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

PART II. SOIL CHEMICAL, MICROBIOLOGICAL AND ZOOLOGICAL PARAMETERS

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Abstract. The aim of this study was to assess the influence of different long-term agricultural practices on chemical, microbiological and zoological soil parameters along the Austrian-Hungarian border, where 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 pH-values of the studied soils were slightly acidic to neutral and within each transect similar, except for transect I, where the Hungarian site I/H showed higher pH-values due to liming practices. 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 trace elements (As, Co, Cr, Cu, Mo, Ni, Sr, Zn) were found due to application of high dosages of P-fertilizers and to alloyers used in agricultural machines. In Austria a higher Cd-content could be traced. Comparing the nutrient status (N, P, K) of the investigated soils, the effects of different fertilization practices and different agricultural utilization along the transects could be evaluated. 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, whereas the microbial biomass-N seemed not to be effected by different arable cultivation systems. 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 nutrients, CEC, soil biology, agricultural practices

INTRODUCTION

With the change of the landuse, alterations of the environmental equilibrium in soils can be expected. The influence of cultivation on soil properties has been studied by several scientists. Tischler and Alterrmann [31] reported increased soil microbial activities in green fallows as compared with that in arable soils. Similar conclusions were drawn by Heimann and Beese [14] and Schleuss and Blume [27]. The effects of different cultivation practices on soil biology were studied by Frank and Malkolmes [13], Kandeler and Murer [22], Linn and Doran [24] and Tischler and Altermann [31].

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. 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.

MATERIAL AND METHODS

A general geomorphological, climatic and historical description of the investigated sites and soil profiles is given by Rampazzo *et al.* [25].

Soil sampling

Soil sampling for chemical analyses

Soil bulk samples from two layers (0-15 cm and 15-30 cm) were randomly taken from each plot.

Soil sampling for microbiological analyses

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

Soil 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 dug out.

Analytical methods

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) were used to combine the chemical, physical and microbiological data. One way ANOVA (modified LSD-test) with a significance level 0.05 were used to distinguish differences between the Austrian, Hungarian and Reference fields. The normal distribution of the data was tested with the Kolmogorov-Smirnov Goodness of Fit-test.

Soil chemical analyses

- 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 [30].
- $CaCO_3$ content (Scheibler-method).
- Soluble nitrogen fractions (NH_4^+ , NO_3^- , N_{min}) contents, Bremner-method according to SSSA [28].
- Total nitrogen (N_t) content, regular macro-Kjeldahl-method, according to SSSA [29].
- 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.
- Trace element (As, B, Co, Cr, Cu, Mo, Ni, Pb, Sr, Zn) contents in aqua regia-extract.

Soil microbiological analyses

- Microbial nitrogen (N_{mic}) by fumigation-extraction, according to Brookes [8], Jenkinson and Powison [19] and Vance *et al.* [33].
- Substrate-induced-respiration-rate (SIR) and microbial carbon (C_{mic}) according to Anderson and Domsch [2], Heilmann and Beese [15] and Jenkinson and Powison [19].
- Basal respiration, according to Heilmann and Beese [15].
- Dimethylsulfoxide-reductase-activity (DRA) according to Alef and Kleiner [1].
- Ergosterol content, according to Djajakirana [10].
- Metabolic quotient ($q\ CO_2$).

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.

RESULTS AND DISCUSSION

Chemical data

pH-value

The pH-values of the investigated soils are shown on Table 1. The chemical reactions of

Table 1. pH (H_2O and KCl), salt content, electrical conductivity (EC), C_{org} and soil organic matter (SOM) of the investigated soils

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

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 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 $q\,CO_2$ (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 1. Thus contamination of the investigated soils with sulphates, chlorides etc. can be excluded.

Organic carbon (C_{org}), soil organic matter (SOM)

Concerning the cultural management practices the amount of SOM can be raised by, e.g., agricultural extensification measures [7], application of organic fertilizers [23] and crop rotation [26]. 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 on Table 1.

Transect I

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.

Transect II

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 type of plants.

Transect III

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

Correlation analysis with microbiological and soil structural parameters [25] 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 2. The cation saturation in % of the CEC_{eff} and the base saturation are quoted in Table 3. The data show that soils have weak acidic characteristics, nevertheless, the exchangeable Fe, Mn and Al content is negliable. 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.

