCO_2).

Soil zoological analyses (earthworms distribution)
The soil was cut out with a core sampler respectively with a spade and the earthworms picked out by hand on the spot. The worms were counted, taken to the laboratory, their biomass recorded and the species determined according to ZICSI (1967).

3. Results and discussion

3.1 Mineralogical data

The mineralogical data of the investigated soils are shown in table 3, table 4, table 5.

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 3). 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, and organic matter occurs (see table 4 and table 5). The increasing amount of oxalate-soluble Fe (Fe_o) in the cambic horizon also explains the moderate weathering process in this soil (see table 5).

The comparison of the three investigated areas over tran-

Table 3: Semiquantitative primary mineral content in the fine earth of the investigated soils in weight %
Tabelle 3: Semiquantitative Gesamtmineralzusammensetzung im Feinboden der untersuchten Böden in Gew. %

Transect	quartz	chlorite	micas	feldspars	calcite	dolomite
Transect I						
I/R/Ah	74	4	20	2	tr.	tr.
I/R/Bv	75	11	13	1	–	–
I/R/BvCv	81	15	4	tr.	–	–
I/R/Cv	80	17	2	tr.	<1	–
I/A (0–15)	68	10	20	2	tr.	–
I/A/(15–30)	82	16	2	tr.	–	–
I/H/(0–15)	83	14	12	1	–	–
I/H/(15–30)	66	7	24	3	–	–
Transect II						
II/R/Ah	62	11	19	7	<1	–
II/R/Bv	44	24	26	6	–	–
II/R/Abur	63	15	17	5	–	–
II/R/Bbur	82	6	10	2	–	–
II/A/(0–15)	50	17	27	6	–	–
II/A/(15–30)	35	25	30	6	<1	–
II/H/(0–15)	33	35	23	8	<1	–
II/H/(15–30)	50	17	29	4	–	–
Transect III						
III/R/Ah	39	14	37	9	<1	–
III/R/A(E)	85	12	3	tr.	–	–
III/R/Bt	71	19	9	1	–	–
III/R/BtCv	62	16	16	4	<1	<1
III/A/(0–15)	88	10	1.5	0.5	–	–
III/A/(15–30)	87	7	5	1	–	–
III/H/(0–15)	66	14	16	4	–	–
III/H/(15–30)	69	15	12	4	–	–

Table 4: Semiquantitative clay mineral content in the fine earth of the investigated soils in weight %
Tabelle 4: Semiquantitative Tonmineralverteilung im Feinboden der untersuchten Böden in Gew. %

Transect	illite	chlorite	smectite	vermiculite	kaolinite
Transect I					
I/R/Ah	63	14	21	–	2
I/R/Bv	55	13	27	–	5
I/R/BvCv	58	12	26	–	2
I/R/Cv	45	14	39	–	2
I/A/(0–15)	73	14	8	–	5
I/A/(15–30)	80	15	–	–	5
I/H/(0–15)	81	10	–	–	9
I/H/(15–30)	72	10	11	–	7
Transect II					
II/R/Ah	60	20	18	–	2
II/R/Bv	56	13	21	–	10
II/R/Abur	40	14	41	–	5
II/R/Bbur	45	8	43	–	4
II/A/(0–15)	58	12	25	–	5
II/A/(15–30)	42	13	38	–	7
II/H/(0–15)	43	13	40	–	4
II/H/(15–30)	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/BtCv	44	16	36	–	4
III/A/(0–15)	76	11	13	–	–
III/A/(15–30)	72	15	10	–	3
III/H/(0–15)	51	11	38	–	tr.
III/H/(15–30)	64	16	16	–	4

Table 5: Dithionite-(d), oxalate-(o) and pyrophosphate-(p) soluble Fe-oxides of the investigated soils in mg/kg fine earth
Tabelle 5: Dithionit-(d), oxalat-(o) and pyrophosphat-(p) lösliche Fe-Oxyde der untersuchten Böden in mg/kg Feinboden

Transect	Fe_d	Fe_o	Fe_p	Fe_o/Fe_d
Transect I				
I/R/Ah	11080	1290	277	0.12
I/R/Bv	15250	1320	10	0.09
I/R/BvCv	11970	1145	533	0.10
I/A/(0–15)	12560	1400	233	0.11
I/A/(15–30)	12800	1370	237	0.11
I/H/(0–15)	13630	1728	150	0.13
I/H/(15–30)	13990	690	126	0.12
Transect II				
II/R/Ah	10150	3090	596	0.30
II/R/Bv	10660	3760	487	0.35
II/R/Abur	11660	5050	490	0.43
II/R/Bbur	9860	4975	385	0.50
II/A/(0–15)	6390	4550	650	0.71
II/A/(15–30)	11460	4450	634	0.39
II/H/(0–15)	11540	4275	652	0.37
II/H/(15–30)	11560	4200	568	0.36
Transect III				
III/R/Ah	8200	1928	494	0.24
III/R/A(E)	8830	1788	402	0.20
III/R/Bt	14810	1160	213	0.08
III/R/BtCv	10630	825	38	0.08
III/A/(0–15)	8540	2178	412	0.26
III/A/(15–30)	7580	1918	391	0.25
III/H/(0–15)	11840	1468	337	0.12
III/H/(15–30)	11390	1645	278	0.14

sect 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 silicates (see table 3) which could have been caused by deeper tillaging 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 3). The same tendency is given by the distribution of smectite and kaolinite (see table 4). 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), see table 5. Like in transect I, the mineralogical distribution in the tilled horizons of the Hungarian site behaves contrarily as compared with the Austrian and the reference site, as a probably consequence of deep tillage practices of the Hungarian site.

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 7). This process leads to loss of mobile minerals (layer silicates and chlorite) and the relative accumulation of quartz in the eluviated horizon (see table 3), respectively in the accumulation of illite and transport downwards of chlorite and smectite (see table 3). Fe-oxides are also affected by this process and accumulate in the Bt-horizon, as shown in table 5. The formation of a Luvisol 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 meq/kg in the E-horizon and 142 meq/kg in the Bt-horizon) and clay coatings in the Bt-horizon.

3.2 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 6), 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 (1973) indicated a maximum of 1,55 g/cm^3 for bulk density as critical level for plant growth, which is not reached in any horizon of the investigated soils. On the other hand, BECKMANN and ALTEMÜLLER (1989), 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 exception, again, of transect I (I/R/A), as a consequence of their undisturbed development, the higher organic matter and the high developed rooting system. The total porosity of the reference sites (R) (table 6), calculated from density values, shows the decreasing tendency of the total porosity with the depth.

Table 6: Bulk density (dB), total porosity (TP), and soil aggregate stability (SAS) of the investigated soils
Tabelle 6: Lagerungsdichte (dB), Gesamtporenvolumen (TP) und Aggregatstabilität (SAS) der untersuchten Böden

Transect	dB g/cm³	TP vol%	SAS %
Transect I			
I/R/Ah	1.43	46	90
I/R/Bv	1.42	47	78
I/R/BvCv	1.40	47	82
I/R/Cv	not sampled	–	64
I/A/(0–15)	1.27	52	68
I/A/(15–30)	–	–	56
I/H/(0–15)	1.32	50	61
I/H/(15–30)	–	–	60
Transect II			
II/R/Ah	1.06	60	75
II/R/Bv	1.34	49	56
II/R/Abur	1.33	50	53
II/R/Bbur	1.45	45	22
II/A/(0–15)	1.35	57	67
II/A/(15–30)	–	–	64
II/H/(0–15)	1.30	51	56
II/H/(15–30)	–	–	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/BtCv	1.49	44	38
III/A/(0–15)	1.41	47	27
III/A/(15–30)	–	–	33
III/H/(0–15)	1.31	50	76
III/H/(15–30)	–	–	66

Particle size distribution

The particle size distribution of the investigated soils is shown in table 7 and reflects a relativly high soil homogenity between tilled (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 6 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 the most horizons are loams or silty loams, as shown in table 7. The texture class can be used for estimating the productivity of a soil. Loamy soils and silty soils with a middle amount of clay have sufficient aeration and storage capacity for available water if their bulk density is not too high. Moreover, silty soils with less than 17 % clay tend to sludge in the crumb and erode (SCHEFFER and SCHACHTSCHABEL, 1992).

Soil Aggregate Stability (SAS)

The stability of soil aggregates in water is affected by various biotic and abiotic factors and the landuse practices. The concept of the soil aggregate stability reflects many soil structural parameters (BLUM and RAMPAZZO, 1993; RAMPAZZO et al., 1994), but as a result, it is a function of whether the cohesive forces between particles resist the applied disruptive force of water. Table 6 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 (ALEXANDER, 1977). SAS decreases in Austrian and Hungarian soils as a consequence of tilling, lower organic carbon content, mostly uncovered soil surface and microbiological activity. The lower SAS can also be caused by using chemical fertilizers (MURER et al., 1993).

Pore size distribution

Table 8 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 the medium pores. Moreover, the result show that the amount of medium pores in the A-horizons is not distinctly affected by tillage practices and 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 tilled A-horizons (I/H/Ap and I/A/Ap) show a higher content of coarse pores than the reference horizon (I/R/A), 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 out 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.

