Journal of Agricultural Sciences
Vol. 59, No. 2, 2014
Pages 151-160

DOI: 10.2298/JAS1402151G
UDC: 631.412(497.11);631.445.4(497.11)
Original scientific paper

EFFECT OF LAND USE CHANGE ON THE STRUCTURE OF GLEYIC FLUVISOLS IN WESTERN SERBIA

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Abstract: Changes in land use can significantly affect aggregate distribution and water stability of structural aggregates. This study was conducted in the Kolubara River Valley, Western Serbia, to determine the effects of land use changes on composition and water stability of aggregates in humus horizons (0–30 cm) of noncarbonated Gleyic Fluvisols. This study was conducted at nine sites, where each site contained two adjacent land uses of natural grassland and arable land which underwent crop rotation for >100 years. Soil samples were taken from depths of 0–10, 10–20 and 20–30 cm for each land use. When the grassland was converted into arable land, the content of the agronomically most valuable aggregates (0.25–10 mm) of cultivated soils for a depth of 0–30 cm was significantly reduced by 22–40%, while the percentage of cloddy aggregates (>10 mm) increased by 41–68%, compared to grassland. In addition, the long-term arable soil had significantly ($p<0.05$) lower aggregate stability, determined by wet sieving, than grassland. The lowest aggregate stability was found in aggregates > 3 mm. Their content is ≈ 2.3 times lower in arable soil (12.6%) than in grassland (28.6%) at a depth of 0–10 cm. In addition, meanweight diameters of dry and wet-stable aggregates and structure coefficient showed significant differences between land use at a depth of 0–30 cm. The results showed that the conversion of natural grassland to arable land in the lowland ecosystems of Western Serbia degraded aggregate distribution and stability.

Key words: Gleyic Fluvisols, aggregate distribution, water-stable aggregates, mean weight diameter, structure coefficient, land use, soil tillage.

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Introduction

The development of civilization requires more or less serious intervention of man in the environment. The consequences are increasingly obvious and deep, attracting the attention of an increasing number of investigations in various scientific fields.

At present, anthropogenic influences of various types and intensities, distributed within traditional appropriating of new arable lands, disturb complex ecosystems and change character, direction and mutual relations of natural pedogenic processes (Lebedeva and Tonkonogov, 1994). This anthropogenic soil tranformation is dependent on its initial characteristics, characteristics of natural conditions of pedogenesis, as well as on the character of anthropogenic influence.

The available experience shows that human activity mainly caused the degradation of soil and the soil cover as a whole (Tanzybayev and Kulizhskiy, 1994; Bondarev and Kuznetsova, 1999). Increased anthropogenic influence on soil leads at first to its degradation, i.e. deformation and destruction of micro- and macro-aggregates. Soil aggregate composition is very susceptible to soil tillage (Hamblin, 1985). Li et al. (2007) showed that soil aggregate stability was significantly decreased (by 27–54%) at a depth of 0–30 cm in cultivated native pasture.

Aggregate-size distribution, i.e. the soil structure is one of the main indicators of physical prerequisites for soil fertility. For that reason, the investigations of soil transformations in the process of agricultural utilization have great importance, not only from agricultural (Utkayeva et al., 1986), but also from ecological aspect (Lal, 1991).

According to Sorochkin (1991), Voronjin stated that for the estimation of soil structure, size and form of macroaggregates are very important, together with their mechanical strength, stability and porosity. From the agricultural aspect, structural aggregates with the diameter of 1–10 mm create the most favorable conditions for the optimal growth of cultivated plants. These aggregates ought to be water-stable and to show a favorable ratio of big pores, with the diameter of >75 μm, which allow good drainage, and aeration during humid seasons, and medium pores (with the diameter of 30–0.2 μm), which retain the water available to plants during dry seasons (Tisdall, 1996).

