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AGRICULTURAL UTILIZATION AS A FACTOR IN INCREASING BULK DENSITIES OF SOILS

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A b s t r a c t. Investigations on the influence of agricultural utilization on soil profile morphology, soil structure and other properties were carried out during the years 1986-1990. The following soil types were involved: Haplic Phaeozem developed from loess, Orthic Luvisol developed from loess, Stagnogleyic Luvisol developed from silt of water origin and from loam, Orthic Luvisol developed from sandy loam and Leptic Podzol developed from sand. The following agricultural utilization ways were taken into account in the detailed analysis: soils in natural forest conditions, soils utilized for agriculture in unmechanized farms, soils utilized for agriculture in farms with a full mechanization of field work, soils utilized for a more than 50 years as vegetable gardens.

Data have shown significantly higher densities of arable-humus layers when compared to the corresponding horizons of forest soils. Mechanization of field work resulted in deterioration of soil structure as well as additional compaction of arable humus horizons and subsoils. These effects are different in different soils. The alteration of forest soil management to agricultural leads to a decrease of acidification and a different distribution of organic matter in the soil profile. These effects are related to the level of mechanization and to intensity of land use.

INTRODUCTION

The widespread opinion in agriculture that agricultural utilization improves properties of soils and increases their productivity has recently become more and more doubtful, as it has been noticed that agrotechnical activities are likely to bring about degradation of arable-humus layers [2,3,7,8,9,12,13,15,16,18]. In soils with deficient organic nutrition and an increasing amount of cereals in crop rotations, tillage can lead to a decrease of humus content and deterioration of humic compounds as a result of stronger oxidation and quicker mineralization of the organic matter in the arable layer [20]. These phenomena are commonly defined as the degradation processes.

An important factor having a degrading effect on the properties of all soils is intensive compaction by machinery wheel traffic and tillage tools [4,5,6,10,17,19].

Different levels of farming intensity with various rates of mechanized field work are possible to research in Poland. There are farms using only horses as tractive power where soil is not strongly compacted. Nearby, there are farms applying full mechanization of cultivation and crop harvesting. This situation offers excellent opportunities for estimation of the effects of agricultural utilization on physical properties of different soils.

The aim of this paper is to show the changes in compaction, resulting from various cultivation methods, as well as to determine whether these processes lead to deterioration of soil properties or not and the consequence of their changes.

METHODS

The investigations were carried out during the years 1986-1990 on soils belonging to the following units:

1 - Haplic Phaeozem developed from loess,
2 - Orthic Luvisol developed from loess,
3 - Orthic Luvisol (Stagnogleyic Luvisol) developed from silt of water origin,
4 - Stagnogleyic Luvisol developed from loam,
5 - Orthic Luvisol developed from sandy loam,
6 - Leptic Podzol developed from sand.

The basic properties of these soils are presented in Tables 1-6.

In each soil unit, comparable soil profiles were selected for detailed investigations. The basic difference between the soil profiles within a unit consisted in their different agricultural utilization.

Soil profile morphology, soil structure and basic chemical and physical properties were analyzed in all genetic horizons and layers.

The following land uses were taken into account for detail analysis:

F - soil in natural forest habitat,
UM - soil utilized for agriculture in unmechanized farms or in farms with poor mechanization of field work, i.e., still using horses as traction power,
FM soil utilized for agriculture in farms with full field work mechanization for many years,

Table 1. The basic properties of Haplic Phaeozem developed from loess

Land use	Genetic horizon depth (cm)	Depth of sampling (cm)	Granulometric composition (%,w/w)				Humus content	pH (KCl)
			1 - 0.1	0.1 - 0.02	< 0.02	< 0.002	(%, w/w)	
F*	0, 0 - 1	1 - 5	3	58	39	10	2.64	3.6
	Ah, 1 - 66	10 - 15	3	54	43	10	1.96	3.2
UM	Ap, 0 - 25	10 - 15	1	55	44	14	1.91	4.9
	Ah, 25 - 45	25 - 45	1	54	45	14	1.40	5.0
FM	Ap, 0 - 25	10 - 15	1	54	45	14	2.59	6.3
	Ah, 25 - 70	30 - 35	1	57	42	20	1.50	6.9
G	Ap, 0 - 25	10 - 15	9	55	36	8	3.62	6.8
	Ah, 25 - 60	30 - 35	7	54	39	15	1.14	6.9

* F - forest; UM - unmechanized farm; FM - fully mechanized farm; G - garden.