Table 7: 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)

Tabelle 7: Korngrößenverteilung (Gew.%) und Bodenart der untersuchten Böden. (cS = Grobsand, mS = Mittelsand, fS = Feinsand, cU = Grobschluff, mU = Mittelschluff, fU = Feinschluff, c = Ton).

Transect	cS	mS	fS	ΣS	cU	mU	fU	ΣU	C	texture class
Transect I										
I/R/Ah	2.6	2.6	8.9	14.1	32.9	18.6	3.3	54.8	31.0	uL
I/R/Bv	5.5	3.0	9.2	17.7	31.9	11.2	9.1	52.2	30.1	L
I/R/BvCv	5.4	2.9	10.4	18.8	30.2	8.0	16.5	54.7	26.5	L
I/R/Cv	5.7	4.8	12.8	23.2	20.8	16.5	5.5	42.8	34.0	L
I/A/(0–15)	0.3	2.3	7.0	9.5	34.7	11.2	12.0	57.9	32.5	uL
I/A/(15–30)	1.5	1.9	6.8	10.2	31.0	21.9	6.4	59.3	30.5	uL
I/H/(0–15)	2.7	1.9	7.1	11.7	32.0	11.7	8.5	52.2	36.1	L
I/H/(15–30)	2.3	2.5	6.8	11.6	30.7	19.4	5.7	55.8	32.6	uL
Transect II										
II/R/Ah	0.2	0.9	12.6	13.8	32.0	18.7	7.5	58.2	28.0	uL
II/R/Bv	0.2	1.6	16.9	18.7	40.2	12.7	5.4	58.4	22.9	lU
II/R/Abur	0.1	1.8	14.0	15.9	30.1	15.0	14.0	59.1	25.0	uL
II/R/Bbur	0.5	3.8	20.3	24.6	28.9	14.0	12.0	54.9	20.5	sL
II/A/(0–15)	0.1	1.9	12.8	14.8	23.3	20.3	11.1	54.7	30.5	L
II/A/(15–30)	0.1	1.1	8.7	10.0	24.8	22.0	1.6	58.3	31.7	uL
II/H/(0–15)	0.2	1.2	9.6	11.0	31.3	17.5	8.3	57.1	32.0	uL
II/H/(15–30)	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/BtCv	1.3	3.8	12.9	18.0	31.0	17.5	8.5	57.0	25.0	lU
III/A/(0–15)	0.5	2.4	10.6	13.5	33.3	20.4	8.8	62.5	23.9	lU
III/A/(15–30)	0.4	2.0	11.3	13.7	32.5	20.8	9.2	62.5	23.9	lU
III/H/(0–15)	0.3	2.6	12.0	14.9	34.8	14.0	1.7	50.4	34.7	L
III/H/(15–30)	0.4	2.8	12.3	15.5	31.8	15.8	7.5	55.0	29.5	L

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

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 (HARTGE and HORN, 1991; HARTGE and HORN, 1992). Table 8 shows the K_{sat}-values of the investigated soils in 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 15 repetitions were done for each horizon. Since the saturated hydraulic conductivity is not a normal distributed parameter, it is not correct to calculate its arithmetic average but the geometric average (HARTGE and HORN, 1992), as shown in table 8.

The 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} (HARTGE and HORN, 1992). In the case of the investigated topsoils, the influence of aggregation-induced 'secondary' pores is evident. HARTGE and HORN (1992) found that silty soils show 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. FLÜHLER (1991) shows a classification of water conductivities of soils. The most of the upper horizons are classified as 'overabundant conductive' and the others as 'normally conductive'.

Table 8: Pore size distribution (vol %) and saturated hydraulic conductivity (k_{sat}) of the investigated soils
Tabelle 8: Porenverteilung (Vol. %) und gesättigte hydraulische Leitfähigkeit (k_{sat}) der untersuchten Böden

Transect	coarse pores (> 10 µm)	medium pores (10–0.2 µm)	fine pores (< 0.2 µm)	k_{sat} cm/s
Transect I				
I/R/Ah	11.4	17.6	17.1	7.4×10^{-4}
I/R/Bv	16.0	9.4	21.1	5.1×10^{-4}
I/R/BvCv	13.4	11.8	22.0	$4{,}5 \times 10^{-3}$
I/R/Cv	not sampl.	not sampl.	not sampl.	not sampl.
I/(0–15)	16.3	18.4	17.2	7.2×10^{-3}
I/H/(0–15)	16.3	18.0	16.0	4.6×10^{-3}
Transect II				
II/R/Ah	27.4	19.2	13.4	1.5×10^{-3}
II/R/Bv	21.8	9.8	17.7	5.0×10^{-4}
II/R/Abur	20.3	11.4	18.0	1.7×10^{-3}
II/R/Bbur	14.6	12.9	17.7	4.9×10^{-4}
II/A/(0–15)	25.6	15.0	16.1	2.8×10^{-3}
II/H/(0–15)	19.0	17.0	15.0	1.0×10^{-4}
Transect III				
III/R/Ah	32.2	14.8	11.1	4.1×10^{-3}
III/R/A(E)	18.8	16.1	15.9	2.1×10^{-3}
III/R/Bt	9.2	13.7	21.8	3.3×10^{-3}
III/R/BtCv	12.9	10.7	20.1	5.7×10^{-4}
III/A/(0–15)	15.1	13.4	18.5	3.0×10^{-4}
III/H/(0–15)	17.6	15.2	17.7	6.1×10^{-3}

Unsaturated hydraulic conductivity (K_u)

In figure 2 the curves calculated from conductivity and water tension show that the values of the three top soils in transect I behave almost equal. The similarity of the hydraulic function in transect I is also confirmed by the data of the particle size distribution which are rather equal as well. All three curves show an almost steady course. Between 30–40 hPa and 110–130 hPa the function is decreasing 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 this values are almost equal in the three described horizons.

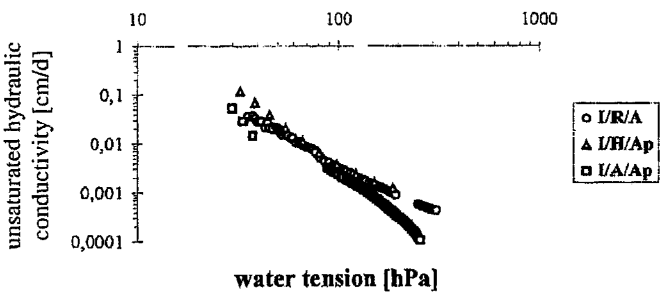

Figure 2: Unsaturated hydraulic conductivity (K_u) of the A-horizons of transect I as a function of the water tension
Abbildung 2: Ungesättigte hydraulische Leitfähigkeit (K_u) der A-Horizonte in Transekt I als Funktion des Matrixpotentials

So it must be caused by a different evaporation conditioned by a different structure.

The curves in figure 3 are less steady as the ones in figure 30. 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 as the other ones.

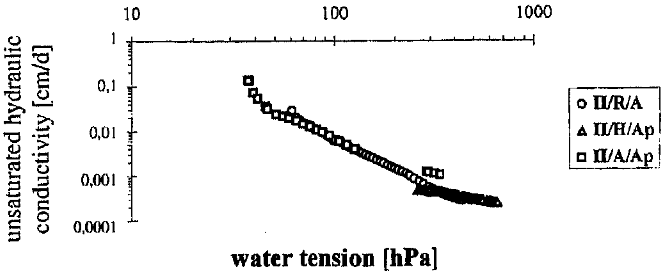

Figure 3: Unsaturated hydraulic conductivity (K_u) of the A-horizons of transect II as a function of the water tension
Abbildung 3: Ungesättigte hydraulische Leitfähigkeit (K_u) der A-Horizonte in Transekt II als Funktion des Matrixpotentials

Figure 4 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). This two curves have the III/R/Ah curve (meadow) in their middle. So no tendency can be observed which would be deduced from the values of conductivity of disturbed horizons. An almost equal decrease of the curves like in the other curves of transect I and II is observed.

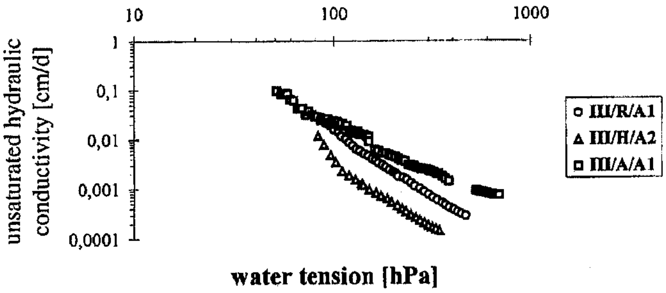

Figure 4: Unsaturated hydraulic conductivity (K_u) of the A-horizons of transect III as a function of the water tension
Abbildung 4: Ungesättigte hydraulische Leitfähigkeit (K_u) der A-Horizonte in Transekt III als Funktion des Matrixpotentials

3.3 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 signes of clay translocation are visible but not enough pronounced to imply a diagnostic "argillic" horizon, see figure 5 and figure 6.

The eutric 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. The 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, see figure 7, 8, 9, 10.