Transect I

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.

Transect II

A comparison of CEC_{eff} between the reference and both arable soils showed, again, a clear correlation with pH and C_{org}, with a strong decrease of CEC_{eff} in the arable soils.

Transect III

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 turns in a dynamic status. 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 4.

The different N_{min}-concentrations in the arable soils come 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 references reflected the natural level under meadow. In the

Table 2. CEC$_{eff}$ and exchangeable cations of the investigated soils in meq/kg

Transect	CEC$_{eff}$	Ca	Mg	K	Na	Fe	Al	Mn
Transect I								
I/R/ (0-15 cm)	202.1	162.3	30.3	4.4	0.1	0.00	0.0	4.6
I/R/ (15-30 cm)	227.3	194.1	30.3	3.1	2.7	0.00	0.0	2.6
I/A (0-15 cm)	157.0	120.6	26.3	3.9	2.2	0.00	0.0	4.1
I/A (15-30 cm)	165.5	126.3	26.4	4.4	2.6	0.00	0.0	5.8
I/H/ (0-15 cm)	227.5	198.1	22.2	3.8	2.0	0.00	0.0	1.3
I/H (15-30 cm)	220.5	189.8	22.7	4.4	1.6	0.00	0.0	1.9
Transect II								
II/R/ (0-15 cm)	246.5	193.0	47.0	2.3	2.0	0.00	0.0	2.2
II/R/ (15-30 cm)	188.1	145.0	36.1	2.0	2.3	0.00	0.0	2.2
II/A (0-15 cm)	213.8	164.6	42.3	2.3	2.6	0.00	0.0	2.0
II/A (15-30 cm)	211.1	162.4	41.9	2.3	2.3	0.00	0.0	2.1
II/H/ (0-15 cm)	206.2	164.1	33.7	3.4	2.1	0.00	0.0	2.9
II/H (15-30 cm)	208.5	166.4	33.7	2.5	2.2	0.02	1.7	3.5
Transect III								
III/R/ (0-15 cm)	134.9	99.3	23.4	4.5	1.7	0.04	12.6	4.6
III/R/ (15-30 cm)	104.0	75.3	17.2	2.4	1.8	0.02	34.1	3.5
III/A (0-15 cm)	76.0	49.2	10.3	6.0	2.5	0.02	44.0	3.0
III/A (15-30 cm)	80.7	59.3	10.9	6.3	1.7	0.00	0.0	2.7
III/H/ (0-15 cm)	169.3	133.3	25.9	3.4	1.4	0.13	11.0	4.0
III/H (15-30 cm)	144.7	11.4	24.4	2.6	1.6	0.02	21.2	2.4

Table 3. Base saturation and saturation of exchangeable cations in % of the CEC$_{eff}$ in the investigated soils

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

upper horizon, where microbiological activity is concentrated, the NH_4^+ concentration was hightened 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

Table 4. Nitrogen fractions (NH_4^+ , NO_3^- , N_{org}, N_t) and plant available P_2O_5 and K_2O of the investigated soils

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

related to the loss of C_{org}. Regarding the vertical N_{org} distribution in the soil, a decrease of N_{org} by almost 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 4. 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) indicate the P-supply under natural conditions. The P (AL)-content of the different soils are classified according to the guidelines of the Austrian Ministry for Agriculture and Forestry (1991), 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 4 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 filled up with K, whereas the Hungarian soil was low in K-supply.

Trace elements

The determined trace elements are As, B, Co, Pb, Cu, Zn, Cr, Ni, Sr, Cd. To evaluate the environmental hazards of trace elements, 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 trace elements 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 the given trace elements in the soil. The amounts of trace elements, found in the investigated soils, are listed on Table 5.

