ISSN-1332-9049

Č

Č

Bašić F.[1*], I. Kisić[1], O. Nestroy[2], A. Butorac[1], M. Mesić[1]

ABSTRACT

Water erosion was recorded during a four-year period (1994-1998.) on Luvic stagnosol (pseudogley), in the Daruvar area (Central Croatia), in different crop development stages according to USLE, under six tillage treatments in growing common arable crops in the common crop sequence. A much higher rate of erosion, higher than Soil loss tolerance (T value) was recorded in the growing of spring crops (row crops) than in winter crops of high plant density, where it was below the T value. In the growing of spring crops, the critical period with maximal water erosion was the period of seedbed preparation (SB period according of USLE), the period just after sowing. In the growing of maize and soybean, this is the period when over 80% of the overall annual erosion occurs in all tillage variants. As expected, the maximal rate of soil erosion, higher than the T value, was recorded in the standard plot according to USLE, followed by the variant of conventional up/down the slope tillage. Soil erosion was much smaller and below the T value in the no-tillage variant and in all variants with tillage across the slope. This means that these variants of soil tillage can be defined as conservation tillage in agroecological conditions of this part of Croatia. In growing winter crops of high density (wheat and oil seed rape), no critical periods were observed and erosion was much below the T value and was uniformly distributed throughout the whole growing season. According to the results, to reduce soil erosion below the T value on slopes of inclination higher than 9%, soil conservation practices are all tillage operations across the slope and/or a reduced crop rotation, without row crops.

KEYWORDS: Water erosion, Crop development stages, Conservation tillage, Soil loss tolerance – T value.

[1]Department of Agronomy, Faculty of Agriculture, Zagreb, Croatia
[2]Technische Universität, Graz, Austria
*Corresponding author: Tel: 385 1 23 93 959 Fax: 385 1 23 93 981 email: fbasic@agr.hr

anuscript received January 15, 2000
Accepted for publication February 18, 2000

Č Č

Bašić F.[1*], I. Kisić[1], O. Nestroy[2], A. Butorac[1], M. Mesić[1]

SAŽETAK

Tijekom četvorogodišnjeg razdoblja (1994-98) na pseudogleju središnje Hrvatske pri različitim varijantama obrade tla istraživana je erozija tla vodom. U istraživanja su uključeni usjevi koji dominiraju u ovom podneblju, dok su varijante obrade slijedeće: 1. Standardna parcela prema USLE - crni ugar 2. Konvencionalno oranje (do 25 cm) uz i niz nagib 3. Izostavljanje obrade - izravna sjetva, 4. Konvencionalno oranje okomito na smjer nagiba 5. Vrlo duboko oranje (do 50 cm) okomito na smjer nagiba. 6. Podrivanje na 60 cm dubine + konvencionalno oranje okomito na smjer nagiba.

Temeljem polučenih rezultata i odnosa s tolerantnom erozijom za ovaj tip tla zaključujemo da su erozijski nanosi pri u uzgoju jarina rijetkog sklopa (kukuruz i soja) mnogo veći u odnosu na tolerantno odnošenja za ovaj tip tla. Kritično razdoblje pri uzgoju ovih kultura je neposredno poslije sjetve ovih usjeva (razdoblje nicanja pa dok usjev nije prekrio 10% površine). U ovom razdoblju utvrđeno je preko 80 % ukupne godišnje erozije, bez obzira na smjer obrade. Pri uzgoju ozimih kultura gustog sklopa (pšenica i uljana repica) nisu zabilježeni kritična razdoblja, dok je ukupna erozija izrazito niža od tolerantnog odnošenja, pa u obzir dolaze svi istraživani načini obrade tla.

Temeljem svega navedenog zaključujemo da je obrada uz/niz nagib pri uzgoju jarina rijetkog sklopa visoko rizična na nagnutim terenima, pa bi taj način obrade tla trebalo napustiti. Izostavljanje obrade i bilo koji od načina obrade okomito na nagib preporučamo za širu primjenu u poljoprivrednoj proizvodnji. Smatramo da je riječ je o načinima obrade tla koji su u skladu s održivom poljoprivredom u ovom podneblju.

