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The Influence of Tillage and Crops on Particle Size Distribution of Water-Eroded Soil Sediment on Stagnosol

*Ivica KISIC, Igor BOGUNOVIC and Darija BILANDZIJA**

Department of General Agronomy, Faculty of Agriculture, University of Zagreb, Zagreb, Croatia
**Corresponding author: dbilandzija@agr.hr*

Abstract

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The influences of six different tillage treatments and five different crops on soil losses by water erosion were studied during a twenty-year period (1995–2014) on Stagnosol in central lowland Croatia. The aim of the study was to determine how the quantity of soil sediment, different tillage treatments and crops influence the particle size distribution (PSD) of soil sediment. During the studied period, total number of non-eroded soil samples was 60 and total number of soil sediments samples was 445. Significantly lower amounts of fine sand and higher amounts of clay and silt were determined in sediments compared to the non-eroded soil regardless of cover crop and tillage treatment, with the exception of bare cultivated soil. Generally, when quantities of soil sediments were higher, textural differences between non-eroded and eroded soil were lower. Very week negative correlation was determined between the quantity of soil sediment and the content of clay (r = –0.25) as well as the content of silt (r = –0.23). A very weak positive correlation (r = 0.23) was determined between the content of fine sand and the quantity of soil sediment, while non correlation (r = –0.02) was determined between the content of coarse sand and the quantity of soil sediment.

Keywords: Croatia; soil loss; soil management; soil texture

As a polydisperse system, soil is composed of particles of different sizes the composition of which defines the soil texture. The proportion of textural classes contributes to the physical, chemical, and biological properties of soil and thus the susceptibility of a particular soil type to erosion processes.

Pieri *et al.* (2009) indicated that many factors affect sediment detachment and redistribution including rainfall intensity, topography, land use, soil texture, soil organic matter content, soil moisture, soil management, and tillage operations. Meyer *et al.* (1980) indicated that particle size distribution (PSD) of eroded sediment has changed relatively little with major changes in rain intensity, continued erosion, and the presence or absence of crop canopy. Research results on this subject are contradictory. Some researches (Lal 1976; Alberts *et al.* 1980; Ampontuah *et al.* 2006) demonstrate a higher percentage of larger soil particles in sediments. Many previous studies have reported that eroded materials were enriched in silt-sized particles and clay relative to the non-eroded soil (Mannering & Bertrand 1971; Alberts *et al.* 1983; Bašić *et al.* 2002; Zhao *et al.* 2011; Shi *et al.* 2012). Conversely, others (Packer *et al.* 1992; Martinez-Mena *et al.* 2000; Jin *et al.* 2009) concluded that there are no differences between the non-eroded soil and soil sediments. However, these investigations were carried out under different agroecological conditions, on different soil types, and under different tillage treatments and cover crops.

The aim of this study was to determine which particle size classes were predominantly transported along the slope under different tillage treatments and crops. This paper provides information on how soil erosion processes affect PSD of eroded sediment and whether there are some differences in sediment yield and PSD that can be attributable to tillage and crop interaction.

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MATERIAL AND METHODS

The experiment was carried out in Daruvar in central lowland Croatia (45°33'48''N, 17°02'06''E, altitude 133 m a.s.l.) on Stagnosol (IUSS 2006).

Six different tillage treatments (area of one treatment is 41.3 m^2, 22.1 m long and 1.87 m wide) on a 9% slope were investigated: (*i*) Control plot (black fallow, BF) tillage up and down the slope. Applied tillage practices included: ploughing to a depth of 30 cm and seedbed preparation with a harrow, but the soil was kept bare at all time. The weeds were suppressed by total herbicides. This is the plot in which maximum soil loss was expected. (*ii*) Ploughing up and down the slope to a depth of 30 cm (PUDS). Seedbed preparation and sowing were performed in the same direction. (*iii*) No-tillage (NT) included sowing with a special seeder – John Deere 750A (John Deere, Mannheim, Germany) into the dead mulch up and down the slope. 2–3 weeks before sowing, weeds were suppressed by total herbicides. From the beginning of this investigation no cultivation has been done. Plant residues were retained on soil surface. (*iv*) Ploughing across the slope to a depth of 30 cm (PAS). (*v*) Very deep ploughing across the slope to a depth of 50 cm (VDPAS). In contrast to all other ploughing which was done with multi-furrow ploughs, a single-bottom plough was used in this treatment. (*vi*) Subsoiling to a depth of 50 cm (SSPAS). Subsoiling operation was performed with tines spaced 50 cm apart. Very deep ploughing and subsoiling were not applied every year, since their residual effect was taken into account. These practices were repeated every three to four years, in accordance with the crop rotation of investigated crops. In the last three tillage treatments seedbed preparation and sowing were performed across the slope.