The soil in transect III is confirmed as a Luvisol. This can be proven from the micromorphological features, which show the presence of an "argillic" horizon. The red colour of the clay coatings gives the impression that this is an old

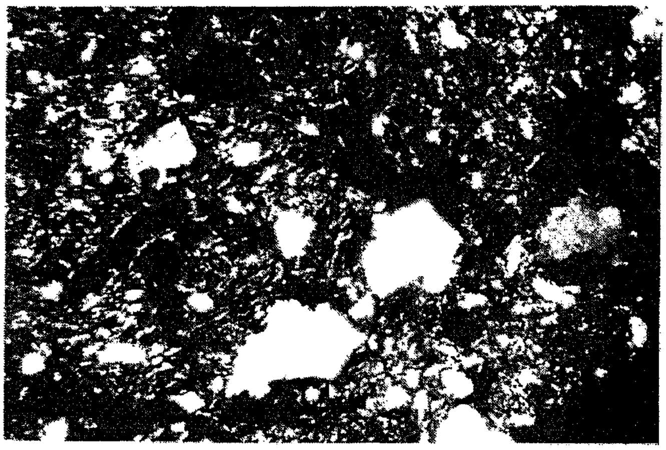

Figure 5: Ca-oxalate crystalls in the pores of the undisturbed A-horizon of transect I, (I/R/A, 0–22 cm, 86 x magnification)
Abbildung 5: Ca-Oxalatkristalle in den Poren des Referenzbodens von Transekt I (A-Horizont, I/R/A, 0–22 cm, 86-fache Vergrößerung)

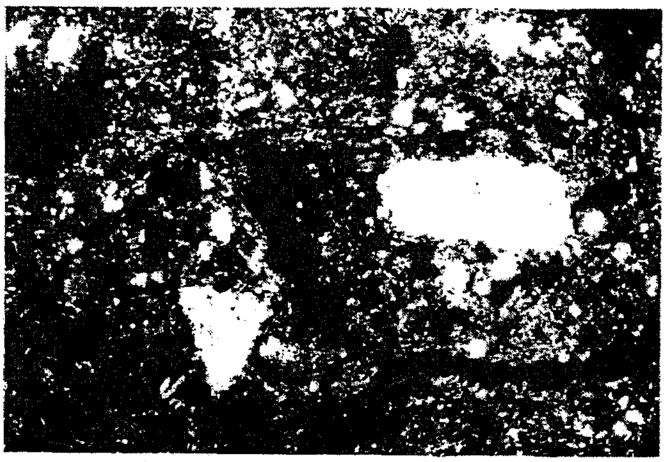

Figure 6: Calcite, partially weathered, in the reference BC-horizon of transect I (I/R/BC, 40–50 cm, 27 x magnification)
Abbildung 6: Angewittertets Kalzit im Referenzboden von Transekt I (I/R/BC, 40–50 cm, 27-fache Vergrößerung)

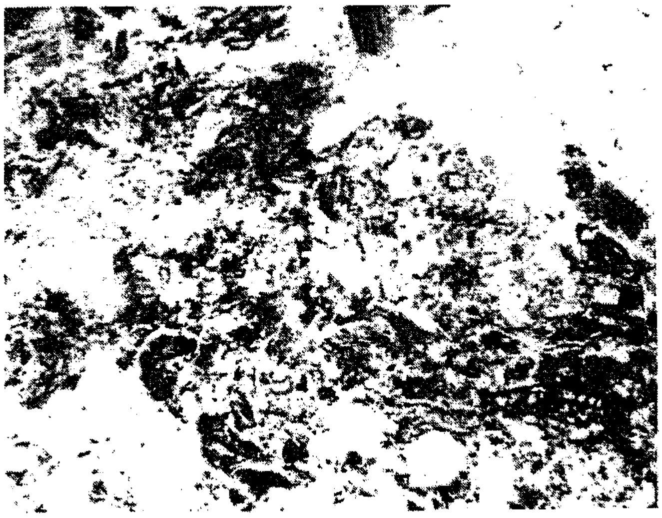

Figure 7: Organic debris in the reference A-horizon of transect I (I/R/A, 0–22 cm, 86 x magnification)
Abbildung 7: Organische Reste im Referenzboden von Transekt I (I/R/A, 0–22 cm, 86-fache Vergrößerung)

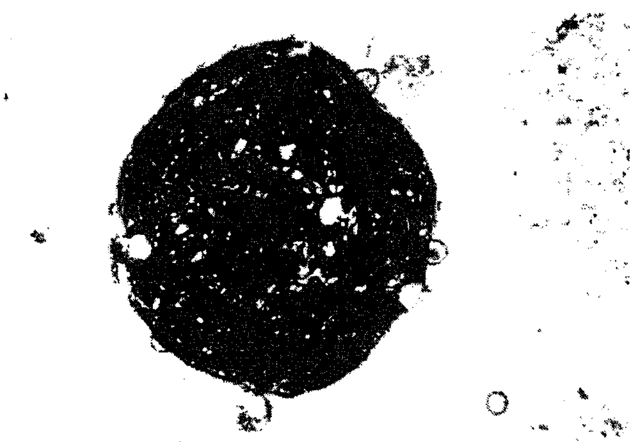

Figure 8: Concentric iron nodules in the reference B-horizon of transect I (I/R/B, 22–40 cm, 27 x magnification)
Abbildung 8: Fe-Konkretionen im Referenzboden von Transekt I (I/R/B, 22–40 cm, 27-fache Vergrößerung)

horizon formed under warm and more humid conditions, see figure 11 and figure 12.

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 main differences in the microstructure, with mostly crumby microstructure in the undisturbed reference soils, whereas the tilled soils tend to form subangular, cracky microstructure, as shown in figures 13, 14, 15.

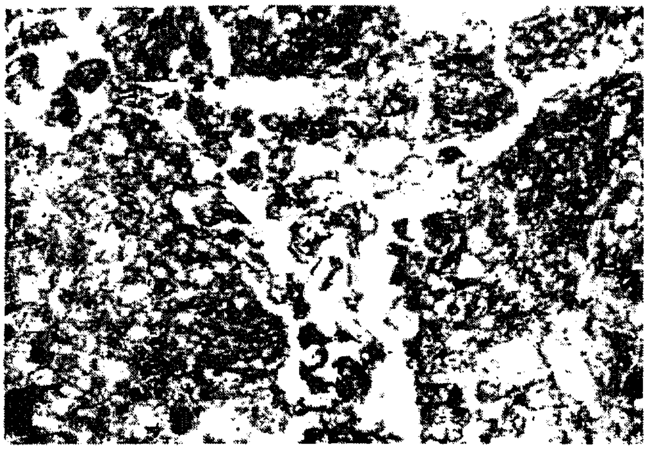

Figure 9: Pedotubes with organic debris and loose excremental infillings in the reference A-horizon of transect II (II/R/A, 0–20 cm, 45 x magnification)

Abbildung 9: Bodenporen mit organischen Resten und Tierexkrementen im Referenzboden von Transekt II (II/R/A, 0–20 cm, 45-fache Vergrößerung

Figure 10: Secondary Fe-mottles in the reference Bb-horizon of transect II (II/R/Bb, 65–95 cm, 27 x magnification)

Abbildung 10: Pedogene Fe-Flecken im Referenzboden von Transekt II (II/R/Bb, 65–95 cm, 27-fache Vergrößerung).

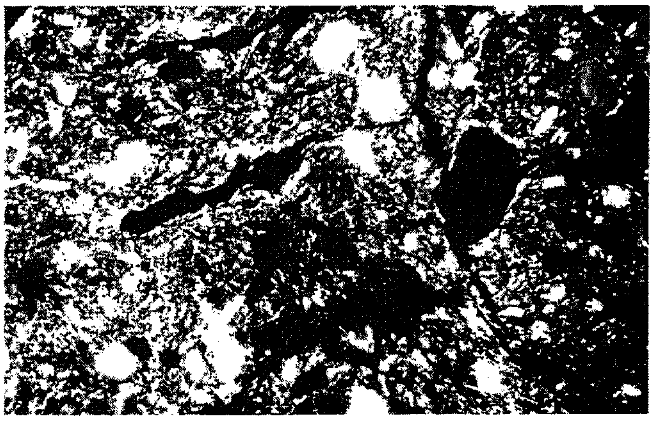

Figure 11: Clay coatings in the reference Bt-horizon of transect III (III/R/Bt, 32–48 cm, 86 x magnification)

Abbildung 11: Toncutane im Referenzboden von Transekt III (III/R/Bt, 32–48 cm, 86-fache Vergrößerung)

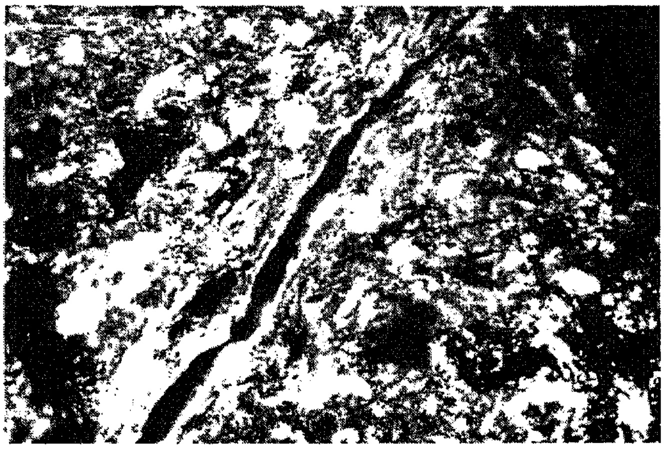

Figure 12: Clay coatings in the reference C-horizon of transect III (III/R/C, 70–95 cm, 170 x magnification)