By comparing the values of the aqua regia fraction (Table 5) with the Eikmann/Kloke-limits [12] for arable soils and also compared to

Table 5. Trace element contents (mg/kg) in the aqua regia-extract in the investigated soils

Transect	As	B	Co	Pb	Cu	Zn	Cr	Ni	Sr	Cd
Transect I										
I/R/ (0-15 cm)	12.1	2.2	11.5	20.3	16.4	77.6	25.9	28.4	10.2	0.46
I/R/ (15-30 cm)	11.4	2.6	12.2	19.9	15.4	57.1	26.9	29.3	9.1	0.43
I/A (0-15 cm)	10.1	2.7	13.0	17.2	18.6	61.6	28.1	25.9	9.2	0.37
I/A (15-30 cm)	12.7	3.0	13.0	20.1	16.2	61.8	28.5	27.3	10.0	0.43
I/H/ (0-15 cm)	12.4	2.7	13.5	16.9	16.4	66.2	30.4	29.4	20.6	0.38
I/H (15-30 cm)	11.7	2.6	13.5	17.4	17.4	67.2	29.5	29.4	20.6	0.23
Transect II										
II/R/ (0-15 cm)	11.0	1.4	10.1	19.2	17.9	76.2	22.9	25.9	16.1	0.52
II/R/ (15-30 cm)	10.7	0.8	10.0	13.9	16.1	62.9	23.3	25.0	15.7	0.44
II/A (0-15 cm)	13.2	1.4	10.0	19.5	13.4	51.7	23.2	19.5	7.2	0.33
II/A (15-30 cm)	13.3	0.7	12.2	17.5	27.6	83.2	29.8	26.7	17.9	0.47
II/H/ (0-15 cm)	14.1	1.0	12.2	17.8	19.8	85.6	27.2	27.1	22.9	0.28
II/H (15-30 cm)	13.8	1.0	11.8	17.4	20.3	84.8	29.5	26.9	22.4	0.44
Transect III										
III/R/ (0-15 cm)	7.8	1.8	9.1	20.5	13.8	58.6	19.8	21.3	7.4	0.51
III/R/ (15-30 cm)	8.4	1.2	9.5	16.8	12.1	49.2	18.7	21.8	6.4	0.37
III/A (0-15 cm)	7.2	1.3	9.3	16.3	9.5	49.5	17.8	19.6	7.0	0.38
III/A (15-30 cm)	8.2	1.4	10.1	17.0	10.2	53.7	21.1	19.0	7.0	0.26
III/H/ (0-15 cm)	11.3	2.6	11.4	16.6	16.4	64.0	27.1	26.9	8.8	0.38
III/H (15-30 cm)	11.7	1.4	10.3	16.6	43.7	61.1	24.1	26.3	7.5	0.42

the background concentrations of the reference, it could be stated that the As, B, 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. In spite 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).

Microbiological data

The microbial activity and biomass fluctuate during a year and change with the successional status of the ecosystem [17]. The amount of the microbial biomass is also influenced by anthropogenical impacts such as agricultural management practices [4], application of contaminated sewage sludge and atmospheric emmissions (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 6.

After a multiple range test a significant difference between the reference and the arable

Table 6. Microbial biomass-N (N_{mic}), substrate-induced-respiration-rate (SIR), microbial biomass-C (C_{mic}) and basal respiration rate (BR) in the investigated soils

Site	N_{mic} (mg/kg dry mass)	SIR (mgCO$_2$/100 g soil h)	C_{mic} (mg CO$_2$/100 g soil)	BR (µg CO$_2$/g dry mass 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

soils could be determined only for transect III, in which the reference and forest soil showed twice as high N_{mic} contents as in 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 6.

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 to the clay content, in contrast to Van Veen *et al.* [32], nor to the CEC$_{eff}$, in contrast to Kaiser *et al.* [21] and to the pH. The SIR rates were positively correlated with other microbial parameters such as with the basal respiration ($r = 0.87$, $P = 0.002$), with the DRA ($r = 0.9$, $P = 0.001$) and with 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 respectively 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. The low data 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 [4]. 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 6.

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 enters, via precipitation, 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 [1] 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 7.

The results can be related to other microbiological data. The DRA 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 to the C_{org} content (r=0.84, P=0.005), to N_t (r=0.8, P=0.01) and to 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 = 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 membranes. The ergosterol/Cmic ratio represents a relative measure for the mycological contribution in 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 of heavy metals as compared with bacteria. The ergosterol contents found in the investigated soils are listed on Table 7. As the quantity of extracted ergosterol depends on the amount of the microbial biomass, the ergosterol contents are related to Cmic and the resulting ergosterol/C_{mic} ratios are also listed in Table 7.