The experimental plot was fenced off with a tin fence that was removed before each tillage operation and then placed back into the soil for the remainder of the growing season. Filtration equipment was set up at the lower end of each plot and was designed for volume measurement of water and sediment transported by surface runoff (Figure 1).

After each rainfall event that created soil loss, soil sediments were collected. During the studied period, total number of non-eroded soil samples was 60 and total number of soil sediments samples was 445 (133 on BF, 93 on PUDS, 52 on NT, 60 on PAS, 53 on VDPAS, and 54 on SSPAS). Also, some basic soil properties were determined in each soil horizon at the beginning of the research in 1995 (pH, soil organic matter, available phosphorus and potassium content, and PSD). Soil samples were transported to the laboratory for determination of soil properties. Soil samples were prepared in accordance with ISO 11464:2006. Soil reaction (KCl) was determined according to HRN ISO 10390:2005, soil organic matter content was determined according to HRN ISO 10694:2004, available phosphorus and potassium content was determined according to Egner *et al.* (1960). Particle size distribution or texture was determined according to ISO 11277:2009. The determined texture classes were: coarse sand (2–0.2 mm), fine sand (0.2–0.02 mm), silt (0.02–0.002 mm), and clay (less than 0.002 mm).

The crops on each experimental plot (apart from the control plot) were grown in a crop rotation that is typical for this part of Europe: 1995, 2000, 2008, and 2012 – maize (*Zea mays* L.); 1996, 2001, 2005, and 2009 – soybean (*Glycine hispida* L.); 1996/97, 2001/02, 2005/06, and 2012/13 – winter wheat (*Triticum aestivum* L.); 1997/98, 2002/03, 2006/07, and 2010/11 – oil seed rape (*Brasicca napus* var. *oleifera* L.) and double crop: 1998/99, 2003/2004, 2009/10, and 2013/14 – spring barley (*Hordeum vulgare* L.) with soybean.

Analysis of variance (ANOVA) was conducted using the GLM procedure (SAS Institute, Version 9.1.3) to evaluate the effects of tillage and crop on the quantity of sediment and its PSD. An estimate of the least significant difference (Tukey's LSD) between

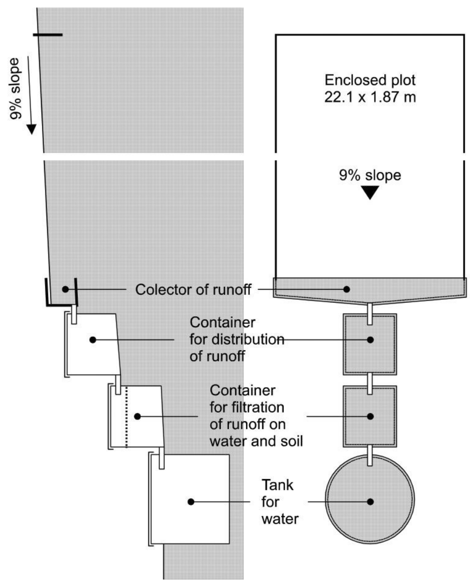

Figure 1. Measurement equipment for determining runoff and quantity of soil sediments (cited from Bašić *et al.* 2004)

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treatments was obtained. Statistical differences were declared significant at $P < 0.05$. The value of the correlation coefficient was ranked by Roemer-Orphal scale (0.0–0.10: no correlation, 0.10–0.25: very weak, 0.25–0.40: weak, 0.40–0.50: modest, 0.50–0.75: strong, 0.75–0.90: very strong, 0.90–1.0: full correlation) (Vasilj 2000).

RESULTS AND DISCUSSION

Soil properties of non-eroded soil. Parent material at this experiment site is loess of Upper Pleistocene origin – Riss, Würm (i.e. loess transformed into mottled, non-carbonate loam). Soil texture throughout the profile of non-eroded soil (0–95 cm) is a homogeneous loam. Soil was very acid in the arable layer and acid in the Btg horizon. There was little organic matter in the arable layer, medium phosphorus availability, and good potassium availability. Availability of these nutrients was low in the subsoil horizon. Basic soil profile characteristics are shown in Table 1.