The stability of structural aggregates is a performance of soil quality (Mapa and Ariyapala, 1998). Haghighi et al. (2010) observed the significant land use impact on water-stable aggregates. The quality of the structure, and of the soil itself, depends on the influence of many factors participating in aggregation, as for instance, of organic matter content, clay, iron and aluminum oxides and plant root activity. The aim of this paper was to assess the long-term (more than 100 years) effects of grassland conversion to arable lands on aggregate-size distribution and water stability of structural aggregates of noncarbonate Gleyic Fluvisols in the lowland ecosystems of Western Serbia.

Material and Methods

Site description and experiment design

The study was conducted in the Kolubara River valley, western Serbia (44°23’57.6”–44°35’37.9”N, 20°11’35”–20°11’55.5”E). The soil is a Gleyic Fluvisols (FAO, 2006) formed over poorly carbonated alluvial deposit, with silt clay texture. Nine sites were selected, where each site contained two adjacent land uses of natural grassland and arable land (converted from grassland more than 100 years ago). Major plant species of grassland included *Medicago lupulina* and *Lathyrus* sp. which have been cultivated with wheat and corn for over 100 years. The region is characterized by an annual mean precipitation of 726 mm, and annual mean air temperature of 11°C.

Soil sampling and analysis

Nine soil samples of roughly ≈ 4,000 g were collected for each land use at depths of 0–10, 10–20 and 20–30 cm (54 samples) from a hand-dug cross-sectional test pit. Immediately after sampling, in the laboratory the larger clods were gently crumbled by hand into aggregates <20 mm. Soil samples were air-dried and passed through a 2-mm sieve and physical and chemical soil properties were measured.

Aggregate-size distribution was determined using the dry-sieve method by Savinov (Gajić, 2005). Water-stable aggregates were fractionated according to Savinov (Gajić, 2005). By dry sieving, 8 classes of structural aggregates were separated by their size (>10; 10–5; 5–3; 3–2; 2–1; 1–0.5; 0.5–0.25 and <0.25 mm), and by the wet sieving procedure 6 classes were separated (>3; 3–2; 2–1; 1–0.5; 0.5–0.25 and <0.25 mm). The results were expressed as a mean weight diameter (MWD) corresponding to the sum of the mass fraction remaining on each sieve multiplied by the mean intersieve sizes (Hillel, 2004). Mean weight diameters were calculated for dry (dMWD) and wet (wMWD) sieving. Mean weight diameter was used as an index of soil aggregation. The larger wMWD values represented greater aggregate stability. Structure coefficient (Ks) was calculated as the ratio between the content of agronomically most favourable structural aggregates, with the diameter of 0.25–10 mm, and the total content of the aggregates of >10 mm and <0.25 mm separated by dry sieving (Shein et al., 2001). Shein et al. (2001) assigned classes of Ks >1.5, 1.5–0.67, and <0.67 to soils of good, satisfactory, and unsatisfactory structure with respect to soil fertility.

An analysis of variance was performed using a generalised linear model to compare the impact of land use on soil properties. The level of significance was set at $p<0.05$.

Table 1 shows average values of soil properties for each of the two land use types. The detailed presentation of physical and chemical characteristics of these soils is given previously (Gajić, 1998).

Table 1. Effects of two adjacent land use types on humus content and particle size distribution. Standard deviations are given in brackets.

Soil use	Depth (cm)	Humus content (%)	Particle-size distribution (%)			Textural classes (USDA)
			Sand	Silt	Clay	
Grassland	0–10	1.41 (±5.2)	7.5 (±0.5)	55.0 (±0.3)	37.5 (±4.3)	Silt clay
	10–20	1.51 (±3.4)	8.6 (±0.8)	54.2 (±0.4)	37.2 (±1.2)	Silt clay
	20–30	1.56 (±2.6)	8.9 (±1.1)	53.3 (±1.1)	37.8 (±3.4)	Silt clay
Arable land	0–10	1.31 (±2.3)	9.5 (±0.7)	49.1 (±0.7)	41.4 (±1.2)	Silt clay
	10–20	1.44 (±1.6)	9.6 (±0.3)	49.1 (±0.7)	41.3 (±1.0)	Silt clay
	20–30	1.50 (±2.2)	11.0 (±0.4)	49.5 (±0.4)	39.5 (±1.9)	Silt clay

Sand: 50–2000 μm; silt: 50–2 μm; clay: < 2 μm.