KLJUČNE RIJEČI: Erozija tla vodom, periodi razvoja usjeva, konzervacijska obrada, tolerantno odnošenje tla

[1]Department of Agronomy, Faculty of Agriculture, Zagreb, Croatia
[2]Technische Universität, Graz, Austria
*Corresponding author: Tel: 385 1 23 93 959 Fax: 385 1 23 93 981 email: fbasic@agr.hr

1. Introduction and investigation goal

The investigation goal is to determine the critical crop-stage periods and soil conservation practices on Luvic stagnosol (pseudogley) in the growing of common field crops. We search for the answer to the question whether it is possible to reduce water erosion to or below the Soil loss tolerance level (T value) by applying different soil tillage practices, crop management and crop sequence. Based on the results obtained, the optimal conservation tillage has to be determined for Luvic stagnosol, as a soil very prone to erosion.

The results should provide elements for recommending the optimal method of conservation tillage on Luvic stagnosol, as a very widespread soil type in this part of Europe.

2. Materials and methods

The stationary field trial was set up in the summer of 1994, after the oil seed rape harvest, on arable land of the farm "Poljodar" in Daruvar, central Croatia, on Luvic stagnosol [31]. Erosion was measured on 6 enclosed trial plots, according to the USLE propositions [30], viz. on a 9% slope, length 22.1 m, width 1.87 m, or a plot area of 41.3 m^2. Plots are enclosed by a sheet-metal fence, which is removed before each tillage operation, and then put up again after the operation is completed. The fence is set up so as to ensure that soil suspension cannot penetrate the trial plot from the sides or run off from the enclosed plot area. To facilitate the application of agricultural machinery, the trial variants are set 15 m apart, which allows for free and easy turning of a tractor with the longest trailing implement.

The experimental station consists of the following six treatments: ❶ Standard plot according to USLE, tilled up/down the slope. All tillage operations are applied in this variant (mouldboard to 30 cm deep, disc-harrowing, dragging), but it is unsown. ❷ Conventional (mouldboard) ploughing up/down the slope to 30 cm deep. Sowing and all the other agricultural practices commonly applied to relevant crops are performed in the same direction. ❸ No-tillage, sowing with a special seeder into dead mulch, up/down the slope. A week to two weeks before sowing, weeds are eradicated using total herbicides. ❹ Conventional (mouldboard) ploughing across the slope to 30 cm deep. ❺ Very deep ploughing across the slope (to 50 cm deep). In contrast to all other ploughing practices, which are done with multi-furrow ploughs, the single-furrow plough is applied in this treatment. ❻ Subsoiling to the depth of 60 cm, subsoiler working bodies set 70 cm apart, with conventional (mouldboard) ploughing across the slope to 30 cm deep. In the last three variants, sowing and all other agricultural practices are performed across the slope.

Special equipment enabling separation and filtration of soil suspension has been set up on the lower part of each trial plot, clean water is collected in a separate container while solid drift remains on the cloth serving as filter.

Crops were grown on experimental plots in the following crop sequence: 1994/95 - maize (Zea mays), 1995/96 - soybean (Glycine hispida max), 1996/97 - winter wheat (Triticum aestivum), 1997/98 - oil seed rape (Brassica napus v. oleifera).

Crop development is monitored per stages of crop growing according to USLE [28] and [30]: Period F - rough fallow (ploughing to sowing); Period SB - seedbed (sowing to 10% of area covered by crop), Period 1 - establishment of crop (SB to 50% of area covered by crop); Period 2 – crop development (100% of area covered by crop); Period 3 – crop maturing (to harvest); Period 4 - residue or stubble (crop harvest to mouldboard ploughing or new sowing).

3. Results and discussion

3.1. Characteristics of the climate

Major long-term (1959-1998) indicators of climatic properties in the course of investigation are shown in Table 1. It is noticeable that the long-term precipitation mean amounts to 863 mm, with a monthly rain maximum in June.