Table 1. Soil profile characteristics of the Stagnosol at the experimental site (average value ± standard deviation)

	Horizons		
	Ap + Eg	Eg + Btg	Btg
Depth range (mm)	0–24	24–35	35–95
pH in KCl	4.21 ± 0.15	4.20 ± 0.18	4.81 ± 0.23
Soil organic matter (g/kg)	16 ± 3.3	14 ± 4.2	6 ± 3.8
Available P_2O_5 (g/kg)	172 ± 18	65 ± 4	244 ± 24
Available K_2O (g/kg)	308 ± 6	123 ± 8	502 ± 12
Clay (< 0.002 mm) (g/kg)	154 ± 25	148 ± 44	196 ± 40
Silt (0.02–0.002 mm) (g/kg)	242 ± 35	260 ± 54	254 ± 32
Fine sand (0.2–0.02 mm) (g/kg)	586 ± 37	571 ± 59	545 ± 69
Coarse sand (2–0.2 mm) (g/kg)	18 ± 4.7	21 ± 5.5	5 ± 2.3

(Source: Bašić *et al.* 2001)

Quantity of soil sediments. Information on the quantity of soil sediments in the investigated period per crop and tillage treatment is presented in Figure 2. The highest quantity of soil sediments was recorded under the BF tillage treatment. At all treatments with low density spring crops (maize and soybean) significantly higher quantity of soil sediments was recorded compared to treatments with high density autumn crops (winter wheat and oil-seed rape) and double crops (spring barley with soybean). In years with low density spring row crops in treatment with

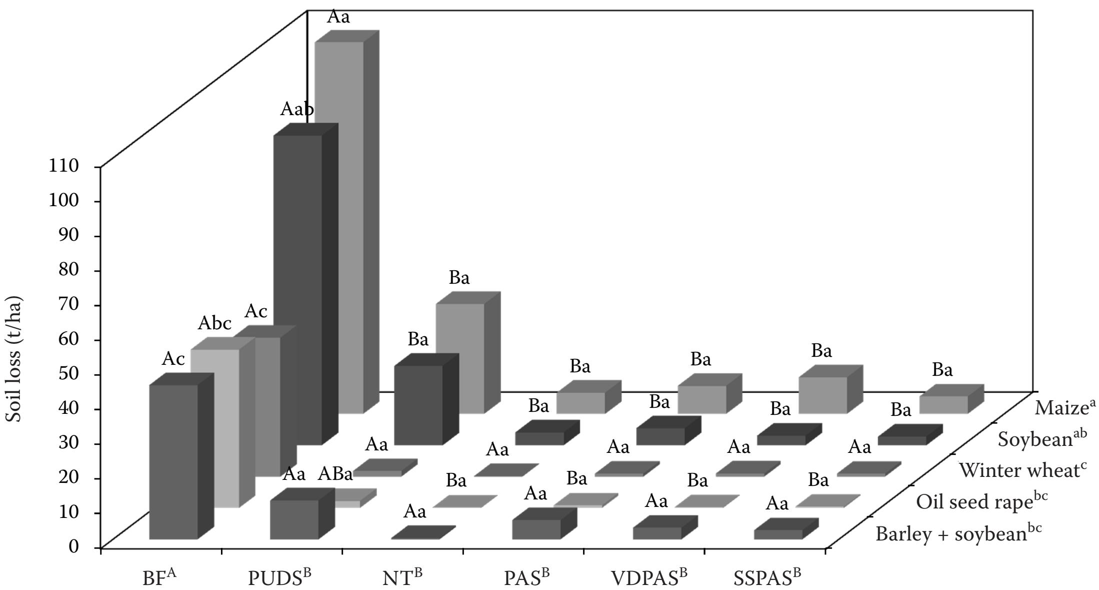

Figure 2. Average quantity of soil sediments under different tillage treatments and crops from 1995 until 2014; different letters indicate significant differences ($P < 0.05$) between crops (low-case letters) and tillage treatments (capital letters) BF – black fallow; PUDS – ploughing up and down the slope; NT – no-tillage; PAS – ploughing across the slope; VDPAS – very deep ploughing across the slope; SSPAS – subsoiling across the slope

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tillage up and down the slope, the quantity of soil sediments exceeded the soil loss tolerance level (10 t/ha/year) according to Schertz and Nearing (2002) and Li *et al.* (2009). For all other treatments in the production of high density winter crops the overall erosion was within the limits of tolerance levels. Tillage treatment had no significant effect on the overall erosion under wheat, which is in accordance with the results obtained in other studies (Tebrügge & Düring 1999; Van Muysen *et al.* 2002; Klima & Wisniowska-Kielian 2006).