Abbildung 12: Toncutane im Referenzboden von Transekt III (III/R/C, 70–95 cm, 170-fache Vergrößerung)

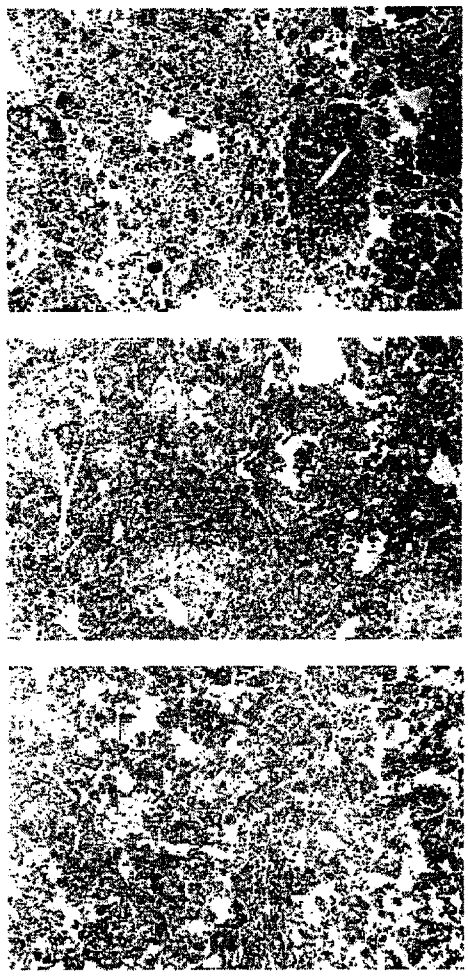

Figure 13: Microstructure of the topsoils of transect I (Reference above, Austria middle, Hungary below, 4 x magnification)

Abbildung 13: Mikrostruktur der Oberböden von Transekt I (oben Referenzboden, mitte österreichischer Boden, unten ungarischer Boden, 4-fache Vergrößerung)

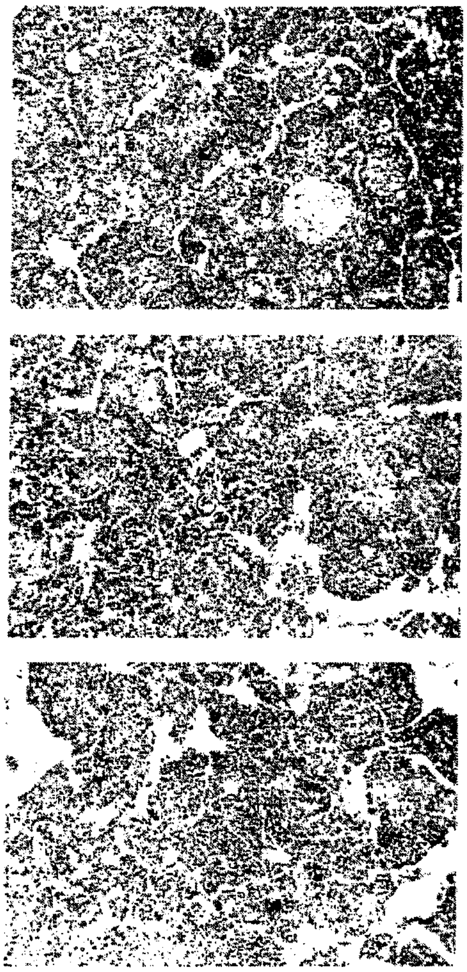

Figure 14: Microstructure of the topsoils of transect II (Reference above, Austria middle, Hungary below, 4 x magnification)
Abbildung 14: Mikrostruktur der Oberböden von Transekt II (oben Referenzboden, mitte österreichischer Boden, unten ungarischer Boden)

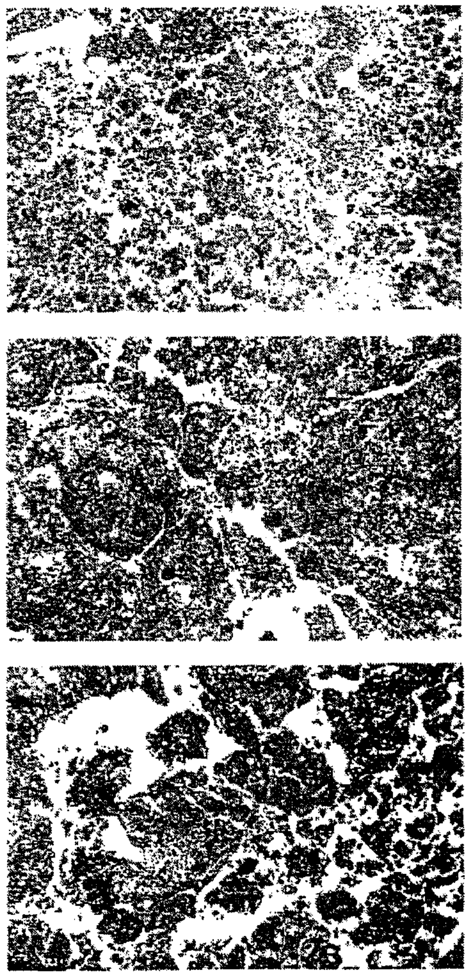

Figure 15: Microstructure of the topsoils of transect III (Reference above, Austria middle, Hungary below, 4 x magnification)
Abbildung 15: Mikrostruktur der Oberböden von Transekt III (oben Referenzboden, mitte österreichischer Boden, unten ungarischer Boden, 4-fache Vergrößerung)

3.4 Chemical data

pH-value
The pH-values of the investigated soils are shown in table 9. The chemical reactions of the studied soils are slightly acidic to neutral and within the transects rather similar. Only field I/H shows higher pH-values due to liming. The pH is positively correlated with the amount of Ca ($BaCl_2$) ($r = 0.8$, $P = 0.05$) and with the cation exchange capacity ($r = 0.75$, $P = 0.02$). The influence of the soil acidity on the physiological properties of the soil microflora is expressed by the negative relationship to the qCO_2 ($r = -0.7$) and the positive relation to the C_{mic}/C_{org} ratio ($r = 0.87$).

Electrical conductivity (EC)
The electrical conductivity represents the amount of soluble salts in the soil. High salt concentrations affect soil microorganisms by reducing their enzymatic activities. The investigated soils are characterized by very low water soluble salt contents, except for plot I/R (15–30 cm) and I/H, which shows slightly enhanced values, see table 9. Thus contamination of the investigated soils with sulphates, chlorides etc. can be excluded.

Organic carbon (C_{org}), soil organic matter (SOM)
Concerning the landuse and soil management the amount of SOM can be raised by e.g. agricultural extensification measures (BEYER et al., 1992), application of organic fertilizers (LEITHOLD, 1992) and crop rotation (SCHEFFER and

Table 9: pH (H_2O and KCl), salt content, electrical conductivity (EC), organic carbon (C_{org}) and soil organic matter (SOM) of the investigated soils

Tabelle 9: pH (H_2O und KCl), Salzgehalt, elektrische Leitfähigkeit (EC), organischer Kohlenstoff (C_{org}) und Humusgehalt (SOM) der untersuchten Böden

Transect	pH H_2O	pH KCl	salt %	EC Ohm/cm	C_{org} %	SOM %	$CaCO_3$ %
Transect I							
I/R/ (0–15cm)	5.9	4.8	<0.02	0.40	1.9	3.3	0.25
I/R/ (15–30cm)	7.0	6.0	0.02	0.47	1.2	2.1	0.42
I/A (0–15cm)	5.6	4.4	<0.02	0.33	1.0	1.7	0.00
I/A (15–30cm)	6.0	4.8	<0.02	0.34	1.0	1.7	0.00
I/H/ (0–15cm)	7.0	6.3	0.03	0.49	1.0	1.7	0.29
I/H (15–30cm)	6.9	6.1	0.02	0.46	1.0	1.7	0.13
Transect II							
II/R/ (0–15cm)	6.2	5.2	<0.02	0.34	2.2	3.7	0.15
II/R/ (15–30cm)	7.1	6.4	0.03	0.47	1.0	1.7	0.89
II/A (0–15cm)	5.8	4.6	<0.02	0.40	0.9	1.6	0.00
II/A (15–30cm)	5.6	4.5	<0.02	0.32	1.3	2.2	0.00
II/H/ (0–15cm)	5.7	4.7	<0.02	0.31	1.7	3.0	0.00
II/H (15–30cm)	5.6	4.7	<0.02	0.27	1.6	2.8	0.00
Transect III							
III/R/ (0–15cm)	5.4	4.4	<0.02	0.27	2.6	4.4	0.13
III/R/ (15–30cm)	5.3	4.0	<0.02	0.20	1.2	2.0	0.13
III/A (0–15cm)	5.0	4.0	<0.02	0.40	1.1	1.8	0.00
III/A (15–30cm)	5.0	3.9	<0.02	0.32	0.9	1.5	0.00
III/H/ (0–15cm)	5.3	4.2	<0.02	0.33	2.0	3.4	0.00
III/H (15–30cm)	5.3	3.9	<0.02	0.27	1.0	1.7	0.00

SCHACHTSCHABEL, 1992). Since within the transects the natural conditions (climate, soil type, relief) for the three sites are the same, changes of C_{org} reflect the effects of various agricultural management practices on the amount of soil organic matter, as shown in table 9. The C_{org} content in the reference soil I/R indicates the natural balance of soil organic matter under undisturbed grassland. The arable soils I/A and I/H, showed a decrease of about 50% of C_{org}, as a consequence of intensive landuse, application of artificial fertilizers and field clearing.