TABLE 1. Long-term (1995-1998) rainfall distribution and average temperature of the Daruvar area

Period – Year		Total monthly, average monthly temperature (^0C), maximal daily and maximum 30 min. intensity of rain – mmn. intensity of rain – mm												Total, mm
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Average ^0C
1995	**total monthly**	46	68	42	39	80	154	3	136	183	13	89	59	912
	average temp. ^0C	**1.1**	**6.6**	**5.4**	**11.6**	**15.2**	**18.2**	**23.3**	**19.4**	**14.8**	**11.6**	**4.3**	**1.7**	11.1
	max. daily rain, mm	**13.6**	**28.1**	**10.5**	**12.1**	**16.1**	**33.0**	**2.0**	**34.9**	**71.2**	**8.5**	**24.7**	**16.1**	
	max. 30 min. inten.	**3.1**	**3.6**	**4.7**	**3.0**	**8.7**	**11.7**	**0.5**	**26.7**	**14.9**	**2.3**	**2.4**	**1.3**	
1996	**total monthly**	75	24	24	65	94	40	93	37	226	45	109	60	893
	average temp. ^0C	**-1.3**	**-1.1**	**3.2**	**10.8**	**17.2**	**20.2**	**19.4**	**19.8**	**12.8**	**11.2**	**7.8**	**-1.2**	9.9
	max. daily rain, mm	**21.2**	**11.0**	**12.2**	**18.7**	**33.0**	**13.5**	**45.8**	**12.1**	**62.5**	**15.7**	**29.3**	**14.4**	
	max. 30 min. inten.	**1.9**	**1.7**	**1.2**	**3.0**	**12.9**	**11.1**	**9.5**	**8.1**	**8.9**	**3.6**	**5.0**	**1.2**	
1997	**total monthly**	47	55	23	43	66	91	112	79	22	64	106	64	771
	average temp. ^0C	**-1.5**	**0.6**	**3.1**	**8.4**	**15.1**	**16.1**	**17.9**	**19.9**	**15.9**	**10.9**	**5.7**	**1.6**	9.5
	max. daily rain, mm	**9.7**	**26.8**	**12.6**	**13.0**	**27.7**	**28.8**	**23.5**	**24.4**	**13.8**	**29.1**	**38.4**	**19.1**	
	max. 30 min. inten.	**2.3**	**2.5**	**1.4**	**2.9**	**3.8**	**17.2**	**12.4**	**8.0**	**4.0**	**9.7**	**2.3**	**3.8**	
1998	**total monthly**	62	5	64	69	75	100	82	84	114	119	77	47	898
	average temp. ^0C	**3.1**	**4.6**	**4.3**	**12.2**	**15.1**	**20.2**	**21.1**	**20.3**	**15.3**	**11.9**	**3.4**	**-2.9**	10.7
	max. daily rain, mm	**27.4**	**3.4**	**19.5**	**17.6**	**17.2**	**18.8**	**25.5**	**34.7**	**25.9**	**35.3**	**16.6**	**23.2**	
	max. 30 min. inten.	**1.9**	**0.8**	**2.6**	**4.6**	**4.3**	**10.0**	**19.6**	**9.0**	**4.6**	**8.2**	**3.1**	**0.7**	
Average, mm: 1959-1998		55	47	58	73	88	97	85	82	62	70	83	63	863
Average, ^0C: 1959-1998		-0.4	1.9	6.3	10.9	15.5	18.9	20.6	19.9	15.9	10.9	5.7	1.6	10.7

3.2. Properties of the soil

According to soil classification [31], the soil type of the experimental station is defined as Luvic stagnosol, formed on non-carbonate Pleistocene loam as parent material, with A_{ch}+E_{cg}–E_{cg}+B_{tg}–B_{tg} sequence of soil horizons. Due to its physical (high content of fine sand and loam) and chemical properties (calcium deficiency, low content of organic matter), this soil type is very erodible. Data from Table 2 indicate that this is a poorly porous to porous soil of a medium water holding capacity.

TABLE 2. Physical properties of the soil

Soil depth, cm	Soil horizon	Porosity, (% Vol.)	Water holding capacity, %	Air capacity, %	Specific density, g/cm³ Bulk	Real
0-24	**Ach + Ecg**	**43.8**	**35.0**	**8.8**	**1.45**	**2.58**
24-35	**Ecg + Btg**	**43.3**	**35.4**	**7.9**	**1.43**	**2.52**
35-95	**Btg**	**41.8**	**39.1**	**2.6**	**1.52**	**2.61**

The soil is sandy loam in all horizons. It is characterized by a high content of fine sand and silt. Differences in clay content are not large and are generally a consequence of soil mixing through tillage. Clay content is increased in the B_{tg} horizon (Table 3).