Results and Discussion

Agregate-size distribution

The distribution of the aggregate size classes for each of the two land use types is presented in Table 2.

The results show a significant change in aggregate-size distribution of the arable soil due to long-term tillage in comparison with the grassland. The arable soils had significantly lower mass of aggregates in the smaller diameter classes (<10 mm) than the grassland. In the >4 mm class, however, the grassland and arable soils showed an approximately equal number of aggregates.

The content of the agronomically most valuable aggregates with the diameters between 0.25 and 10 mm in arable soil is significantly lower (21.6–39.7%) than in grassland at a depth of 0–30 cm (A_h horizon). On the basis of the content of these aggregates, and according to the classification by Shein et al. (2001), the arable land does not have satisfactory soil structure, while the grassland is well structured in the dry state.

Due to the application of various agrotechnical measures, in the arable soils the content of clods (>10 mm) and microaggregates (<0.25 mm) is significantly higher than in grassland at a depth of 0–30 cm. The content of these aggregates in humus horizon of grassland ranged within rather a narrow interval, from 35.2 to 38.4%, and in the arable soils within much wider interval, from 49.2 to 62.9%. Tillage in the arable soils disintegrated the large aggregates into smaller aggregates, resulting in the lower proportion of small aggregates (10–0.5 mm) in these soils (Table 2). Our results are in accordance with that of Cotching et al. (2002), who found significantly higher content of dry aggregates > 9.5 mm in the surface (0–75 mm) layer of cropped paddocks than in the same depth zone of a long-term pasture, on Dermosols in Northern Tasmania.

Table 2. Effects of two adjacent land-use types on dry aggregate-size distribution. Standard deviations are given in brackets.

Depth (cm)	% of structural aggregates of size (mm)									Ks	dMWD
	>10	10–5	5–3	3–2	2–1	1–0.5	0.5–0.25	<0.25	10–0.25		
Grassland											
0–10	36.6	35.7	12.9	6.7	5.3	1.3	0.3	1.2	62.2	1.65	7.09
	(±1.2)	(±1.5)	(±1.0)	(±0.6)	(±0.4)	(±0.1)	(±0.0)	(±0.1)	(±1.6)	(±0.1)	(±0.2)
10–20	37.0	34.9	11.7	7.0	6.1	1.6	0.3	1.4	61.6	1.60	8.53
	(±2.1)	(±0.9)	(±0.7)	(±0.4)	(±0.7)	(±0.3)	(±0.1)	(±0.3)	(±2.3)	(±0.2)	(±0.3)
20–30	34.2	35.4	13.0	7.9	6.7	1.5	0.3	1.0	64.8	1.84	7.71
	(±2.2)	(±1.3)	(±0.4)	(±0.4)	(±0.5)	(±0.2)	(±0.0)	(±0.2)	(±3.8)	(±0.2)	(±0.4)
Arable land											
0–10	57.6	25.5	5.8	3.1	3.7	0.8	0.3	0.7	39.2	0.71	11.02
	(±2.4)	(±0.8)	(±0.6)	(±0.5)	(±0.6)	(±0.1)	(±0.0)	(±0.1)	(±2.0)	(±0.1)	(±0.3)
10–20	62.1	26.3	5.6	2.7	1.9	0.4	0.2	0.8	37.1	0.59	11.62
	(±2.0)	(±1.0)	(±0.4)	(±0.2)	(±0.1)	(±0.0)	(±0.0)	(±0.0)	(±0.9)	(±0.0)	(±0.1)
20–30	48.3	31.3	9.9	5.1	3.5	0.7	0.3	0.9	50.8	1.03	10.19
	(±3.1)	(±1.5)	(±0.6)	(±0.5)	(±0.3)	(±0.1)	(±0.0)	(±0.1)	(±3.2)	(±0.1)	(±0.4)

Ks: Structure coefficient; dMWD: Mean weight diameter of dry aggregates.