Worldwide, many research studies showed that soil tillage and cultivation of wide-row spring crops up and down the slope is the combination which will cause the greatest amount of soil sediments (Fiener & Auerswald 2007; Sasal *et al.* 2010). In addition to tillage, vegetation cover had a significant impact on the total quantity of soil sediments (Figure 2). Since maize and soybean are wide-row low density crops (common maize sowing density is 75 000 plants per ha and soybean sowing density is about a million plants per ha), this is the main reason for creating conditions that cause greater erosion in comparison with high-density winter crops. Sowing density for oil seed rape is 3–3.5 million plants per ha and sowing density for winter wheat is 6–6.5 million plants per ha.

Particle size distribution of non-eroded soil and soil sediments. Figure 3 shows the PSD values in treatments on the non-eroded soil (NES) and soil sediments (SS). In terms of coarse sand (Figure 3a) there were no significant differences between non-eroded soil and soil sediments under the BF treatment and treatments with tillage across the slope (PAS, VDPAS, SSPAS). Under the PUDS and NT treatments significantly lower content of coarse sand was recorded in soil sediment compared to non-eroded soil. In terms of fine sand under the BF treatment, no significant differences were recorded between non-eroded soil

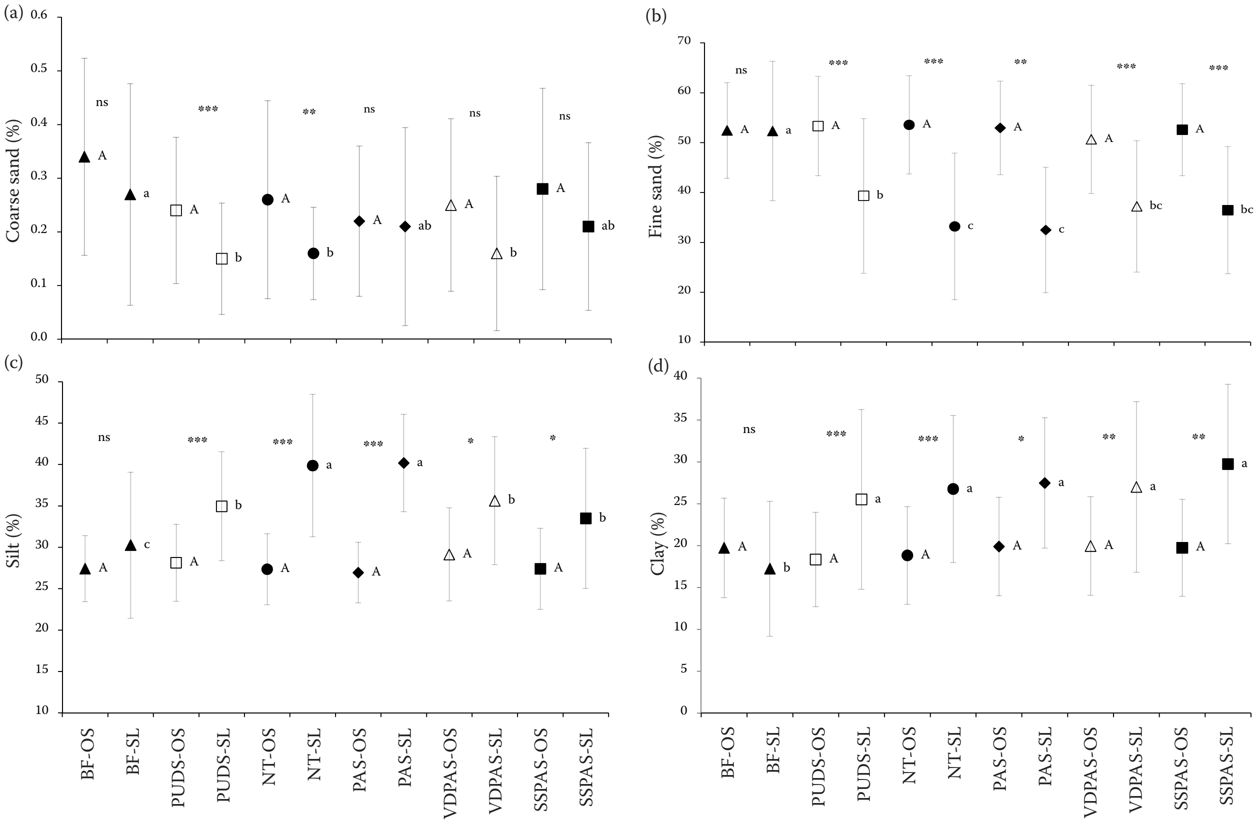

Figure 3. Content of coarse sand (3a), fine sand (3b), silt (3c), and clay (3d) in non-eroded soil (OS) and soil sediment (SL) under different tillage treatments; different letters indicate significant differences between tillage treatments in soil sediment (low-case letters) and non-eroded soil (capital letters); *, **, *** indicate significant difference in the treatment between non-eroded soil and soil sediment at $P < 0.05$, ** < 0.01, and *** < 0.001; ns – not significant

BF – black fallow; PUDS – ploughing up and down the slope; NT – no-tillage; PAS – ploughing across the slope; VDPAS – very deep ploughing across the slope; SSPAS – subsoiling across the slope

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and soil sediments (Figure 3b). The remaining treatments recorded significantly lower content of fine sand in soil sediment in relation to non-eroded soil.

Considering the content of silt and clay particles at BF treatment, no significant differences between non-eroded soil and soil sediment were determined (Figure 3c, d). At all other studied treatments, significantly higher contents of silt and clay particles were observed in soil sediment compared to non-eroded soil (Figure 3c, d). The highest content of silt in soil sediment was found under the NT and PAS treatments (Figure 3c). The BF treatment had a higher content of silt in soil sediment, but not at significant level. A similar situation was determined regarding clay particles (Figure 3d). The BF treatment recorded a lower content of clay particles in soil sediments, while the remaining treatments recorded significantly higher clay content in soil sediment.