TABLE 3. Soil texture

Soil horizon	Depth cm	% particle size distribution, mm				
		Coarse sand	Fine sand	Silt	Clay	Texture
$A_{ch}+E_{cg}$	0-24	1.8	58.6	24.2	15.4	Sandy loam -SL
$E_{cg}+B_{tg}$	24-35	4.1	55.1	26.0	14.8	Sandy loam- SL
B_{tg}	35-95	0.5	51.5	25.4	19.6	Sandy loam- SL

Soil reaction is very acid in the topsoil and acid in the B_{tg} layer (Table 4). Related to this, the soil is also of high hydrolytic acidity. There is a low humus content in the plough layer, soil supply of plant available phosphorus is medium, and of plant available potassium good.

TABLE 4. Chemical properties of the soil

Soil horizon	Depth cm	pH in nKCl	Humus, %	Hydrolytic acidity, Y_1	mg/100 g soil P_2O_5	K_2O
$A_{ch}+E_{cg}$	0-24	4.21	1.6	13.2	10.56	10.00
$E_{cg}+B_{tg}$	24-35	4.20	1.4	12.3	9.02	8.98
B_{tg}	35-95	4.81	0.6	5.0	5.69	6.18

3.3. Erosion in different tillage treatments and in growing different crops

Investigations were conceived so as to obtain the answer to the set investigation goal by applying adequate methods of basic soil tillage and of growing the main field crops. It is assumed that the differences that will occur in surface runoff and erosional drift will be directly dependent on the applied soil tillage methods and crops. The obtained results will serve as the basis for determining the tillage method that will most efficiently stop erosional processes, that is, reduce erosion risk in crop growing, protect the environment, at the same time sustaining or increasing the attained growing levels.

3.3.1. Erosion in the growing of row (spring) crops

Numerous studies conducted in the world, among which mention is made of only some of the authors, from North America – [15] and [19], South America – [9], Australia – [23], Asia – [20], Africa – [1], [4], [6], [17], [26] and [27], and Europe - [2], [5], [14], [22] and [24], have proven that conventional up/down the slope ploughing and sowing is the least favourable tillage method, since it leads to highest erosion, whereas no-tillage and ploughing across the slope are much more efficient in terms of erosion control. This has also been confirmed by our investigations.

Row (spring) crops were grown in the first two investigation years (maize 1994/95 and soybean 1995/96). Erosion in those years was determined per different stages of crop development according to USLE and is shown in Table 5.

Table 5. Soil erosion in different crop-stages of row (spring) crops

Crop-stage	Standard plot (Black fallow)	Ploughing up/down the slope	No tillage	Ploughing	Very deep ploughing across the slope	Subsoiling +ploughing
			MAIZE GROWING			
Period SB – Seedbed (t/ha)	**34.74**	**28.86**	**18.48**	**9.54**	**18.80**	**2.69**
% of the rate	23.7	74.9	80.8	81.8	88.9	90.0
Period 1 – establishment (t/ha)	1.37	0.36	0.015	-	-	-
% of the rate	0.9	1.0	0.1			
Period 2 – development (t/ha)	**50.24**	**5.22**	**1.58**	**0.65**	**1.13**	**0.05**
% of the rate	34.3	13.5	6.9	5.6	5.4	1.8
Period 3 – maturing (t/ha)	**59.97**	**4.09**	**2.78**	**1.47**	**1.19**	**0.24**
% of the rate	41.1	10.6	12.2	12.6	5.7	8.2
Rate of erosion (t/ha) October 1994-October 1995	**146.32**	**38.53**	**22.86**	**11.66**	**21.12**	**2.99**
			SOYBEAN GROWING			
Period F - Rough fallow (t/ha)	**0.048**	**0.091**	**0.009**	**0.015**	**0.023**	**0.063**
% of the rate	0.1	0.2	0.1	0.3	0.5	2.2
Period SB – Seedbed (t/ha)	**32.41**	**37.43**	**13.4**	**5.13**	**4.89**	**2.54**
% of the rate	29.4	98.0	98.6	95.7	93.2	87.4
Period 1 – establishment (t/ha)	**1.304**	**-**	**-**	**-**	**-**	**-**
% of the rate	1.2	-	-	-	-	-
Period 2 –development(t/ha)	**2.024**	**0.008**	**0.025**	**-**	**-**	**-**
% of the rate	1.8	0.1	0.2	-	-	-
Period 3 – maturing (t/ha)	**73.10**	**0.64**	**0.10**	**0.20**	**0.32**	**0.27**
% of the rate	66.4	1.6	1.0	4.0	6.0	9.4
Period 4 – residue (t/ha)	**1.26**	**0.02**	**0.002**	**-**	**0.015**	**0.024**
% of the rate	1.1	0.1	0.1	-	0.3	1.0
Rate of erosion (t/ha) November 95-October 96	**110.14**	**38.18**	**13.53**	**5.35**	**5.26**	**2.90**