Although the Austrian arable soil II/A was cultivated till 1989 as orchard, 5 years of intensive single-crop farming (maize) caused a decrease of C_{org} from 100 % (= II/R) to 42 % (II/A). The more favourable values of C_{org} in the adjacent Hungarian arable soil (II/H, 79% of the reference) may result from the nourishing effects of crop rotation and from the cultivated crops. Also in transect III the influence of agricultural landuse on the soil organic matter is evident. Within 10 years the decrease in C_{org} of III/A amounts to 58 % as compared with the reference. Correlation analysis of C_{org} with microbiological and soil structural parameters of the investigated soils show a positive correlation with the microbial biomass C_{mic} ($r = 0.76$, $P = 0.01$) and with the soil aggregate stability ($r = 0.6$, $P = 0.01$).

Effective cation exchange capacity (CEC_{eff}) and exchangeable cations

Due to the variable charges of particular soil components, the CEC mainly depends on the soil pH. The CEC determined in the neutral range (pH 7–7.5) of the soil solution represents the potential CEC (CEC_{pot}). The CEC determined at a given soil pH indicates the actual capacity of the soil and is called effective CEC (CEC_{eff}).

The CEC_{eff} and the amount of exchangeable cations of the investigated soils are shown in table 10. The cation saturation in % of the CEC_{eff} and the base saturation are quoted on table 11. The data show that soils have weak acidic characteristics, nevertheless, the exchangeable Fe, Mn and Al contents are neglectable. All soils have sufficient amounts of exchangeable Mg, Ca and little Na. Al in exchangeable form occurs in transect III under forest and arable field.

Comparing the soils of transect I, the Hungarian arable soil I/H (rape) showed the highest and the Austrian arable soil I/A (peas) the lowest CEC_{eff}, in agreement with pH and C_{org} content. Ca-saturation predominated 76 to 87 %. The base saturation was very high (99%). Fe and Al are not exchangeable at this range of soil pH. A comparison of CEC_{eff} between reference and both arable soils in transect II showed, again, a clear correlation with pH and C_{org}, with

Table 10: CEC_{eff} and exchangeable cations of the investigated soils
Tabelle 10: Effektive Kationenaustauschkapazität und austauschbare Kationen in den untersuchten Böden

Transect	CEC_{eff} meq/kg	Ca	Mg	K	Na meq/kg	Fe	Al	Mn
Transect I								
I/R/ (0–15cm)	202.1	162.3	30.3	4.4	0.1	0.00	0.0	4.6
I/R/ (15–30cm)	227.3	194.1	30.0	3.1	2.7	0.00	0.0	2.6
I/A (0–15cm)	157.0	120.6	26.3	3.9	2.2	0.00	0.0	4.1
I/A (15–30cm)	165.5	126.3	26.4	4.4	2.6	0.00	0.0	5.8
I/H/ (0–15cm)	227.5	198.1	22.2	3.8	2.0	0.00	0.0	1.3
I/H (15–30cm)	220.5	189.8	22.7	4.4	1.6	0.00	0.0	1.9
Transect II								
II/R/ (0–15cm)	246.5	193.0	47.0	2.3	2.0	0.00	0.0	2.2
II/R/ (15–30cm)	188.1	145.6	36.1	2.0	2.3	0.00	0.0	2.2
II/A (0–15cm)	213.8	164.6	42.3	2.3	2.6	0.00	0.0	2.0
II/A (15–30cm)	211.1	162.4	41.9	2.3	2.3	0.00	0.0	2.1
II/H/ (0–15cm)	206.2	164.1	33.7	3.4	2.1	0.00	0.0	2.9
II/H (15–30cm)	208.5	166.4	33.7	2.5	2.2	0.02	1.7	3.5
Transect III								
III/R/ (0–15cm)	134.9	99.3	23.4	4.5	1.7	0.04	12.6	4.6
III/R/ (15–30cm)	104.0	75.3	17.2	2.4	1.8	0.02	34.1	3.5
III/A (0–15cm)	76.0	49.2	10.3	6.0	2.5	0.02	44.0	3.0
III/A (15–30cm)	80.7	59.3	10.9	6.3	1.7	0.00	0.0	2.7
III/H/ (0–15cm)	169.3	133.3	25.9	3.4	1.4	0.13	11.0	4.0
III/H (15–30cm)	144.7	11.4	24.4	2.6	1.6	0.02	21.2	2.4

Table 11: Base saturation and saturation of exchangeable cations in % of the CEC_{eff} in the investigated soils
Tabelle 11: Basensättigung und Sättigung an austauschbaren Kationen der untersuchten Böden in % der effektiven Kationenaustauschkapazität

Transect	CEC_{eff} %	Base saturat.	Ca %	Mg %	K %	Na %	Fe %	Al %	Mn %
Transect I									
I/R/ (0–15cm)	100	97.5	80.3	15.0	2.2	0.0	0.0	0.0	2.3
I/R/ (15–30cm)	100	98.9	85.4	11.0	1.4	1.1	0.0	0.0	1.1
I/A (0–15cm)	100	97.4	76.8	16.7	2.5	1.4	0.0	0.0	2.6
I/A (15–30cm)	100	96.5	76.3	16.0	2.6	1.6	0.0	0.0	3.5
I/H/ (0–15cm)	100	99.4	87.1	9.8	1.6	0.9	0.0	0.0	0.6
I/H (15–30cm)	100	99.1	86.1	10.3	2.0	0.7	0.0	0.0	0.9
Transect II									
II/R/ (0–15cm)	100	99.1	78.3	19.1	0.9	0.8	0.0	0.0	0.9
II/R/ (15–30cm)	100	98.8	77.4	19.2	1.0	1.2	0.0	0.0	1.2
II/A (0–15cm)	100	99.1	77.0	19.8	1.1	1.2	0.0	0.0	0.9
II/A (15–30cm)	100	99.0	77.0	19.9	1.1	1.1	0.0	0.0	1.0
II/H/ (0–15cm)	100	98.6	79.6	16.4	1.6	1.0	0.0	0.0	1.4
II/H (15–30cm)	100	98.2	79.8	16.1	1.2	1.1	0.0	0.8	1.7
Transect III									
III/R/ (0–15cm)	100	95.5	73.6	17.4	3.3	1.2	0.0	9.3	3.4
III/R/ (15–30cm)	100	93.0	72.5	16.5	2.3	1.7	0.0	32.8	3.3
III/A (0–15cm)	100	89.5	64.8	13.6	7.9	3.3	0.0	57.9	4.0
III/A (15–30cm)	100	96.7	73.4	13.5	7.7	2.1	0.0	0.0	3.3
III/H/ (0–15cm)	100	96.8	78.7	15.3	2.0	0.8	0.1	6.5	2.4
III/H (15–30cm)	100	96.7	77.0	16.8	1.8	1.1	0.0	14.6	1.6

strong decrease in the arable soils. In transect III the reference forest soil (III/H) showed the highest CEC_{eff}, resulting from the high clay (35%) and C_{org} content. The base saturation was high. The occurance of Fe, Al and increased Mn values are due to the lower pH values of these soils.

Nitrogen, phosphorus and potassium

The inorganic form of nitrogen (N_{min}) constitutes a very small fraction (2–5 %) of the total nitrogen (N_t). The N_{min} forms, however, are available to plants. NH_4^+ and NO_3^- are the main N_{min}-compounds. The available nitrogen in soils undergoes a dynamic cycle. Plant uptake, microbial assimilation, volatilization and leaching easily alter the level of available soil nitrogen. Hence, periodic determination would be necessary to obtain information on the levels and fluctuations of available nitrogen in the soil. The major part of the nitrogen in the soil forms a compound of the soil organic matter. The N_{org}-content can be related to the C_{org}-content and its concentration depends on climate, relief, vegetation and cultivation practices. The quantities of the different nitrogen compounds are listed in table 12.

The different N_{min}-concentrations in the arable soils originate from different fertilization practices as well as from microbial mineralisation of organic nitrogen compounds. The microbiological activity is governed by the climate, vegetation and soil properties and naturally shows seasonal fluctuations. Thus, the amount of N_{min} also alterates during a year. The N_{min}-concentrations of the reference plots reflected the natural level under meadow. In the upper horizon, where microbiological activity is concentrated, the NH_4^+ concentration was higher as compared to the layer 15–30 cm. The NO_3^- content of the upper layer was very low, resulting from root-uptake, denitrification and leaching. With regard to N_{org}, the concentrations of the reference soils and the forest soil (III/H) indicate the N_{org} content under natural conditions and their magnitudes are almost twice as high as found in the arable soils. The loss of N_{org} in soils under agricultural management is evident and can be closely related to the loss of C_{org}. Regarding the vertical N_{org} distribution in the soil, a decrease of N_{org} by almost the half in the deeper horizons of the reference and forest soils is obvious, whereas in the arable soils the differences become indistinct due to plowing.