Crops that were grown during this investigation did not have a direct impact on PSD of soil sediment. Their influence was indirect, depending on the total amount of soil sediment (Figure 2). Regardless of the grown crop, the following rule could be applied: if the quantity of soil sediment was higher (when corn and soybean were grown), the differences in PSD between eroded and non-eroded soil were smaller. The higher the amount of soil sediment was, its PSD corresponded more to non-eroded soil. If the amount of soil sediment was lower (when wheat, oil seed rape, and double crop were grown), the observed differences in PSD were higher. In this case more silt and clay particles were recorded in comparison to fine sand in soil sediment.

The research was carried out on Stagnosols, a soil type which is also known as pseudogley in this part of Europe (Bašić 2013). The physical composition (e.g. high content of silt and fine sand), chemical properties (low pH value, calcium carbonate deficiency, low content of soil organic matter), and a very low structural stability make these soils highly susceptible to water erosion on slopes (Kisić *et al.* 2017).

The twenty-year research project indicates that the only way to mitigate soil erosion by water in the cultivation of low density spring crops is tillage and sowing across the slope or a no-tillage management, which is consistent with the conclusions of other researches (Wagger & Denton 1989; Govers *et al.* 1994; Schuller *et al.* 2007). According to the presented results, when high density winter crops were cultivated on the arable land using any method and direction of tillage and planting, the erosion did not exceed soil loss tolerance for this soil type. Schwertmann *et al.* (1987) report a tolerant loss of 10 t/ha/year for this type of soil. The tillage method is not sustainable if the annual erosion exeeds 10 t/ha per year (Bašić *et al.* 2004; Verheijen *et al.* 2009). Data presented in this paper indicate that the BF and PUDS treatments are not sustainable agricultural practices (if spring row crops are grown), while all other investigated tillage treatments and crops are sustainable.

The results of the investigation suggest that erosion by water in agroecological conditions of central lowland of Croatia on Stagnosol does not equally remove all soil particles. Research has confirmed that finer soil particles (≤ 0.02 mm) were dominant in soil sediments. Richter and Negendank (1977) show that soils with 40–60% silt content are the most erodible, as is the case with the soil type on which this investigation was carried out. Research results have indicated that the total amount of soil sediment has an influence on its PSD. By comparing the values presented in Figure 2 on the total amount of soil sediment and differences in PSD (Figure 3) it is evident that the amounts of soil sediments per erosion event have implications on soil texture in soil sediments. In this case, the PSD of soil sediment was almost identical to the non-eroded soil.