Both structure coefficient and mean weight diameter values support the conclusion that the aggregate-size distribution of arable soils during long-term tillage suffered significant qualitative changes (Table 2). In the humus horizon of the grassland, Ks is significantly higher than in the arable soils. The values of Ks in the grassland are regularly >1.5, i.e. they vary between 1.60 and 1.84. According to the classification of Shein et al. (2001), the values are characteristic for the soils of a good structure. In the top 10 cm of arable soils, Ks is 0.71, which is, according to Shein et al. (2001), an indicator of a satisfactory structure. With Ks = 0.59, the subsurface layer at a depth of 10–20 cm shows an unsatisfactory structure. The arable land had the satisfactory structure at the 10 to 20-cm soil depth, Ks = 1.03.

The mean weight diameter of dry soil aggregates was significantly greater in the arable soils (10.19–11.02) than in the grassland (7.09–8.53) (Table 2). Tillage caused 55.4% increases in dMWD for the 0 to 10-cm layer, 36.2% for the 10 to 20-cm layer, and 32.2% for the 20 to 30-cm layer.

Aggregate stability

The data presented in Table 3 show that, under the influence of long-term tillage, there was a significant decrease in aggregate stability at a depth of 0–10 cm. The lowest soil stability was found in structural aggregates of >3 mm. The content of these aggregates in humus horizon of the grassland is about 2.3 times greater than in arable soils. There was no significant difference in the amount of stable aggregates of >3 mm between the grassland and arable soil at a depth of 10–30 cm. Distribution of water-stable aggregates differed significantly between the arable soils and the grassland soils. The arable soils had significantly higher mass of aggregates in the smaller diameter classes (1–0.5, 0.5–0.25 and <0.25 mm) than the grassland at a depth of 0–10 cm. The arable and grassland soils did not differ in the mass of these aggregates for the 10 to 30-cm layer. There were no significant differences in the classes of 3–2 and 2–1 mm, between the arable and grassland for either depth.

Table 3. Effect of the land use change on size distribution of water-stable aggregates at two land use types. Standard deviations are given in brackets.

Depth (cm)	% of water-stable aggregates of size (mm)						wMWD
	>3	3–2	2–1	1–0.5	0.5–0.25	<0.25	
			Grassland				
0–10	28.6 (±4.4)	8.6 (±0.8)	21.0 (±1.9)	12.9 (±1.4)	5.3 (±0.4)	23.6 (±2.3)	2.32 (±0.3)
10–20	17.3 (±4.9)	8.1 (±1.4)	24.4 (±1.8)	16.2 (±2.4)	6.9 (±0.8)	27.1 (±2.8)	2.02 (±0.4)
20–30	9.8 (±3.4)	7.3 (±1.7)	26.6 (±1.3)	18.2 (±2.1)	7.5 (±0.7)	30.6 (±3.8)	1.52 (±0.3)
			Arable land				
0–10	12.6 (±2.6)	7.3 (±1.4)	22.0 (±2.3)	15.6 (±1.0)	8.5 (±1.0)	34.0 (±3.9)	1.21 (±0.2)
10–20	15.6 (±3.6)	9.2 (±1.6)	22.8 (±0.6)	14.9 (±1.6)	7.6 (±0.8)	29.9 (±2.8)	1.37 (±0.3)
20–30	9.8 (±2.6)	10.5 (±2.1)	27.7 (±1.3)	15.0 (±1.3)	7.2 (±0.9)	29.7 (±2.9)	1.25 (±0.2)

wMWD: Mean weight diameter of water-stable aggregates.

A comparative analysis indicates that under the tillage in the layer of 0–10 cm, there was a significant decrease in the stability of microaggregates of <0.25 mm. The content of these aggregates was higher on arable soils by 44% at a depth of 0–10 cm. At a depth of 10–30 cm, there was no significant difference in the amount of stable aggregates of <0.25 mm, between the grassland and arable soils. Since small aggregate size (<1.2 mm) was found to be a useful indicator of soil degradation (Whalen and Chang, 2002), tillage in the cultivated soils disintegrated the large aggregates into smaller aggregates, resulting in the higher proportion of small aggregates (<1.0 mm) in these soils (Table 3) (Unger, 1997; Materechera and Mkhabela, 2001). The results of this study are comparable to those of Spohn and

Giani (2010), who observed a significantly lower content of water-stable macroaggregates (aggregates of >200 μm) in course of the first 46 years of cultivation than in the permanent pasture sites, on Gleysols in Northwest Germany.