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

Table 7. Dimethylsulfoxid-reductase-activity (DRA), absolute ergosterol contents and ergosterol/C_{mic}-ratio in the investigated soils

Site	DRA (µg DMS/g soil 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

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 $q\,CO_2$ and C_{mic}/C_{org} ratio are two parameters, which can be employed to characterize the physiological status of the microbial communities.

Metabolic quotient q CO_2, C_{mic}/C_{org} ratio

The metabolic quotient $q\,CO_2$ is an ecophysiological parameter and describes the C-turnover. The $q\,CO_2$ 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 [17]. Thus, the metabolic quotient represents the ratio between the basal respiration and microbial biomass-C and is expressed as:

$$qCO_2 = \mathrm{mg}CO_2 - C g^{-1} C_{\mathrm{mic}}\, \mathrm{h}^{-1} . \quad (1)$$

The effect of environmental influences or particularly that of different cropping systems on the microbial pool may be reflected in such $q\,CO_2$. The $q\,CO_2$ calculated for the investigated soils are listed in Table 8.

Table 8. Metabolic quotient ($q\,CO_2$) and C_{mic}/C_{org} ratio in the investigated soils

Site	$q\,CO_2$ mg CO_2-C/mg C_{mic} 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 workers [6,18] reported, that the $q\,CO_2$ 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 $q\,CO_2$. Typically, a high $q\,CO_2$ is found in arable soils with recent input of easily degradable substrates. This tendency was confirmed for transects 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 [17]. According to Andersen and Domsch [6] there is no influence of fertilizers, previous crop cover, soil type, and % clay on the $q\,CO_2$.

In contrast to transects I and II, the reference and forest soils in transect III showed very high $q\,CO_2$ resulting from moisture 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 $q\,CO_2$. The magnitude 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 [18], substrate quantity and quality [16], agricultural practices such as tillage, cropping sequences, manuring or residue incorporation [9,11,20].

Crop rotations usually exhibit a higher C_{mic}/C_{org} ratio than monocultures do. Recent investigations [4,5] show 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 8. In contrast to Insam [17] 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).

Also, in contrast to Wolters and Joergensen [34], 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 [17], 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 with the adjacent reference soil, the arable soils show similar C_{mic}/C_{org} ratio. The reason for the relatively high ratio can be found in the low C_{org} content of the Ap horizon and the overproportional 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 deep 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.

Zoological data

Earthworms

Earthworms generally prefer soils with near neutral pH values and there are few earthworms in acid soils. Earthworms are found in higher abundancy 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 [35], show the abundancy of the earthworms got decimated. At the time of sampling the soil was still very dry to 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 9.

Nine different species were found in the investigated soils. Five 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. r*ubellus mainly lives in the surface organic horizon (epigaeic type) and are not typical for the investigated plots II/R and II/A. This species generally inhabit forest soils, thus the investigated biotops may formerly have been covered with forest. *L. rubellus* is a common species the total European continent. L. *polyphemus*, *F.p. platyura* and *F.p. depressa* are subsurface species (anecic type), that 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 abundancy 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 are not very significant, though experience shows, that the abundancy of earthworms in undisturbed biotops (e.g., pasture) is increased compared to that in arable soils [35]. It seemed possible that the reference soils were not thoroughly wetted by the rain and thus the earthworms still inhabited the deeper horizons and thus were not seized with the method applied.

Regarding the homogenity within transect I the abundancy of the reference could be significantly

Table 9. Species, abundancy, diversity and biomass of earthworms in the investigated soils

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. Platyura	0	0	0	2	0	0	6	0	0
Fitzingeria pl. Depressa	0	0	0	0	2	2	2	0	2
Lumbricus rubellus	0	0	0	2	0	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

distinguished from the adjacent arable soils. At the time of sampling the arable soils were ploughed 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 factor, which shows stronger effects on the worm populations could only be determined by further long-term investigations.

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.

This study was a unique opportunity to evaluate the influence of long-term agricultural practices on the soil components. The results showed, in general, a modification of the whole soil environment, expressed by chemical and microbiological parameters. Considering also the results of Part I of this study [25], it could be shown how sensitive basic soil parameters (e.g., pH, C_{org}) are to agricultural practices and how close their relation to almost all other soil features are. This resulted also in different kinds of soil structure and structure-related-processes.

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