The amounts of plant available P (P_2O_5) in the investigated soils are listed in table 12. The data showed how the P-content in the soil depends on the fertilization practices. In all arable soils (I/A, I/H, II/A, II/H, III/A) the increased P concentrations can be attributed to fertilizers, whereas the amount of phosphorus in the reference soils (I/R, II/R, III/R) and in the forest soil (III/H) indicates the P-supply under natural conditions. The P (AL)-content of the different soils are classified according to the guidelines of the BMFL (1999), in which the limiting P concentration in arable soils (0–15 cm) is specified with 60 mg P_2O_5 per kg fine earth. All arable soils (I/A, I/H, II/A, II/H and III/A) were sufficiently supplied with P due to fertilization.

Table 12 shows the amount of plant available potassium (K_2O). As the results show, the K-content in the soil depends mainly on the fertilization practices. Particularly in transect II the Austrian soil was sufficiently supplied with K, whereas the Hungarian soil was low in K-supply.

Table 12: Nitrogen fractions (NH_4^+, NO_3^-, N_{org}, N_t) and plant available P_2O_5 and K_2O of the investigated soils
Tabelle 12: Stickstofffraktionen (NH_4^+, NO_3^-, N_{org}, N_t) und planzenverfügbares P_2O_5 und K_2O in den untersuchten Böden

Transect	NH_4^+ mg/kg	NO_3^- mg/kg	N_{org} mg/kg	N_t mg/kg	P_2O_5 mg/kg	K_2O mg/kg
Transect I						
I/R/ (0–15cm)	17.2	6.9	2389	2413	34	246
I/R/ (15–30cm)	6.9	10.3	1596	1613	10	196
I/A (0–15cm)	20.6	10.3	1381	1412	69	241
I/A (15–30cm)	13.7	3.4	1441	1469	69	241
I/H/ (0–15cm)	6.9	3.4	1333	1344	139	221
I/H (15–30cm)	10.3	13.7	1346	1370	174	250
Transect II						
II/R/ (0–15cm)	13.7	3.4	2534	2551	26	133
II/R/ (15–30cm)	0.0	0.0	1198	1198	11	101
II/A (0–15cm)	10.3	13.7	1296	1320	145	322
II/A (15–30cm)	10.3	10.3	1983	2004	25	125
II/H/ (0–15cm)	13.7	6.9	2166	2186	115	175
II/H (15–30cm)	20.6	13.7	2040	2074	87	139
Transect III						
III/R/ (0–15cm)	24.0	6.9	2744	2775	27	263
III/R/ (15–30cm)	13.7	3.4	1309	1326	11	158
III/A (0–15cm)	10.3	13.7	1276	1300	139	294
III/A (15–30cm)	13.7	3.4	1169	1186	131	300
III/H/ (0–15cm)	20.6	13.7	2037	2071	29	206
III/H (15–30cm)	17.2	3.4	1150	1180	1	157

Heavy metals

To evaluate the environmental hazards of heavy metals, the so-called "background concentrations" has to be known. The *"Iron Curtain"* region can serve as a control area for that, because in the past 40–50 years the only source of pollution by heavy metals in the strict border zone was airborne pollution. The results of the aqua regia-fraction give information about the "total" concentration or the "potential hazard" of heavy metals in soils. The amounts found in the investigated soils are listed in table 13.

By comparing the values of the aqua regia fraction (table 13) with the Eikmann/Kloke-limits (EIKMANN and KLOKE, 1993) for arable soils and also compared to the background concentrations of the reference, it could be stated that the As, Co, Cr, Cu, Ni, Sr, and Zn contents of the arable soils were above the "background" concentrations of the reference, but still far below the Eikmann/Kloke-limits. Especially in Hungary the As, Co, Cr, Cu, Ni, Sr and Zn concentrations were enhanced due to the application of fertilizers (Kola-phospate) containing As and Sr as by-minerals and to alloyers, which were used in agricultural machines having an attrition (Cr, Ni, Co, Cu). The concentrations of these elements in the Austrian fields were near the "background" concentrations of the reference soils and referred to the geochemistry of the region. Despite of the lower dosage of P-fertilizers in Austria, the Cd concentration was higher in the Austrian soils than in the Hungarian rape fields. The reason for this was addressed to the higher amount of Cd in the P-fertilizers used in Austria. The highest concentrations of Cd are found in the forest and reference, where the original amount of Cd has remained in the soil due to the absence of plant uptake by the crop (no loss of elements by agricultural products).

3.5 Microbiological data

The microbial activity and biomass fluctuate during a year and change with the successional status of the ecosystem (INSAM, 1990). The amount of the microbial biomass is also influenced by anthropogenical impacts such as agricultural management practices (ANDERSON and DOMSCH, 1989), application of contaminated sewage sludge and atmospheric immissions (particularly near industrial areas). By comparing soils which had developed under identical environmental conditions but under different cultivation the performance of the soil organisms can be related to the cultivation practices.

Microbial biomass nitrogen (N_{mic})

Soil microbial biomass usually comprises about 3 % of the soil organic matter. N_{mic} represents a biomass parameter and fluctuations in N_{mic} reflect environmental impacts on the soil populations (e.g. acid rain, contaminations with heavy metals and pesticides treatments). The N_{mic} pools of the investigated soils are shown in table 14.

Table 13: Heavy metal contents (mg/kg) of the investigated soils in the aqua regia-extract
Tabelle 13: Schwermetallgehalte der untersuchten Böden im Königswasser-Extrakt

Transect	As	Co	Pb	Cu	Zn	Cr	Ni	Sr	Cd
Transect I									
I/R/ (0–15cm)	12.1	11.5	20.3	16.4	77.6	25.9	28.4	10.2	0.46
I/R/ (15–30cm)	11.4	12.2	19.9	15.4	57.1	26.9	29.3	9.1	0.43
I/A (0–15cm)	10.1	13.0	17.2	18.6	61.6	28.1	25.9	9.2	0.37
I/A (15–30cm)	12.7	13.0	20.1	16.2	61.8	28.5	27.3	10.0	0.43
I/H/ (0–15cm)	12.4	13.5	16.9	16.4	66.2	30.4	29.4	20.6	0.38
I/H (15–30cm)	11.7	13.5	17.4	17.4	67.2	29.5	29.4	20.6	0.23
Transect II									
II/R/ (0–15cm)	11.0	10.1	19.2	17.9	76.2	22.9	25.9	16.1	0.52
II/R/ (15–30cm)	10.7	10.0	13.9	16.1	62.9	23.3	25.0	15.7	0.44
II/A (0–15cm)	13.2	10.0	19.5	13.4	51.7	23.2	19.5	7.2	0.33
II/A (15–30cm)	13.3	12.2	17.5	27.6	83.2	29.8	26.7	17.9	0.47
II/H/ (0–15cm)	14.1	12.2	17.8	19.8	85.6	27.2	27.1	22.9	0.28
II/H (15–30cm)	13.8	11.8	17.4	20.3	84.8	29.5	26.9	22.4	0.44
Transect III									
III/R/ (0–15cm)	7.8	9.1	20.5	13.8	58.6	19.8	21.3	7.4	0.51
III/R/ (15–30cm)	8.4	9.5	16.8	12.1	49.2	18.7	21.8	6.4	0.37
III/A (0–15cm)	7.2	9.3	16.3	9.5	49.5	17.8	19.6	7.0	0.38
III/A (15–30cm)	8.2	10.1	17.0	10.2	53.7	21.1	19.0	7.0	0.26
III/H/ (0–15cm)	11.3	11.4	16.6	16.4	64.0	27.1	26.9	8.8	0.38
III/H (15–30cm)	11.7	10.3	16.6	43.7	61.1	24.1	26.3	7.5	0.42

Table 14: Microbial biomass-N (N_{mic}), substrate-induced-respiration-rate (SIR), microbial biomass-C (C_{mic}) and basal respiration rate (BR) in the investigated soils

Tabelle 14: Mikrobieller Biomasse-N (N_{mic}), Substrat-Induzierte-Respirations-Rate (SIR), mikrobieller Biomasse-C (C_{mic}) und Basal Respirations Rate (BR) in den untersuchten Böden

Site	N_{mic} mg/ kg dry mass	SIR $mgCO_2$/ 100g soil x h	C_{mic} $mgCO_2$/ 100g soil	BR μgCO_2/ g dry mass x h
Transect I				
Reference	9.6	2.79	57.22	7.8
Austria	6.8	1.80	37.10	2.6
Hungary	27.2	2.92	47.10	1.6
Transect II				
Reference	18.6	5.74	117.28	8.4
Austria	25.7	2.40	49.32	4.3
Hungary	26.1	3.52	72.11	7.3
Transect III				
Reference	40.3	2.97	60.99	7.8
Austria	23.3	1.41	23.62	2.7
Hungary	50.8	2.41	49.42	6.5

After a multiple range test a significant difference between the reference and the arable soils could be determined only for transect III, in which the reference and forest soil showed twice as high N_{mic} contents as the arable soil.