Figure 4 shows a correlation between the quantity of soil sediment (t/ha) and certain textural classes. A very weak negative correlation was determined between the quantity of soil sediment and the content of clay ($r = -0.25$) and also between the quantity of soil sediment and the content of silt ($r = -0.20$). At the same time, a very weak positive correlation ($r = 0.23$) was determined between the content of fine sand and the quantity of soil sediment, while there was no correlation ($r = -0.02$) determined between the content of coarse sand and the quantity of soil sediment. Although the studied correlations were statistically insignificant, we assume that the decrease of silt and clay and increase of fine sand content depends on the quantity of soil sediment because a higher quantity of smaller particles was recorded when the amount of soil sediment was lower. As indicated above, Stagnosols are a highly erodible soil type with poor and unstable structure and when amounts of soil sediments are smaller, the separation of the smallest particles from non-eroded soil is easier and by erosional processes these particles are removed down the slope. The mentioned facts should be tested by other methods (e.g. use of rainfall simulations several times per season) in the future to achieve better conclusions. Additionally,

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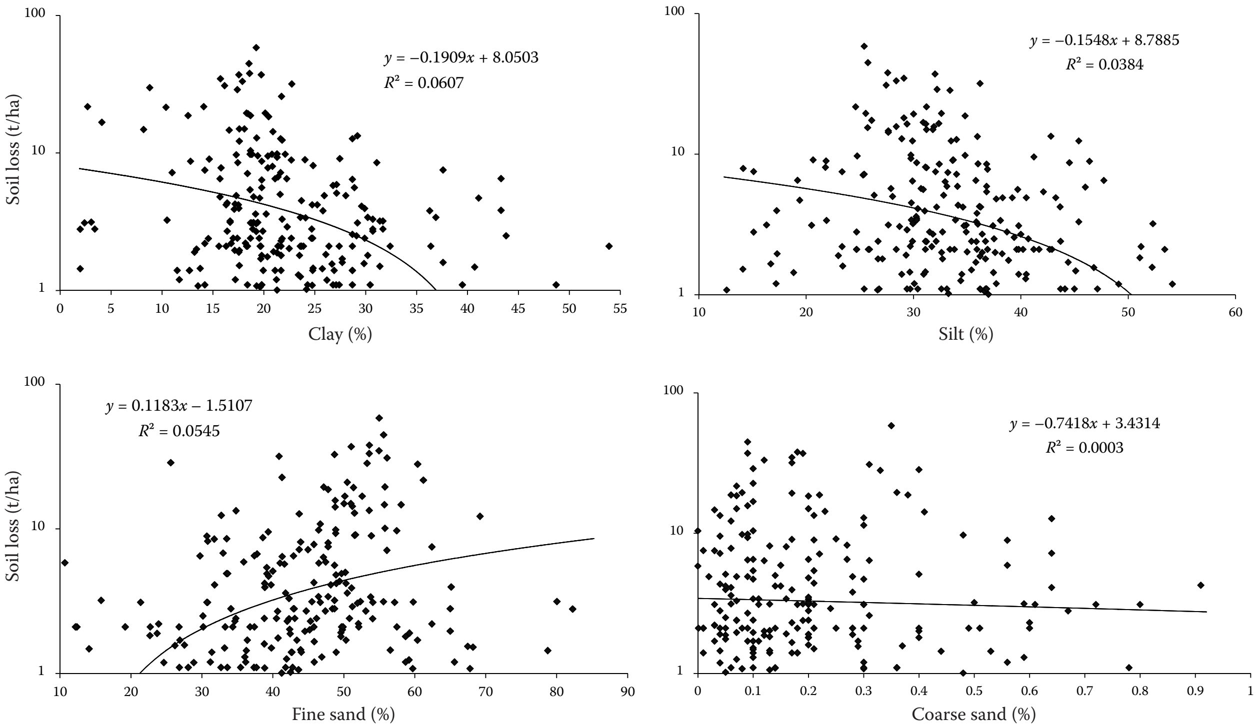

Figure 4. Correlation between percentage/content of clay, silt, fine sand, and coarse sand and soil sediments

according to Bašić (2013), erosional processes on this type of soil could be mitigated by improving soil chemical characteristics, by increasing the level of soil reaction and soil organic matter content.

