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AGGREGATE COMPOSITION AND STABILITY OF STRUCTURAL AGGREGATES OF NON-CALCAREOUS RENDZINAS IN EASTERN SERBIA

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Abstract: The present study includes the results of comparative investigations of aggregate composition and water stability of structural aggregates in humus horizons of non-calcareous rendzina under native forest and pasture vegetations and the same rendzina utilized long-term as arable field. The results show that aggregate composition and water stability of structural aggregates in the cultivated non-calcareous rendzina are significantly impaired due to a long-term anthropogenization. In the cultivated rendzinas the content of agronomically most valuable aggregates (0.25–10 mm) significantly decreased, while the percentage of cloddy aggregates (>10 mm) was increased about 1.5 to 3.5 times in comparison with the rendzina under pasture and forest vegetations. The structure coefficient of cultivated soils was lower (2.61) than in forest (4.63) and pasture (10.47) rendzinas. The cultivated non-calcareous rendzina had lower (59.12%) aggregate water stability than rendzina under pasture (82.66%) and forest (91.92%). Mean weight diameters of water stable agregates was higher in forest (1.44 mm) and pasture (1.20 mm) than in cultivated (0.65 mm) rendzina.

Key words: non-calcareous rendzina, aggregate size distribution, soil aggregate water stability, different land-use managements.

Introduction

The rendzina is a shallow soil rich in organic matter and biological activity. It has a stable crumb structure and is dark in colour. Soil structure is nominated as a key soil property because of its critical role in soil water dynamics, plant growth and development, and the suitability of habitat for soil biota. Soil structure dynamics therefore influences agricultural productivity and environmental impact at the catchement scale, and vice versa (Southorn and Cattle, 2004).

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According to B r o n i c k and L a l (2005) soil structure exerts important influences on the edaphic conditions and environment. It can be significantly modified through management practices and environmental changes. Soil structure and aggregation are strongly influenced by processes such as tillage, cropping system and climate (G u e r i f et al., 2001). Aggregate size and aggregate stability are state indicators of soil structure, and as such, their mean weight percent and mean weight diameters are useful to characterise the effects of increasing duration of conventional cultivation on the quality of the soil tilth (S h e p h e r d et al., 2001).

From the agronomical point of view, structural aggregates with the diameter of 1-10 mm provide the most favourable conditions for optimal growth of crops (E d w a r d s, 1991). Such aggregates should be water stable. Tillage disrupts soil aggregates and decreases soil organic matter (P a u s t i a n et al., 1997; P l a n t e and Mc G i l l, 2002). According to S i x et al. (2000) soil disturbance by tillage is a major cause of organic matter depletion and reduction in the number and stability of soil aggregates when native ecosystems are converted to agriculture.

According to A m e z k e t a (1999), soil aggregate stability is a crucial soil property affecting soil sustainability and crop production. Soil aggregate stability is a performance quality of soil resulting from integration of many factors to related to aggregate agents, such as soil organic matter, clay content, iron and aluminium oxides and root activity (M a p a and A r i y a p a l a, 1998). Many investigations have shown that no-tillage improves soil aggregation and aggregate stability (B e a r e et al., 1994; S i x et al., 1999; F i l h o et al., 2002). After ploughing grassland, aggregate stability decreased rapidly and significantly (K a n d e l e r and M u r e r, 1993; S h e p h e r d et al., 2001), and increased dry aggregate size (S h e p h e r d et al., 2001). Stability of structural aggregates and organic carbon content usually decreased with cultivation (F i l h o et al., 2002; P l a n t e and McG i l l, 2002; E y n a r d et al., 2004b).

The objectives of this study were to determine and compare aggregate composition (aggregate size distribution) and stability of structural aggregates of non-calcareous rendzina under native forest and pasture vegetations with the non-calcareous rendzina which has been used for more than 100 years as arable field for agricultural crops (mainly wheat and maize) production.

Material and Methods

Soil and sampling sites

The investigations were carried out with strongly humose, non-calcareous stony silty clay loam to clay loam rendzina formed over marl and marly limestone parent material, in the Eastern Serbia (44°11'N, 22°48'E). The depth of its humus (Ah) horizon is 15–40 cm.