It is obvious that the convincingly greatest rate of erosion (146.32 and 110.14 t/ha) was recorded in the unsown - standard trial variant. This quantity is several times higher than the tolerant level of erosion – T value, which for this type of soil amounts to 10 t/ha/y [3] and [25], This is followed by the variant involving conventional ploughing up/down the slope with 38.53 and 38.18 t/ha, respectively, of eroded soil. A smaller rate of erosion was recorded in the no-tillage variant (22.86 and 13.54 t/ha) and in very deep ploughing across the slope (21.12 and 5.26 t/ha, respectively). This is followed by conventional ploughing across the slope with the rate of erosion of 11.6 and 5.35 t/ha, respectively. The best results in terms of soil conservation were achieved in the variant involving subsoiling with ploughing across the slope, where erosion rates were only 2.99 and 2.9 t/ha, respectively. The results give absolute advantage to ploughing across the slope. Up/down the slope ploughing should be omitted altogether. Maize and soybean are considered to be "high-risk crops" by all the authors studying erosion problems on arable areas, regardless of the tillage direction [2], [4], [10], [12], [13] and [16]. Besides, in early sowing, at a time when the soil is bare and unprotected, of spring row crops, as crops of low density, the large intra- and inter-row spacing enables intensified erosion. Therefore, soil under row crops cannot be fully protected from the direct impact of raindrops even in later stages, which leads to erosion also in later crop-stages. Application of ploughing across the slope may reduce erosion to a tolerant level by comparison with the up/down the slope ploughing and sowing. The position of furrows in this tillage practice prevents excessive surface runoff and thus reduces erosion. In the treatments with deep tillage, the larger depth of the plough-layer enables stronger infiltration of water and in this way additionally reduces surface runoff.

The results show that the critical period in growing row (spring) crops is that of bare soil, the SB period. On the standard plot according to USLE, an erosion rate of 23.7% (maize) or 29.4% (soybean) was recorded in that period. Different results were obtained in other variants. In ploughing up/down the slope, the SB period erosion accounted for 74.9 and 98.0%, respectively, of the total annual erosion while in the no-tillage variant it amounted to 80.8 and 98.6%, respectively. In the variant involving ploughing across the slope, the SB period erosion amounted to 81.8 (maize) and 95.7% (soybean) of the annual rate of erosion while in the variant with very deep ploughing across the slope to 88.9 and 93.2%, respectively. In the variant of subsoiling with ploughing across the slope, the SB period erosion accounted for 90.0 and 87.4%, respectively, of the annual rate. The reason for such high values is that this is the period when the soil is bare and unprotected - without any vegetational cover, immediately after sowing. Raindrops of high intensity fall directly onto the soil, which leads to surface runoff and occurrence of erosion in all trial variants.

3.3.2. Erosion in the growing of winter crops

Winter crops were grown in the last two years (wheat in 1996/97 and oil seed rape in 1997/98). Soil erosion in those years was determined per different stages of crop development according to USLE and is shown in Table 6.

Like in the growing of row crops, the highest rate of erosion was recorded in the standard variant. In winter wheat growing erosion amounted to 86.77 t/ha and in oil seed rape to 54.05 t/ha. Although erosion rates were lower than in the first two trial years, this is still very high erosion, which exceeds the tolerant threshold of soil loss (T value) of 10 t/ha/y for this soil type. Rates of erosion recorded in all the other treatments were below the tolerant soil loss. As expected, relatively higher rates were achieved with ploughing up/down the slope. In this variant, erosional drift amounted to 0.54 t/ha in winter wheat and to 0.40 t/ha in oil rape. The total annual soil loss in the no-tillage variant amounted to 0.22 t/ha (wheat) and 0.34 t/ha (oil seed rape) while in the variant with ploughing across the slope it was 0.07 and 0.13 t/ha, respectively. In the variant with very deep ploughing across the slope, erosion was 0.31 and 0.17 t/ha, respectively. The lowest rates of erosion and the highest efficiency of soil protection were recorded in the variant involving subsoiling and ploughing across the slope. The rates in this variant amounted to 0.13 t/ha and 0.08 t/ha of eroded soil.