Table 2. The basic properties of Orthic Luvisol developed from loess

Land use	Genetic horizon depth (cm)	Depth of sampling (cm)	Granulometric composition (%,w/w)				Humus content	pH (KCl)
			1 - 0.1	0.1 - 0.02	< 0.02	< 0.002	(%, w/w)	
F*	Ah, 3 - 18	3 - 18	3	64	33	5	1.66	3.2
		8 - 13	2	62	36	6	-	-
	E, 18 - 35	18 - 25	2	66	32	8	0.62	3.6
UM	Ap, 0 - 19	3 - 8	1	61	38	5	1.36	5.0
	E, 19 - 30	20 - 25	1	60	39	8	1.01	3.8
FM	Ap, 0 - 23	2 - 7	1	63	36	6	1.40	5.5
	E, 23 - 32	24 - 29	1	66	33	10	0.42	5.8
G	Ap, 0 - 27	2 - 7	2	60	38	9	1.71	6.4
		24 - 29	1	63	36	6	0.60	6.3

* F - forest; UM - unmechanized farm; FM - fully mechanized farm; G - garden.

Table 3. The basic properties of Orthic Luvisol (Stagnogleyic Luvisol) developed from silt of water origin

Land use	Genetic horizon depth (cm)	Depth of sampling (cm)	Granulometric composition (%,w/w)				Humus content	pH (KCl)
			1 - 0.1	0.1 - 0.02	<0.02	< 0.002	(%, w/w)	
F*	Ah, 2 - 15	3 - 8	6	58	36	6	2.19	6.4
	Eg, 15 - 31	16 - 21	5	59	36	7	0.70	3.6
	g > 31	31 - 36	6	55	41	14	0.21	3.6
UM	Ap, 0 - 20	3 - 8	6	56	38	4	1.74	3.7
	E, 20 - 25	20 - 25	4	59	37	8	0.29	3.8
FM	Ap, 0 - 23	3 - 8	5	59	36	4	1.37	5.9
	E, 23 - 36	23 - 28	5	56	39	5	1.12	6.2
G	Ap, 0 - 28	5 - 10	30	43	27	6	2.05	6.6
	Ah, 28 - 45	28 - 33	17	48	35	6	1.22	5.6

* F - forest, UM - unmechanized farm, FM - fully mechanized farm, G - garden.

Table 4. The basic properties of Stagnogleyic Luvisol developed from loam

Land use	Genetic horizon depth (cm)	Depth of sampling (cm)	Granulometric composition (%, w/w)				Humus content	pH (KCl)
			1 - 0.1	0.1 - 0.02	< 0.02	< 0.002	(%, w/w)	
F*	Ah, 2 - 15	2 - 7	44	32	24	6	3.04	3.2
	E, 15 - 34	15 - 20	47	30	23	2	1.64	3.7
UM	Ap, 0 - 25	2 - 7	56	24	20	6	1.38	4.8
	E, 25 - 44	25 - 30	55	25	20	6	0.30	5.2
FM	Ap, 0 - 32	1 - 6	56	24	20	6	1.23	5.8
	E, 32 - 50	32 - 37	55	27	18	2	0.36	6.1
G	Ap1, 0 - 24	2 - 7	57	24	19	5	2.66	4.8
	Ap2, 24 - 42	24 - 29	59	24	17	2	0.88	5.6

* F - forest, UM - unmechanized farm, FM - fully mechanized farm, G - garden.