According to Ashagrie et al. (2007) and John et al. (2005), aggregation is influenced by land use and land use change in the way that the proportion of water-stable macroaggregates is reduced in the order forest > pasture/grassland > arable land and is further diminished with the duration of arable use. Microaggregates, however, seem to be less influenced by land use (Puget et al., 2000). The tendency of the decrease of water-stable aggregates under different land use was established by Koposov et al. (1994). The main cause of the decrease of the content of water-stable aggregates after the conversion of native vegetation to cropland is the decrease of the content of organic matter (Lal, 1993; Hamblin, 1985), and some of its components (Caron et al., 1992).

Table 3 shows that there is a significant difference in the values of wMWD between grassland and arable soil. In arable soil at a depth of 0–20 cm, mean values of wMWD are 1.5 to 2 times lower than in the same depth zone of grassland. Somewhat smaller but statistically significant differences in wMWD values were also found at a depth of 20–30 cm. Previous studies showed that soils with a higher wMWD are likely to have a greater resistance to soil degradation (Chan and Mead, 1988; Teixeira and Misra, 1997).

Conclusion

Changes in land use from natural grassland to arable land led to significant changes in soil structure. The degradation of soil structure can negatively affect soil productivity. The farming of virgin soils should be prevented because the change in land use will not be sustainable for long periods and will increase the severity of soil and land degradation. As a key limiting factor of soil productivity, soil structure should be protected and maintained through appropriate land management practices, e.g. the abandonment and the maintenance of native grasslands, in the study area.

Acknowledgements

This work was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (Project No. III43009).

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Received: February 28, 2014
Accepted: March 24, 2014

UTICAJ PROMENE NAČINA KORIŠĆENJA ZEMLJIŠTA NA STRUKTURU LIVADSKE CRNICE U ZAPADNOJ SRBIJI

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Rezime

Istraživanja su sprovedena u dolini reke Kolubare da bi se utvrdili efekti promene načina korišćenja zemljišta na agregatni sastav i vodootpornost strukturnih agregata u humusnom horizontu (0–30 cm) beskarbonatne livadske crnice. Izabrano je devet lokacija koje su na bliskom rastojanju imale površine pod prirodnom livadskom vegetacijom i oranice koje su stvorene pre više od 100 godina razoravanjem prirodnih livada. Nakon razoravanja prirodnih livada i njihovog pretvaranja u oranice, sadržaj agronomski najpovoljnijih strukturnih agregata (prečnika 0,25–10 mm) u oranicama na dubini 0–30 cm, značajno je smanjen, za 22–40%, dok je sadržaj grudvastih agregata (>10 mm) povećan za 41–68 %, u poređenju sa livadom. Pored toga, višegodišnje oranice imaju značajno (p<0,05) manju vodootpornost strukturnih agregata, određenih mokrim prosejavanjem, od livada. Najmanju vodootpornost pokazali su strukturni agregati prečnika >3 mm. Takođe, prosečni maseni prečnici suvih i vodootpornih agregata i koeficijent strukture pokazali su značajne razlike između različitih načina korišćenja zemljišta na dubini 0–30 cm. Razoravanje livadskih crnica pod prirodnom livadskom vegetacijom istraženog područja i njihova višegodišnja obrada doveli su do značajnih negativnih promena agregatnog sastava i smanjenja vodootpornosti strukturnih agregata.

Ključne reči: livadska crnica, agregatni sastav, vodootpornost strukturnih agregata, prosečni maseni prečnik, koeficijent strukture, način korišćenja zemljišta.

Primljeno: 28. februara 2014.
Odobreno: 24. marta 2014.

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