Table 6. Soil erosion in different crop-stages and the rate of erosion in growing winter crops

Crop-stage	Standard plot (black fallow)	Ploughing up/down the slope	No-tillage	Ploughing across the slope	Very deep ploughing across the slope	Subsoiling +ploughing across the slope
WINTER WHEAT GROWING						
Seedbed (t/ha)	12.22	0.226	0.03	0.027	0.172	0.102
% of the rate	14.1	41.9	13.6	36.2	56.3	77.0
Period 1 – establishment (t/ha)	9.112	0.213	0.064	0.002	-	0.018
% of the rate	10.5	39.4	28.7	2.5	-	13.8
Period 2 – development (t/ha)	3.946	0.025	0.023	0.008	-	-
% of the rate	4.5	4.6	10.2	11.5	-	-
Period 3 – maturing (t/ha)	52.54	0.07	0.08	0.035	0.10	0.01
% of the rate	60.6	12.9	38.4	46.6	33.2	7.7
Period 4 – residue (t/ha)	8.94	0.006	0.02	0.002	0.032	0.002
% of the rate	10.3	1.2	9.1	3.2	10.5	1.5
Rate of erosion, (t/ha) October 1996-August 1997	**86.77**	**0.54**	**0.22**	**0.07**	**0.31**	**0.13**
OIL SEED RAPE GROWING						
Period F - rough fallow (t/ha)	0.633	0.002	0.284	0.007	0.112	0.001
% of the rate	1.2	0.5	83.9	5.5	64.0	1.2
Period SB – seedbed (t/ha)	0.007	0.007	0.002	0.002	-	-
% of the rate	0.1	1.7	0.7	1.3	-	-
Period 1– establishment (t/ha)	30.453	0.319	0.020	0.092	0.037	0.042
% of the rate	56.3	80.2	5.9	72.1	21.1	52.2
Period 2 – development (t/ha)	16.533	0.052	0.015	0.027	0.026	0.038
% of the rate	30.6	13.1	4.3	21.1	14.9	46.6
Period 3 – maturing (t/ha)	2.179	0.014	0.015	-	-	-
% of the rate	4.0	3.6	4.5	-	-	-
Period 4 – residue (t/ha)	4.251	0.003	0.002	-	-	-
% of total drift	7.8	0.9	0.7	-	-	-
Rate of erosion, (t/ha) August 1997-July 1998	**54.05**	**0.40**	**0.34**	**0.13**	**0.17**	**0.08**

Accordingly, regardless of the ploughing direction, erosional drifts in the growing of winter crops were much lower than in the first two trial years when row crops were grown. This is the reason why, in soil conservation, we lay greater importance on the crop grown than on the tillage method applied. In the next few sentences, we will try to answer the question why erosion rates were much lower in the growing of winter crops.

Winter crops were sown towards the end of October (winter wheat) and August (oil seed rape). Sowing was preceded by a long and dry summer period, during which rather coarse structure aggregates, which increase the intensity of rainwater infiltration and reduce or prevent surface runoff, were formed. Besides, there are usually no high intensity rains after wheat and oil rape sowing, rain falls onto dry soil and the soil can take up large quantities of water for saturation to field capacity. No surface runoff occurs in such conditions. In the winter period of the year when the soil is fully saturated and if it does not get frozen, erosion does occur but the drift quantity is small.

In the growing of winter crops there are no critical periods with occurrence of large quantities of erosional drift. Data from Table 6 show a uniform distribution of erosion during the whole growing season of winter crops. In the period of the highest erosion risk in the studied area (May-June), winter crops fully cover soil surface with a dense cover. This vegetational cover efficiently protects the soil from the direct impact of raindrops (which are often very intensive in this part of the year) and thus contributes to the reduction of the erosion rate.