Table 5. The basic properties of Orthic Luvisol developed from sandy loam

Land use	Genetic horizon depth (cm)	Depth of sampling (cm)	Granulometric composition (%, w/w)				Humus content	pH (KCl)
			1 - 0.1	0.1 - 0.02	< 0.02	< 0.002	(%, w/w)	
F*	Ah, 7 - 37	9 - 14	40	42	18	2	4.30	3.9
	E, 37 - 57	37 - 42	46	33	21	4	0.71	4.0
UM	Ap, 0 - 22	2 - 7	53	29	18	2	1.33	3.8
	E, 26 - 58	27 - 42	58	25	17	2	0.06	4.5
FM	Ap, 0 - 22	2 - 7	57	27	16	2	1.23	4.0
	E, 22 - 60	23 - 28	60	25	15	2	0.10	5.3
G	Ap, 0 - 45	4 - 9	37	43	20	1	2.66	6.2
	Ehg, 45 - 55	35 - 40	35	44	21	2	1.82	6.3

* F - forest, UM - unmechanized farm, FM - fully mechanized farm, G - garden.

Table 6. The basic properties of Leptic Podzol developed from sand

Land use	Genetic horizon depth (cm)	Depth of sampling (cm)	Granulometric composition (%, w/w)				Humus content (%, w/w)	pH (KCl)
			1 - 0.1	0.1 - 0.02	< 0.02	< 0.002		
F*	Ah, 4 - 16	4 - 9	80	13	7	1	1.57	3.9
	E, 16 - 48	30 - 35	82	13	5	1	0.57	4.0
UM	Ap, 0 - 18	2 - 7	75	17	8	3	0.48	3.8
	E, 18 - 28	18 - 23	70	23	7	2	0.06	4.5
FM	Ap, 0 - 22	2 - 7	75	17	8	2	0.88	4.0
	E, 22 - 44	22 - 27	76	16	8	3	0.12	5.3
G	Ap, 0 - 25	2 - 7	68	22	10	1	1.20	6.2
	Ehg, 25 - 35	25 - 30	65	23	12	2	0.91	6.3

* F - forest, UM - unmechanized farm, FM - fully mechanized farm, G - garden.

G - soils utilized for many years as vegetable gardens, similar hortisols.

On agricultural soils, the choice of the cultivated plant species and crop rotation depends on the ability of the given soil to grow particular plants as well as the tradition of cultivation.

Samples for all investigations were taken in the beginning of June. In cultivated soils, samples were taken from fields under winter cereals since natural compaction of soil occurred throughout the winter and spring season.

The following properties were analyzed in the soil profiles selected for investigations.

(i) Morphological features of the structure on the basic opaque soil block 8 x 9 cm.

(ii) Soil structure has been described on the basis of opaque sections (soil blocks). Samples for studies were taken in the vertical plane, in metal containers measuring 8 x 9 x 4 cm, in two repetitions from the same zones from which samples for the determination of soil physical properties were taken. The method used was that according to Jongerius and Heintzberger [11] as described earlier [14]. Since there was a large amount of data only some examples of structure have been presented in this paper.

(iii) Granulometric composition of soils was analyzed using the method of Bouycouse-Cassagrande modified by Prószyński [1]. Sand fraction was determined by washing samples on a sieve in water.

(iv) Humus content was determined by the method of Turin [1].

(v) pH was determined by the electrometrical method in 1 N KCl.

(vi) Basic physical properties including bulk density, total porosity, water characteristic curve and associated air content were determined in core samples 100 cm^3 volume with 6 replications taken from the each horizon with natural structure. Water characteristics and air content were determined by means of ceramic plates according to Richards [1].

For statistical comparison, results from levels whose depth corresponded to the analyzed layers of arable soils were taken from forest soils for analysis. In this paper only the results of bulk density are presented.

RESULTS

The change of forest to agricultural utilization leads to a considerable change in morphological features of the soil profile, soil structure of genetic horizons, and other soil chemical and physical properties. Agricultural utilization leads to different distribution of organic matter in soil profile. The depth of arable-humus horizon is related to the intensity of agricultural utilization. On extensively managed farms where horses are used as traction power, the arable-humus horizon is usually shallower than on the farms with full mechanization of field work.