Field investigations of rendzinas in Eastern Serbia, soil sample collection, as well as the determination of some of their most important physical and chemical characteristics have been performed by M. Ž i v k o v i ć (M i l o s a v l j e v i ć, 1981). Soil samples for the determination of aggregate composition and stability of structural aggregates in the laboratoty were obtained from the humus horizons of nine profiles. Of the mentioned number, 3 profiles represent non-calcareous rendzinas under forest, 3 profiles rendzinas under pasture and 3 profiles long-term arable rendzinas. All the arable fields were usualy ploughed in autumn. The other pedogenetic agents being similar. At the same time, close to the cultivated soil sampling sites, profiles were opened under native forest vegetation, comprised of the community *Quercus pubescens, Querces cerris*, and *Quercus conferta* and under pasture vegetation, with abundant participation of *Festuca vallesiaca* and *Andrropogon ischaemum*. The long-term pasture had been under natural grass cover for more than 10 years.

Analytical methods

Aggregate size distribution

Aggregate size distribution was determined using a dry-sieve method, according to Savinov (G a j i ć, 2005). The sieved soil was weighed from each sieve and results were used to calculate the percentage of the total soil sample weight.

Structure coefficient (Ks) was calculated as the ratio between the content of agronomically most valuable structural aggregates, with the diameter between 0.25–10 mm, and the total content of the aggregates >10 mm and <0.25 mm separated by dry sieving (S h e i n et al., 2001).

Soil aggregate stability

Soil aggregate stability was determined using a wet sieving method, according to Savinov (G a j i ć, 2005).

Aggregate size distribution as well as soil aggregate stability was also expresed as the mean weight diameter (MWD).

Statistical analysis

Statistical analysis of experimental data was accomplished by standard analysis of variance (ANOVA) using the SAS software package (SAS Institute, 2001).

Results and Discussion

Size distribution of dry aggregates

Mean content of dry structural aggregates of non-calcareous rendzina under various modes of their utilization is presented in Fig. 1.

The obtained results show that there occurred a significant change in aggregate composition of the cultivated non-calcareous rendzina in comparison with the rendzinas under native forest and meadow vegetations, due to a long-term utilization for crop production, i.e. due to the human activity. Soil degradation is accelerated when perennial crops are converted to row crops, especially due to increased soil disturbance from tillage (K a r u n a t i l a k e and van E s, 2002). In the humus horizon of all investigated non-calcareous rendzinas there prevail (>70%), according to M e d v e d e v and C y b u l k o (1995), agronomically most valuable fractions of structural aggregates with the diameter between 0.25 and 10 mm. Due to increased compaction, because of treading during tillage, the cultivated non-calcareous rendzina shows, on average, significantly (P <0.05) lower (70.5%) content of the agronomically most valuable (by size) aggregates than the rendzina under meadow (91.3%) or forest (82.2%). Notwithstanding, on the basis of the contents of these aggregates, and according to the classification cited by S h e i n et al. (2001), all investigated non-calcareous rendzinas are well structured in dry condition. According to M a g d o f f and van E s (2000), perennial crops mostly improve soil structure, while annual row cropping often results in structural degradation, mainly due to a loss of ground cover and organic matter losses from soil disturbance.

Due to the application of various agro-technical measures, in the cultivated rendzina total content of cloddy- (>10 mm) and micro- (<0.25 mm) aggregates (26.2%) is about 3.5 to 1.5 times higher than in the rendzina under pasture (6.9%) and forest (17.0%). C o t c h i n g et al. (2002) found significantly higher content of dry aggregates >9.5 mm in the surface (0–7.5 cm) layer of cropped paddocks than in the same depth zone of a long-term pasture. Similar observations have been reported by S h e p h e r d et al. (2001). At intensive soil cultivation, the size of structural aggregates increases as a result of increased clodding (H a k a n s s o n et al., 1988).

On the basis of both structure coefficient (Ks) and the mean weight diameter (MWD) of dry aggregates, it may be concluded that the aggregate composition of the cultivated non-calcareous rendzina under a long-term cultivation suffered significant quantitative changes. In the humus horizon of cultivated rendzina Ks (Ks=2.6) is 4 to about 2 times lower than in the rendzina under pasture (Ks=10.5) and forest (Ks=4.6). According to the classification cited by S h e i n et al. (2001), Ks values in the all investigated.