As a result of selective removal of soil particles, soil erosion by water gradually leads to a selective distribution of plant nutrients and pollutants (Cihacek & Swan 1994; Fenton *et al.* 2005). This causes soil depletion of plant nutrients and pollutants in the removal zone, i.e. the upper part of the slope, and accumulation of these substances in the zone of sedimentation at the base of the slope in valleys along watercourses and in water accumulations (Holland 2003; Zhang *et al.* 2004).

The above discussion indicates that the PSD quality is affected by all the factors involved in the occurrence of erosion processes, firstly by the quantity of sediment as a consequence of tillage treatments and crops, followed by soil type.

CONCLUSIONS

Based on a twenty-year research on soil erosion by water, the following conclusions can be derived:

– The BF treatment recorded the highest quantity of soil sediments and the smallest differences in PSD between non-eroded soil and soil sediments. In this treatment no differences in PSD between non-eroded soil and soil sediment were detected.
– In treatments with lower amount of soil sediments (NT, PAS, VDPAS, and SSPAS) significant differences in the percentage of fine sand, clay, and silt particles were determined between non-eroded soil and soil sediment. The content of fine sand was lower, and the content of silt and clay particles was higher in the soil sediment compared to non-eroded soil.

References

Alberts E.E., Moldenhauer W.C., Foster G.R. (1980): Soil aggregates and primary particles transported in rill and interrill flow. Soil Science Society of America Journal, 44: 590–595.

Alberts E.E., Wendt R.C., Piest R.F. (1983): Physical and chemical properties of eroded soil aggregates. Transactions of the ASAE, 26: 465–471.

Ampontuah E.O., Robinson J.S., Nortcliff S. (2006): Assessment of soil particle redistribution on two contrasting cultivated hillslopes. Geoderma, 132: 324–343.

Bašić F. (2013): The Soils of Croatia. World Soils Book Series, Dordrecht, Springer.

Bašić F., Kisić I., Butorac A., Nestroy O., Mesić M. (2001): Runoff and soil loss under different tillage methods on Stagnic Luvisols in central Croatia. Soil & Tillage Research, 62: 145–151.

Bašić F., Kisić I., Nestroy O., Mesić M., Butorac A. (2002): Particle size distribution (texture) of eroded soil material. Journal of Agronomy and Crop Science, 188: 311–322.

doi: 10.17221/91/2016-SWR

Bašić F., Kisić I., Mesić M., Nestroy O., Butorac A. (2004): Tillage and crop management effects on soil erosion in Central Croatia. Soil & Tillage Research, 78: 197–206.

Cihacek L.J., Swan J.B. (1994): Effects of erosion on soil chemical properties in the north central region of the United States. Journal of Soil and Water Conservation, 49: 259–265.

Egner H., Riehm H., Domingo W.R. (1960): Untersuchungen über die chemische Bodenanalyse als Grundlage für die Beurteilung des Nährstoffzustandes der Böden. II Chemische Extraktionsmethoden zur Phosphor und Kalium. Kungliga Lantbrukshögskolans Annaler, 26: 45–61.

Fenton T.E., Kazemi M., Lauterbach-Barrett M.A. (2005): Erosional impact on organic matter content and productivity of selected Iowa soils. Soil & Tillage Research, 81: 163–171.

Fiener P., Auerswald K. (2007): Rotation effects of potato, maize, and winter wheat on soil erosion by water. Soil Science Society of America Journal, 71: 1919–1925.

Govers G., Vandaele K., Desmet P., Poesen P., Bunte K. (1994): The role of tillage in soil redistribution on hillslopes. European Journal of Soil Science, 45: 469–478.

Holland J.M. (2003): The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agriculture, Ecosystems & Environment, 103: 1–25.

IUSS (2006): World Reference Base for Soil Resources. 2nd Ed. World Soil Resources Reports No. 103. Rome, FAO.

Jin K., Cornelis W.M., Gabriels D., Baert M., Wu H.J., Schiettecatte W., Cai D.X., De Neve S., Jin J.Y., Hartmann R., Hofman G. (2009): Residue cover and rainfall intensity effects on runoff soil organic carbon losses. Catena, 78: 81–86.