Agricultural soils have a higher pH's than forest soils. Acidification was lower for more intensively managed farms (Tables 1-6). The transition from natural forest to agricultural utilization is also accompanied by a change of the type of soil structure. In the soils with natural aggregation, agricultural practice has led to deterioration or disappearance of aggregates and considerable compaction. In loamy or silty soils under natural forest, structure of the top layer is very loose with numerous zoogenic aggregates and pores. For the arable-humus horizons of these soils utilized by unmechanized farms, structure is characterized as non-aggregated with mainly narrow pores and short fissures.

For the fully mechanized farms, soils are characterized as very compact soil with long narrow fissures often horizontaly oriented. The examples of changes in soil structure described above are presented in Figs 1a, 1b, 2a, and 2b.

Changes in soil compaction as a result of agricultural utilization are shown in Table 7. Agricultural utilization of all soils which were investigated have increased bulk densities in the surface horizons when compared to forest soils. The differences of soil bulk density were statistically significant in all cases.

The compaction of the arable-humus layer of the Haplic Phaeozem was significantly higher than the comparable A horizon of forest soil. However, no significant differences were found in the compaction of arable-humus layers for different levels of mechanization. In the Orthic Luvisol developed from loess there were large differences in soil compaction as a result of structural changes between the soil in the natural forest habitat and agricultural soils. In the horizons of forest soil corresponding to the arable-humus layer, statistically lower densities were obtained. For the soils discussed above, the influence of intensive kneading by heavy machines on the fully mechanized farm could be observed. This effect was manifested by a significantly higher bulk density of the arable layer in the

Table 7. Influence of land use on bulk density (Mg m^{-3}) of investigated soils

Soil	Horizon	Land use				LSD
		F	UM	FM	G	
Haplic Phaeozem developed from loess	Humus or arable -humus	1.01	1.33	1.33	1.24	0.14
	Subsoil	1.44	1.37	1.29	1.36	
Orthic Luvisol developed from loess	Humus or arable-humus	0.83	1.33	1.50	1.27	0.15
	Subsoil	1.13	1.40	1.53	1.48	
Gleyic Luvisol developed from silt of water origin	Humus or arable-humus	1.07	1.22	1.26	1.34	1.17
	Subsoil	1.47	1.51	1.60	1.55	
Gleyic Luvisol developed from loam	Humus or arable-humus	1.10	1.59	1.59	1.67	0.19
	Subsoil	1.63	1.71	1.73	1.84	
Orthic Luvisol developed from sandy loam	Humus or arable-humus	1.09	1.59	1.72	1.30	0.12
	Subsoil	1.55	1.74	1.81	1.55	
Leptic Podzol developed from sand	Humus or arable-humus	1.13	1.52	1.35	1.65	0.07
	Subsoil	1.49	1.69	1.71	1.72	