Due to a long-term cultivation, MWD values of dry aggregates in cultivated non-calcareous rendzinas (4.2 mm), as well as in pasture (4.4 mm), are significantly ($P < 0.05$) lower in comparison with the forest (5.24 mm). S h e p h e r d et al. (2001) reported similar results. They found that long-term cropping increased MWD of dry aggregate-size distribution. In contrast, C o t c h i n g et al. (2002) reported that MWD of dry aggregates, as well as many other physical properties of investigated soils, did not become significantly impaired due to different agricultural management. According to them, one of the reasons was that these soils had not been excessively tilled.non-calcareous rendzinas are characteristic for the soils with good structure.

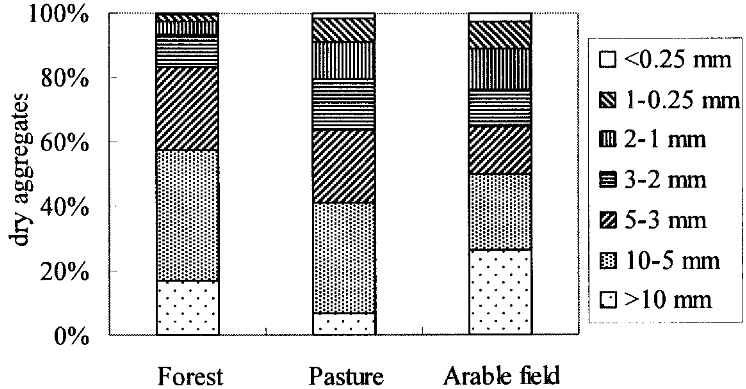

Fig. 1. – Effects of different non-calcareous rendzinas use on dry aggregate size distribution

Water stable aggregates

The data presented in Fig. 2 show that under the influence of long-term cultivation there occurred a significant decrease of the water stability of structural aggregates in arable horizons non-calcareous rendzinas. The long-term cultivated non-calcareous rendzina had the lowest water stable aggregate (>0.25 mm) percentage of the soil-use systems. Similar results were reported by M a r t e n s et al. (2003). They found that soil aggregate stability was much greater in the forest and pasture soils compared with the cropped soil. According to H o l e p l a s s et al. (2004) aggregate water stability increased with increasing concentration of soil organic carbon. The least water stability in the investigated rendzina was found in aggregates >3 mm. Microaggregates exhibit greater stability than macroaggregates (S k j e m s t a d et al., 1990). The content of water stable aggregates >3 mm in the cultivated non-calcareous rendzina (3.6%) is about 17 times lower than in forest (63.3%), and in comparison with the rendzina under pasture vegetation (18.6%) it is lower more than 5 times. The amount of these aggregates in non-calcareous rendzinas under pasture is about 3 times lower than in forest. The percentage of water stable aggregates larger than 2 mm was significantly greater under native savanna than under intervened systems (A m e z q u i t a et al., 1998). J a n k a u s k a s and J a n k a u s k i e n e (2003) reported that perennial grasses significantly increased soil aggregate stability. L a f f a n et al. (1996) observed that cropping paddocks had significantly lower water stable aggregates than long-term pasture, indicating that these paddocks may be more susceptible to erosion and the effects of raindrop impact when not vegetated. In comparison with plowing, no-till management systems have more water stable aggregates and soil organic carbon (F i l h o et al., 2002). Similar observations have been reported by P u l l e m a n et al. (2005). According to them, microaggregates from the pasture contained a larger fraction of total soil organic carbon and were more stable than microaggregates from the arable fields.

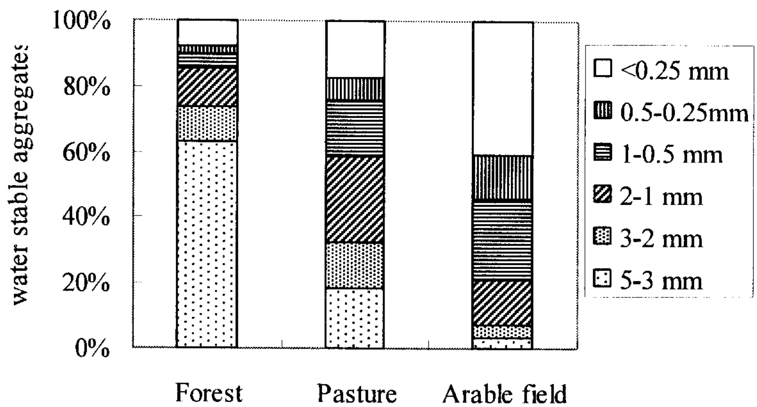

Fig. 2. – Effects of different non-calcareous rendzinas use on size distribution of water stable aggregates