In the foregoing text, soil losses were presented per particular crops. It can be seen that low-density row (spring) crops are subjected to high erosion in the variant involving ploughing and sowing up/down the slope, whereas erosion rates are much smaller in treatments involving ploughing across the slope. Much lower erosion was recorded in the growing of high-density winter crops regardless of the ploughing direction. These results are in agreement with the results obtained by other authors: [7], [8], [11], [18], [21] and [29].

3. Conclusions

The presented results show that water erosion cannot be completely stopped, however it can be reduced to a tolerant level by choosing appropriate tillage treatments.

Appreciably higher rates of soil erosion were recorded in the growing of low-density row (spring) crops (maize and soybean) than in high-density winter crops (wheat and oil seed rape) under the same tillage treatments. The time immediately following the sowing of spring crops (SB-seedbed) is the most critical period, that is, the period when highest soil erosion occurs.

Growing of row (spring) crops, which dominate the crop rotation in the investigated area, on sloping terrains will require a balanced tillage system (no-tillage and ploughing across the slope) and an appropriate crop sequence.

Efficient soil conservation on Luvic stagnosol of 9% and milder slopes can be achieved by no-tillage and all across-the-slope tillage practices. Summing up all the advantages and drawbacks of the studied tillage practices for a wide application in crop growing on this soil type, we recommend no-tillage and conventional ploughing across the slope.

References

1. Abebe, A., 1992. Assessment of runoff and soil losses under different cover crops and slop lengths. Inst. of Agr. Res., Addis Ababa, Ethiopia, 50-56.
1. Bašić, F., I. Kisić, A. Butorac, and M. Mesić. 1997. Soil erosion by different tillage systems on stagnosol in Croatia, Proceedings of the 14th Conf. of ISTRO, Pulawy, Poland, 63-67.
3. Bašić, F., 1992. Bodenerosion in Rahmen des Bodendauerbeobachtungsflachen - programms, Exp. der gemeinsamen Arbeitsgruppe für Bodenschutz, ARGE Alpen, Alpen-Adria und Donauländer, “Bodenerosion und Strukturveränderung”, Bayerisches Staatsministerium für Landesentw. und Umweltfragen, Zagreb, Croatia, pp. 57-76.
4. Bašić, F., I. Šalinović, I. Bašić, A. Kellkayyelah, and A. Butorac, A. 1991. Possibilities of Soil Conservation by Means of Different Tillage Systems on Acric Ferralsol of the Ethiopian Plateau. Proceedings of the 12th Conference of ISTRO: Soil Tillage and Agricultural Sustainability, Ibadan-Nigeria, 58-60.
5. Bašić, F., Butorac, A., Mesić, M., Sabolić, M. 1993a. Aktualna pitanja erozije i smjernice konzervacije oraničnih tala Hrvatske, Polj. aktualnosti 3-4, pp. 227-249.

6. Bašić, F., Butorac, A., Šalinović, I., Bašić, I., 1993b. Agroecological Study of Horo Alleltu Farmland, Proposal for Preliminary Project of Integral Soil Conservation-Guidelines for Conservation Farming System, final revised version, Nekemte - Agroindustrial Project, Ministry of State Farms, Coffee and Tea Development-North Western Agricultural Development Corporation, Addis Ababa-Ethiopia, p. 258.
7. Chisci, G., V. Boschi, 1988. Runoff and Erosion Control with Hill Farming in the Sub-coastal Apennines Climate. Soil and Tillage Research, 12/105-120.
8. Dean, J.E., 1996. Use of hordeum pusillum nut (Little Barley) native cover crop in long-term conservation tillage systems. J. Soil and Water Conserv. 41/4, 359-366.
9. Derpsh, R., C.H. Roth, N. Sidiras, and M. Köpke. 1988. Erosionsbekämpfung in Parana Brasil: Mulchsysteme, Direktsaat und konservierende Trodenbearbeitung, Schrift. der Deutschen Gesell. für Techn. Zusammenarbeit, Eschborn, p. 270.
10. Gil, E. 1990. Rational land use on slopes from the point of view of flood and erosion protection. Problemy Zagospodorovania Ziem Gorskich, Poland, p. 31-48.
11. Jasa, P.J., and E.C. Dickey. 1991. Subsoiling, contouring, and tillage effects on erosion and runoff. Applied engineering in agriculture, University of Nebraska, USA, p. 80-85.
12. Jung, P.K., M.H. Ko, and K.T. Um. 1985. Discussion of cropping management factor for estimating soil loss. J. Korean Soc. Soil Sci. and Fertilizer, Suwon Korea, p. 7-15.
1. Kisić, I., F. Bašić, A. Butorac, and M. Mesić. 1998. Soil erosion in different tillage systems on stagnosol in Croatia. Proceedings of the 16th World Congress of Soil Science, Montpellier, France.
14. Klik, A., F. Fila, N. Spatny, J. Rosner, and O.W. Baumer. 1996. On-Site and Off-Site Effects of Different Tillage Systems under Austrian Farming Conditions. International Annual Meeting ASAE, Phoenix, Arizona.
15. Laflen, J.M., J.L. Baker, R.O. Hartwig, W.F. Buchele, and H.P. Johnson. 1978. Soil and water loss from conservation tillage systems. Trans. ASAE 21, 881-885.
16. Laflen, J.M., and W.C. Moldenhauer. 1979. Soil and Water Losses from Corn-Soybean Rotations. Soil Sci. Soc. Am. J. 43, 1213-1216.
17. Lal, R., 1976. No-tillage effects on soil properties under different crops in western Nigeria. Soil Sci. Soc. Am. J. 40, 762-768.
18. Malone, R.W., R.C. Warner. 1996. Runoff losses of water, soil and surface applied metribuzin as influenced by yard waste compost amendments, no-tillage and conventional tillage systems. J. Soil and Water Conserv. 41/4, 365.
19. Meyers, J.L., and M.G. Wagger. 1996. Runoff and sediment loss from three tillage systems under simulated rainfall. Soil and Tillage Research, No. 39/115-129.