Substrate induced respiration rate (SIR), and microbial biomass carbon (C_{mic})

The substrate induced respiration (SIR) method is a physiologically-based method. The rate of respiration (= CO_2-production) by the microbial population is measured following the addition of substrate to the soil, but before population growth occurs. The data obtained reflect the potential activity of the microbial population, but are also used to estimate microbial biomass. The results are listed in table 14. The SIR correlated positively with the C_{org} content ($r = 0.76$, $P = 0.02$), with the water content ($r = 0.7$, $P = 0.04$) and with N_t ($r = 0.85$, $P = 0.004$). The respiration rate was negatively correlated with the bulk density ($r = -0.55$). No positive relation could be found with the clay content, in contrast to VAN VEEN et al., (1985), nor to the CEC_{eff}, in contrast to KAISER et al. (1992) and to the pH. The SIR rates were positively correlated with other microbial parameters such as the basal respiration ($r = 0.87$, $P = 0.002$), the DRA ($r = 0.9$, $P = 0.001$) and the ergosterol content ($r = 0.79$, $P = 0.01$). A definite correlation with N_{mic} could only be found in transect III ($r = 0.76$, $P = 0.05$).

Differences between the SIR rates and the C_{mic} data of the arable soils and those of the reference soils were significant. A significant difference could also be determined between the Austrian and Hungarian fields for these parameters. The low values of the Austrian soils reflected their low C_{org} contents, whereas in the Hungarian soils the SIR rates and the C_{org} contents were higher.

Basal respiration

The basal respiration, resulting from decomposition of organic matter, indicates the C-mineralisation rate of the soil and is defined as CO_2-release by the indigenous microbial pool such as bacteria, fungi, algae and protozoa (ANDERSON and DOMSCH, 1989). Under undisturbed conditions the ecological balance between soil organisms and their activity is stabilized. Thus the basal respiration represents the metabolic status of the soil microbial population and is affected by environmental impacts. The basal respiration rates of the investigated soils, which strongly correlated to C_{mic}, are shown in table 14. The basal respiration was positively correlated to the SIR ($r = 0.87$, $P = 0.002$), to DRA ($r = 0.83$, $P = 0.005$), to the C_{org} content ($r= 0.78$, $P = 0.01$) and to the N_t content in the soil ($r = 0.82$, $P = 0.007$).

Dimethylsulfoxid-reductase-activity (DRA)

The system dimethylsulfoxide (DMSO) and dimethylsulfide (DMS) plays an important part in the global sulfur cycle, especially between aquatic and terrestrial ecosystems. DMS is chiefly produced by algae and is highly volatile. In the atmosphere DMS is oxidized to DMSO and gets via precipitation to aquatic and terrestrial systems. The reduction of dimethylsulfoxid (DMSO) to dimethylsulfid (DMS) is a widely occuring metabolic process and takes place in microorganisms, higher plants and animals. As reported by ALEF and KLEINER (1989), among 114 strains of soil microorganisms only 5 strains are not capable of reducing DMSO to DMS. Thus by the DMSO-reduction-method the total microbial acitivity in the soil can be described. The DRA data of the investigated soils are listed in table 15.

The results can be related to other microbiological data. The DRA is positively correlated with the basal respiration rate ($r = 0.8$, $P=0.005$) and with the SIR ($r = 0.9$, $P = 0.001$). A positive relation to N_{mic} was found in transect III ($r = 0.84$, $P = 0.05$). A strong positive relation could be found with the C_{org} content ($r = 0.84$, $P = 0.005$), N_t ($r = 0.8$, $P = 0.01$) and the water content ($r = 0.87$, $P = 0.002$). The DRA in the arable soils could be significantly distinguished from the reference and forest soils (significance level =

Table 15: Dimethylsulfoxid-reductase-activity (DRA), total ergosterol contents and ergosterol/C_{mic}-ratio in the investigated soils
Tabelle 15: Dimethylsulfoxid-Reduktase-Aktivität (DRA), Ergosterol Gesamtgehalte und Ergosterol/C_{mic}-Verhältnis in den untersuchten Böden

Site	DRA ng DMS/g soil x h	Ergosterol µg/g soil	Ergosterol/C_{mic} mg/g
Transect I			
Reference	1578	4.77	0.83
Austria	2394	1.98	0.35
Hungary	1885	1.53	0.33
Transect II			
Reference	609	5.16	0.44
Austria	1083	1.98	0.27
Hungary	663	6.32	0.88
Transect III			
Reference	700	4.99	0.82
Austria	1670	1.40	0.59
Hungary	1703	6.69	1.35

0.05), where activities were about twice as high as in the arable soils, resulting from the higher C_{org} and N_t contents and from the more favourable moisture conditions.

Ergosterol
Ergosterol is used to characterize the fungal distribution in the soil, as ergosterol constitutes the most important sterin of the fungal membrans. The ergosterol/C_{mic} ratio represents a relative measure for the mycological contribution to the soil microflora. The magnitude of fungal biomass to the total microbial biomass depends on specific soil properties. Fungi predominate at a soil pH below 6 and are more tolerant to heavy metals as compared with bacteria. The ergosterol contents found in the investigated soils are listed in table 15. As the quantity of extracted ergosterol depends on the amount of the microbial biomass, the ergosterol contents were related to C_{mic} (table 15).

The ergosterol contents of the investigated soils could be related to other microbiological parameters such as to C_{mic} (r = 0.7, P = 0.04), to the basal respiration (r = 0.65, P = 0.05) and to DRA (r = 0.8, P = 0.01). There was also a positive relation to the C_{org} content (r = 0.66, P = 0.05), to the water content (r = 0.72, P = 0.03) and to the amount of N_t (r = 0.69, P = 0.04).

Significant differences between the ergosterol/C_{mic} ratio of the arable soils and that of the reference soils could be found in transect I and III, whereas in transect II this ratio was highest in the Hungarian soil. The differences between the reference and arable soils result from the input of different ligneous substrates and from different fertilizing practices, influencing the pH. High ergosterol concentration were particularly found in the forest soil of Hungary (III/R).

Eco-physiological parameters
The physiological status of the microorganisms is determined by the nutrient-conditions as well as by factors like soil type, climate and environmental impacts. The qCO_2 and C_{mic}/C_{org} ratio are two parameters, which can be employed to characterize the physiological status of the microbial communities.

Metabolic quotient qCO_2, C_{mic}/C_{org} ratio
The metabolic quotient qCO_2, representing the ratio between the basal respiration and microbial biomass-C, is an eco-physiological parameter and describes the C-turnover. The qCO_2 is the amount of CO_2-C respired per unit C_{mic} in a non-amended soil. The more efficiently the soil microorganisms function, the less C is lost via respiration. This fact plays an important part in the soil C budget (INSAM, 1990). The effect of environmental influences or particularly that of different cropping systems on the microbial pool may be reflected in such qCO_2. The qCO_2 calculated for the investigated soils are listed in table 16.

Table 16: Metabolic quotient (qCO_2) and C_{mic}/C_{org} ratio in the investigated soils
Tabelle 16: Metabolischer Quotient (qCO_2) und C_{mic}/C_{org}-Verhältnis in den untersuchten Böden

Site	qCO_2 mg CO_2-C/mg C_{mic} x h 10^3	C_{mic}/C_{org} mg C_{mic}/g C_{org}
Transect I		
Reference	1.31	84.20
Austria	1.92	37.86
Hungary	0.72	61.43
Transect II		
Reference	1.93	54.42
Austria	2.38	54.40
Hungary	2.76	41.91
Transect III		
Reference	3.47	23.76
Austria	2.52	27.10
Hungary	3.55	25.05

Several works (ANDERSON and DOMSCH, 1990; INSAM et al., 1989) reported that the qCO_2 can be correlated with the number of years the plots were under continuous management. The younger the plots were with respect to a particular management, the higher was the observed qCO_2. Typically, a high qCO_2 is found in arable soils with recent input of easily degradable substrates. This tendency was confirmed for transect I and II. Such substrates induce a microflora composed of mainly r-strategy ecotypes, which usually respire more CO_2 per unit degradable C than K-strategists. K-strategists are prevailing in soils that currently have not received fresh organic matter and have evolved a more complex detritus foodweb (INSAM, 1990). According to ANDERSON and DOMSCH (1990), there is no influence of fertilizers, previous crop cover, soil type, and % clay on the qCO_2.