Comparative analysis indicates that under the influence of anthropogenic factors in humus horizon there occurred a significant decrease water stability of microaggregates (< 0.25 mm). The content of these aggregates in cultivated non-calcareous rendzinas (40.9%) is 2.3 to 5 times higher than in rendzinas under pasture (17.3%) and forest (8.1%). M i k h a and R i c e (2004) reported that conventional tillage likely enhanced disruption of soil aggregates resulting in loss of soil organic matter. When pasture soils are brought into cultivation, the stability of soil aggregates and soil organic carbon levels declined rapidly (F r a n c i s, 2001). Higher water stability of structural aggregates in soils under meadow than in cultivated soil was found by K a v d i r et al. (2004), E y n a r d et al. (2004a), as well as H o y o s and C o m e r f o r d (2005).

Cultivated non-calcareous rendzinas had significantly ($P < 0.05$) lower MWD of water stable aggregates than forest and pasture. In the humus horizon of forest (1.44 mm) and pasture (1.20 mm) mean values of MWD of water stable aggregates are almost by about 2 times higher than in cultivated (0.65 mm) non-calcareous rendzina. According to S h e p h e r d et al. (2001), the conversion of pasture soils to continuous cropping using conventional cultivation markedly decreased the water stability of soil aggregates and increased dry aggregate size.

Conclusion

Comparative study of aggregate composition and water stability of structural aggregates of non-calcareous rendzina under natural forest and pasture vegetations, with long-term cultivated rendzina, shows that there occurred a significant impairment of the structure and aggregate composition of humus horizon.

The amount of cloddy (> 10 mm), poorly porous aggregates in cultivated non-calcareous rendzina is increased by about 1.5 to 3.5 times in comparison with the rendzina under natural pasture and forest vegetations. The percentage of agronomically most valuable aggregates (0.25–10 mm) is much decreased in comparison with the rendzina under natural forest and pasture vegetations.

Non-calcareous rendzinas which had been under forest and pasture had a significantly greater aggregate water stability than the long-term cultivated rendzinas.

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AGREGATNI SASTAV I STABILNOST STRUKTURNIH AGREGATA BESKARBONATNIH RENDZINA ISTOČNE SRBIJE

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R e z i m e

U ovom radu je dat prikaz uporednih istraživanja agregatnog sastava i vodootpornosti strukturnih agregata u humusnom horizontu beskarbonatnih, skeletnih, praškasto-glinovito ilovastih rendzina na laporcu i laporovitim krečnjacima, pod prirodnom šumskom i pašnjačkom vegetacijom, i istih rendzina koje se dugotrajno (vekovima) koriste kao njivska zemljišta u istočnoj Srbiji. Dugogodišnja antropogenizacije dovela je do znatnog pogoršanja agregatnog sastav i vodootpornosti strukturnih agregata. Međutim, i pored toga, njivske rendzine se, prema klasifikaciji koju navode S h e i n et al. (2001), još uvek karakterišu dobrim agregatnim sastavom. U njivskim rendzinama sadržaj agronomski najpovoljnijih agregata (prečnika 0.25–10 mm) je znatno smanjen, dok je udeo (prosek 26.15%) grudvastih agregata (prečnika >10 mm) znatno povećan u poredjenju sa šumom (17.00%) i pašnjakom (6.92%). U humusnom horizontu istraženih beskarbonatnih rendzina pod šumom i pašnjakom utvrdjena je znatno veća vodootpornost strukturnih agregata nego u njivskoj rendzini. Najmanju vodootpornost pokazali su strukturni agregati prečnika >3 mm.

Koeficijent strukturnosti u njivskoj redndzini znatno je manji nego pod šumom i pašnjakom. Najveći prosečni prečnik strukturnih agregata (MWD) u suvom stanju utvrdjen je u rendzinama pod šumom (5.24 mm), 4.41 mm pod pašnjakom i 4.20 mm u njivskoj rendzini. MWD vodootpornih strukturnih agregata veći je za oko 2 puta u zemljištu pod pašnjakom (1.20 mm) i pod šumom (1.44 mm) nego u njivskoj (0.65 mm) beskarbonatnoj rendzini.

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