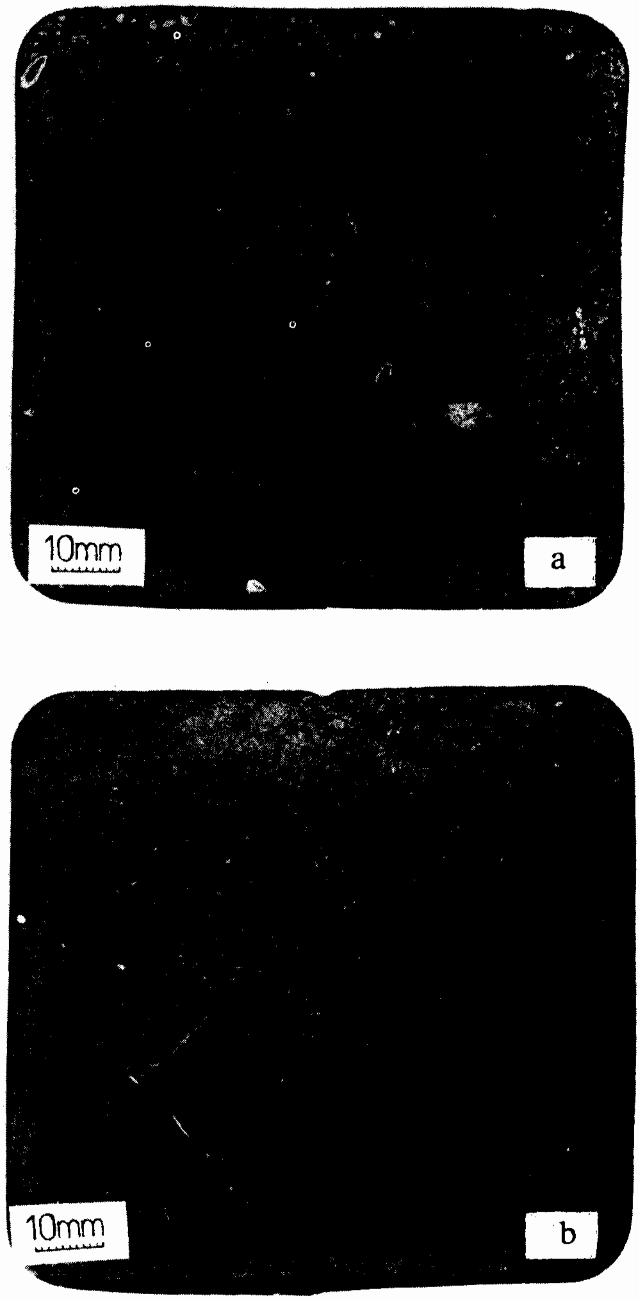

Fig. 1. Structure of the surface layer (0-8 cm) of the Haplic Phaeozem developed from loess. a - forest; b - unmechanized farm. Black colour - pores, white colour - solid phase.

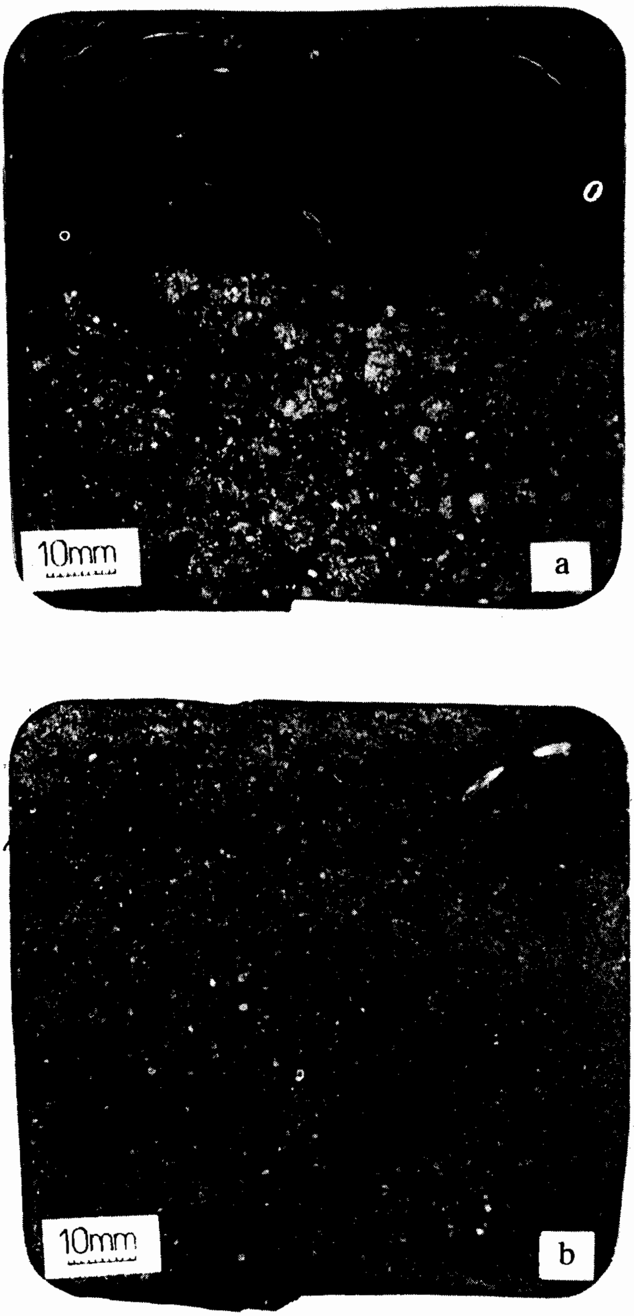

Fig. 2. Structure of the surface layer (0-8 cm) of the Orthic Luvisol developed from sandy loam. a - forest; b - unmechanized farm. Denotations as in Fig. 1.

farms with complete mechanization of field work when compared to the soil of unmechanized farms.