Kisić I., Bogunović I., Birkás M., Jurišić A., Spalević V. (2017): The role of tillage and crops on a soil loss of an arable Stagnic Luvisol. Archives of Agronomy and Soil Science, 63: 403–413.

Klima K., Wisniowska-Kielian B. (2006): Anti-erosion effectiveness of selected crops and the relation to leaf area index (LAI). Plant, Soil and Environment, 52: 35–40.

Lal R. (1976): Soil erosion on Alfisoils in Western Nigeria: V. The changes in physical properties and the response of crops. Geoderma, 16: 416–431.

Li L., Du S., Wu L., Liu G. (2009): An overview of soil loss tolerance. Catena, 78: 93–99.

Mannering J.V., Bertrand J.T. (1971): Physical and Chemical Characteristics of the Soils from the Erosion Experiment Stations. Part I. Technical Bulletin, Washington D.C., USDA.

Martinez-Mena M., Alvarez Rogel J., Albaladejo J., Castillo V.M. (2000): Influence of vegetal cover on sediment particle size distribution in natural rainfall conditions in a semiarid environment. Catena, 38: 175–190.

Meyer L.D., Harmon W.C., McDowell L.L. (1980): Sediment sizes eroded from crop row sideslopes. Transactions of the ASABE, 23: 0891–0898.

Packer I.J., Hamilton G.J., Koen T.B. (1992): Soil loss and soil physical property changes of light textured surface soils from long term tillage treatments. Australian Journal of Soil Research, 30: 789–806.

Pieri L., Bittelli M., Hanuskova M., Ventura F., Vicari A., Rossi Pisa P. (2009): Characteristics of eroded sediment from soil under wheat and maize in the North Italian Apennines. Geoderma, 154: 20–29.

Richter G., Negendank J.F.W. (1977): Soil erosion processes and their measurement in German area of the Moselle river. Earth Surface Processes and Landforms, 2: 261–278.

Sasal M.C., Castiglioni M.G., Wilson M.G. (2010): Effect of crop sequences on soil properties and runoff on natural-rainfall erosion plots under no tillage. Soil & Tillage Research, 108: 24–29.

Schertz D.L., Nearing M.A. (2002): Erosion tolerance/soil loss tolerances. In: Lal R. (Ed.): Encyclopedia of Soil Science. Dordrecht, Springer: 448–451.

Schuller P., Walling D.E., Sepúlveda A., Castillo A., Pino I. (2007): Changes in soil erosion associated with the shift from conventional tillage to a no-tillage system, documented using 137Cs measurements. Soil & Tillage Research, 94:193–192.

Schwertmann U., Vogl W., Kainz M. (1987): Bodenerosion durch Wasser-Vorhersage des Abtrags und Bewertung von Gegenmaßnahmen. Stuttgart, Eugen Ulmer GmbH.

Shi Z.H., Fang N.F., Wu F.Z., Wang L., Yue B.J., Wu G.L. (2012): Soil erosion processes and sediment sorting associated with transport mechanisms on steep slopes. Journal of Hydrology, 454–455: 123–130.

Tebrügge F., Düring R.A. (1999): Reducing tillage intensity – a review of results from a long-term study in Germany. Soil & Tillage Research, 53:15–28.

Van Muysen W., Govers G., Van Oost K. (2002): Identification of important factors in the process of tillage erosion: the case of mouldboard tillage. Soil & Tillage Research, 65: 77–93.

Vasilj Đ. (2000): Biometrics and Experimentation in Plant Production. Zagreb, Croatian Society of Agronomists. (in Croatian)

Verheijen F.G.A., Jones R.J.A., Rickson R.J., Smith C.J. (2009): Tolerable versus actual soil erosion rates in Europe. Earth-Science Reviews, 94: 23–38.

Wagger M.G., Denton H.P. (1989): Influence of cover crop and wheel traffic on soil physical properties in continuous no-till corn. Soil Science Society of America Journal, 48: 152–156.

Zhang Y., Peng B.Z., Gao X., Yang H. (2004): Degradation of soil properties due to erosion on sloping land in southern Jiangsu Province, China. Pedosphere, 14: 17–26.

Zhao P., Shao M., Omran W., Amer A.M. (2011): Effects of erosion and deposition on particle size distribution of deposited farmland soils on the Chinese loess plateau. Revista Brasileira de Ciência do Solo, 35: 2135–2144.

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