20. Oh, S.J., P.K. Jung, M.H. Koh, and T.S. Kih. 1989. Aspects of soil erosion with different clay contents and slope gradients under simulated rainfall. The Research Reports of the Rural Development Administration, Soil and Fertilizer, p. 29-41, Korea.
21. Rejman, J., 1995. Assessment of erosion risk on loess soil. From Soil Survey to Sustainable Farming. Proceedings of Conf. at the 35th Anniversary of the Institute, organized within the ENCY activities, High Tatras, Stara Lesna. p. 343-347.
22. Rejman, J., 1997. Runoff and Soil Loss under Conventional Tillage for Cereal Production in SE Poland. Proceedings of the 14th Conf. of ISTRO, Pulawy, Poland, 559-563.
23. Schultz, J.E., and D.K. Malinda. 1994. Rotation, tillage and residue management effects on rainfall infiltration and soil erosion. Proceedings of the 13th Conference of ISTRO, Aalborg Denmark, p. 353-358.
24. Sibbesen, E., P. Schjonning, A.C. Hansen, J.D. Nielsen, and T. Heidmann. 1994. Surface runoff, erosion and loss of phosphorus relative to soil physical as influenced by tillage and cropping systems. Pro. of the 13th Conf. of ISTRO, Aalborg Denmark, p. 245-250.
25. Schwertmann, U., W. Vogl, and M. Kainz. 1987. Bodenerosion durch Wasser. Vorhersage des Abtrags und Bewertung von Gegenmaßnahmen. Stutgart, p. 86.
26. Šalinović I., Bašić I., Bašić F., Kellkayelah A., Butorac A. (1989). Prediction of Soil Erosion Using USLE in Horo Alleltu Area in Ethiopia. 12th ISTRO Conference. Ibadan. Nigeria. pp. 48-49.
27. Šalinović I. (1997). Procjena erozije tla vodom na važnijim feralitičnim tlima u provinciji Wolega - Etiopija. Magistarski rad. Zagreb, str. 85.
28. Wischmeier, W.H., 1960. Cropping-management factor for a Universal Soil Loss Equation. Soil Science Society Proceedings, pp. 322-326.
29. Wischmeier, W.H., 1973. Conservation tillage to control water erosion. Conservation tillage, Soil Conservation Society of America, 133-141.
30. Wischmeier, W.H., and D.D. Smith. 1978. A Universal soil-loss equation to guide conservation farm planning. In Int. Congr. Soil Sci.,Trans.,7 Int.Soc.Soil Sci., Madison, 418-425.
31. *** 1994. World Reference Base for Soil Resources, ISSS, ISRIC, FAO, Wageningen/Rome.

JOURNAL of Central European Agriculture