In the soils developed from silt of water origin (Stagnogleyic Luvisol) statistically significant differences in soil bulk density were found only between the humus horizon of forest soil and the arable-humus horizons of soils utilized agriculturally. The mechanization of field work did not affect compaction of humus arable layers. The same result was obtained in Stagnogleyic Luvisol developed from loam.

Agricultural utilization of the Orthic Luvisol has led to a significant increase of compaction for both the arable-humus layer and a subsoil layer. In these soils, a distinct effect of kneading by heavy agricultural machines over many years on compaction could also be observed. The density of the arable-humus layer of the soil from the farm with full mechanization of field work was statistically significantly higher than the soil of the adjacent fields of farms not using tractors and other heavy agricultural machines. In this soil both of the fields of mechanized farms had significantly higher compaction of the subsoil when compared with corresponding layers of forest soil and hortisol. Kneading over many years in these soils has resulted in height density of the subsoil.

These results indicate that for soils of a light granulometric composition, kneading by heavy machines may unfavourably change subsoil properties.

The effect of agricultural utilization on compaction of the Leptic Podzol developed from sand was a similar to that observed for soils developed from loam and silt of water origin. Significant differences in soil bulk density were found beetwen forest and agriculturally utilized soils at the depth of the arable-humus horizons. In this soil the effect of mechanized work was not noticed.

In all soils used for vegetable gardens the formation of deep arable humus horizons were observed with higher humus content when compared to typical arable soils. These soils did not have significant increases in soil compaction when compared to analogous layers in typical agricultural soils.

CONCLUSIONS

1. Agricultural utilization of soils results in the formation of arable-humus horizons with different structure and physical and chemical properties when compared to soils in natural forest conditions. These changes are manifested by: (i) decreased acidification; (ii) redistribution of humus compounds in the soil profile; (iii) disappearance of the aggregate structure and numerous zoogenic aggregates; (iv) formation of non-aggregate structure with predominantly narrow pores and short fissures; (v) higher compaction of arable-humus layers.

2. Mechanization of field operations over many years leads to an additional increase of compaction of the arable-humus layer. This effect has different intensities for different soils.

3. Full mechanization of field work has resulted in high density in surface and subsurface horizons with a light granulometric composition.

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UŻYTKOWANIE ROLNICZE JAKO CZYNNIK POWODUJĄCY WZROST GĘSTOŚCI GLEB

Badania wpływu użytkowania rolniczego na morfologię profilu glebowego, strukturę i właściwości gleb przeprowadzono w latach 1986-1990. Badaniami objęto następujące gleby: Haplic Phaeozem (czarnoziem zdegradowany) wytworzony z lessu, Orthic Luvisol (gleba płowa właściwa) wytworzony z lessu, Orthic Luvisol (gleba płowa) wytworzony z pyłów wodnego pochodzenia, Stagnogleyic Luvisol (gleba płowa opadowo-glejowa) wytworzony z gliny, Luvisol (gleba płowa właściwa) wytworzony z gliny piaszczystej, Leptic Podzol (gleba bielicowo-rdzawa) wytworzony z piasku. Do szczegółowych analiz wzięto pod uwagę gleby użytkowane rolniczo w niezmechanizowanych gospodarstwach, gleby użytkowane rolniczo w gospodarstwach o pełnej mechanizacji prac polowych, gleby użytkowane przez ponad 50 lat jako ogród warzywny.

Wyniki pokazują istotnie większe zagęszczenia poziomów uprawno-próchnicznych i podornych gleb. Efekty te są różne na różnych glebach. Zmiana użytkowania gleby z leśnego na rolnicze prowadzi do obniżenia zakwaszenia i zróżnicowania rozmieszczenia materii organicznej w profilu glebowym.