In contrast to transect I and II, the reference and forest soils in transect III showed very high qCO_2 resulting from moister conditions and accelerated decomposition of organic material. The high input of easily degradable plant litter and the lower pH in the forest and reference soil also contributed to the high qCO_2. The contribution of C_{mic} to the amount of C_{org} in the soil is expressed as the C_{mic}/C_{org} ratio (mg C_{mic}/g C_{org}). The C_{mic}/C_{org} ratio is influenced by climatic conditions, in particular, precipitation and evaporation (INSAM et al., 1989), substrate quantity and quality (HERMANN et al., 1977), agricultural practices such as tillage, cropping sequences, manuring or residue incorporation (CARTER and RENNIE, 1982; JUMA and MCGILL, 1986; DORAN, 1987). Crop rotations usually exhibit a higher C_{mic}/C_{org} ratio than monocultures do. Some investigations (ANDERSON and DOMSCH, 1986; ANDERSON and DOMSCH, 1989) have shown that soils under permanent monoculture have significantly lower amounts of C_{mic} per unit C_{org} (23 mg C_{mic}/g C_{org}) than soils under continuous crop rotations (29 mg C_{mic}/g C_{org}). As the climatic conditions for the investigated fields are the same the effect of agricultural practices on the C_{mic}/C_{org} ratio could be evaluated. The C_{mic}/C_{org} ratio of the investigated soils are listed in table 16. In contrast to INSAM (1990), a high positive correlation between the C_{mic}/C_{org} ratio and the pH of the investigated soils could be reported ($r = 0.87$, $P = 0.002$). Moreover, in contrast to WOLTERS and JOERGENSEN (1992), a positive relationship could be established to the amount of exchangeable Ca ($r = 0.75$, $P = 0.02$) and to the cation exchange capacity ($r = 0.73$, $P = 0.02$).

Transect I

Compared to the reference soil I/R, indicating the natural C_{mic}/C_{org} ratio under pasture, the arable soils show a significant lower ratio resulting from the high input of easily degradable organic matter and hence from the enhanced mobility of organic C. Moreover, the protection of organic matter in aggregates by mineral particles against microbiological decomposition is much lower in arable soils than in undisturbed soils. As other investigations showed, the increased C_{mic}/C_{org} ratio of I/H can be due to the high $CaCO_3$-content and thus higher pH-value compared to I/A.

Transect II

As compared to the adjacent reference soil, the arable soils show similar C_{mic}/C_{org} ratios. The reason for the relatively high ratio can be found in the low C_{org} content of the Ap horizon and the overproportionally high C_{mic}. The yield, maintained by fertilization, is supporting C_{mic} by C supply and making it overproportional when compared with C_{org}.

Transect III

The low C_{mic}/C_{org} ratios in the arable, forest and reference soil result from the low pH of these soils. In these soils acidity influence the C_{mic}-to-C_{org} ratio, allowing decomposition only by microorganisms adapted to acid conditions.

3.6 Zoological data

Earthworms

Earthworms generally prefer soils with nearly neutral pH values and there are few earthworms in acid soils. Earthworms are found in higher abundance in pasture soils than in arable and bare fallow soils, reflecting differences in organic matter input, but in general, their distribution within the soil depends on the soil type, pH, temperature and drought. The previous long dry period before sampling, interrupted only by short rainfalls, did not influence the activity of the earthworms, but as previous studies show (ZICSI, 1967), the earthworms got decimated. At the time of sampling the soil was still very dry in a depth of 20-30 cm, especially in transect III.

The species, abundancy and biomass of the earthworms found in the investigated soils are listet in table 17.

9 different species were found in the investigated soils. 5 of them, *A. caliginosa, A. rosea, A. chlorotica, O. lacteum* and *P. tuberculatus* are mineral species (endogaeic type) and have optional periods of diapause. They predominantly inhabit deeper horizons and are not found on the soil surface. *A. caliginosa, A. rosea, A. chlorotica* and *O. lacteum* are peregrin wide-spread and occur most frequently in arable soils. *A. chlorotica* and *P. tuberculatus* indicate good moisture conditions in the soil. *L. rubellus* mainly lives in the surface organic horizon (epigaeic type) and is not typical for the investigated plots II/R and II/A. This species is generally inhabiting forest soils, thus the investigated biotops may formerly have been covered by forest. *L. rubellus* is a species com-

Table 17: Species, abundancy, diversity and biomass of earthworms in the investigated soils
Tabelle 17: Spezies, Abundanz, Diversität und Biomasse von Regenwürmern in den untersuchten Böden

Species	Transect I			Transect II			Transect III		
	I/R	I/A	I/H	II/R	II/A	II/H	III/R	III/A	III/H
Allolobofora caliginosa	40	14	64	10	10	2	0	0	0
Allolobofora chlorotica	0	0	2	0	0	0	0	0	0
Allolobofora rosea	12	38	66	2	4	6	2	2	0
Fitzingeria pl. Platyura	0	0	0	8	12	0	0	4	2
Fitzingeria pl. Depressa	0	0	0	2	0	0	6	0	0
Lumbricus polyphemus	0	0	0	0	2	2	2	0	2
Lumbricus rubellus	0	0	0	2	6	0	0	0	0
Lumbricus sp. Juv.	2	0	2	0	0	0	0	0	0
Octolasium lacteum	2	0	4	2	14	2	8	0	4
Proctodrilus tuberculatus	0	18	46	0	4	2	0	0	0
Abundancy (I/m^2)	56	70	184	26	52	14	18	6	8
Diversity	0.81	1.15	1.26	1.52	1.78	1.47	1.22	0.64	1.39
Biomass (g/m^2)	25.1	27.9	58.1	29.6	43.0	17.4	17.2	4.5	9.2

mon on the whole European continent. *L. polyphemus, F. p. platyura* and *F. p. depressa* are subsurface species (anecic type), burrow deep holes into the ground and consume plant litter. They represent typical species in lessivated soils of *Querco-Carpinetum*-associations and their propagation is restricted to Central Europe.

A distinct difference of the abundance between the reference and the adjacent arable soil could be determined only for transect III. The differences were based on small figures of individuals and so not very significant, although experiences showed, that the abundance of earthworms in undisturbed biotops (e.g. pasture) is increased compared to that in arable soils (ZICSI, 1967). It seemes possible that the reference soils were not thoroughly wetted by rain before sampling and thus the earthworms still inhabited the deeper horizons and were not seized with the method applied. Regarding the homogenity within transect I the abundance of the reference could be significantly distinguished from the adjacent arable soils. At the time of sampling the arable soils were plowed and covered with a winter crop. The species found in these soils indicated a good water supply. Within transect II and transect III a significant difference could be determined between II/R and II/H and between III/R and III/A. The earthworm populations were influenced by the cultivation practices and by the vegetation form (*Robinia pseudoakacia*). The factors, which show stronger impacts on the worm populations could only be determined by further long-term investigations.

4. 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 aim of the study 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 microstructure, leading to a more angular structured type in the tilled 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 tilling , lower organic carbon content, mostly uncovered soil surface and microbiological activity. The

SSSA (SOIL SCIENCE SOCIETY OF AMERICA) (1965): Methods of Soil Analysis Nr.9, Part 2. American Society of Agronomy, Inc. Madison, Wisconsin, USA, 1162–1170.

SSSA (SOIL SCIENCE SOCIETY OF AMERICA) (1996): Methods of Soil Analysis, Part 3. Chemical Methods, American Society of Agronomy, Inc. Madison, Wisconsin, USA, 1001–1010.

SCHULTZ, L. G. (1964): Quantitative interpretation of mineralogical composition from X-ray and chemical data for the Pierre Shale.- U. S. Geol. Surv. Prof. Pap., 391.c.

SCHWERTMANN, U. (1959): Die fraktionierte Extraktion der freien Eisenoxide in Böden, ihre mineralogischen Formen und ihre Entstehungsweisen. Z. Pflanzenernähr. Bodenkd., 84, 194–204.

SCHWERTMANN, U. (1964): Differenzierung der Eisenoxide des Bodens durch Extraktion mit Ammoniumoxalat-Lösung. Z. Pflanzenernähr. Bodenkd., 105, 194–201.

TISCHLER, S. und M. ALTERMANN (1992): Veränderungen der mikrobiologischen Aktivität durch Wechsel der Bodennutzung – Ergebnisse aus dem ehemaligen Grenzstreifen. VDLUFA Schriftenreihe 35, 559–566.

VANCE, E., P. C. BROOKES and D. S. JENKINSON (1987): An extraction method for measuring soil microbial biomass C. Soil Biology and Biochemstry, 19, 697–702.

VAN VEEN, J. A., J. N. LADD and M. AMATO (1985): Turnover of carbon and nitrogen through the microbial biomass in a sandy loam and a clay soil incubated with ^{14}C glucose and $^{15}N(NH_4)_2SO_4$ under different moisture regimes. Soil Biology and Biochemistry, 17, 747–756.

WIND, G. P. (1966): Capillary conductivity data estimated by a simple method. Proc. UNESCO/IASH Symp. Water in the unsaturated zone, Wageningen, The Netherlands, 181–191.

WOLTERS, V. und R. G. JOERGENSEN (1992): Die mikrobielle Biomasse in Böden der Sukzessionsreihe Acker, Brache, Wald. VDLUFA Schriftenreihe, 35, 883–886.

ZICSI, A. (1967): Die Auswirkung von Bodenbearbeitungsverfahren auf Zustand und Besatzdichte von einheimischen Regenwürmern. In: O. GRAFF, J. E. SATCHELL (Eds.): Progress in soil biology. Vieweg und Sohn, Braunschweig, North-Holland Publishing Company, Amsterdam, 290–298.

Address of authors

Univ. Prof. Dr. Nicola Rampazzo, Dr. Axel Mentler, Institut für Bodenforschung, Universität für Bodenkultur, Gregor-Mendel-Straße 33, A-1180 Wien; e-mail: h310t8@edv1.boku.ac.at

Eingelangt am 30. Oktober 2000
Angenommen am 12. Februar 2001