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CRITICAL SEASON FOR SOIL EROSION IN THE MOLDAVIAN PLATEAU

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ABSTRACT. Experiments conducted at Agricultural Research and Development Station of Podu-Iloaiei, Iaşi County, Romania, during 2002 - 2011, followed study runoff and soil erosion in different cultures, and establish critical season of soil erosion in this area. Establish critical season of soil erosion is necessary to satisfy the critical level of ground cover, which is required to maintain a low risk of soil erosion. Average annual soil loss by erosion, recorded in maize and sunflower were (mean on 10 years) of 6.753 and 7.385 t/ha/year, respectively. In sunflower and corn of the total soil loss recorded in the Moldavian Plateau, 19.7- 20.4% occurred in spring, 68.7 to 69.2% in summer and 6.1-6.6% in the autumn. Differences of 4.5 to 4.9% of the total annual soil losses by erosion were recorded in winter, with snow melt. Season critic of soil erosion in the Moldavian Plateau, when recording the most aggressive rain event occurs in June and July. Mean soil loss due to erosion, recorded in June and July were 0.424 t/ha for winter rape, winter wheat 0.291 and 0.093 t/ha the perennial grasses in the second year of vegetation.

Key words: Slope land; Cropping systems; Water erosion; Critical season of soil erosion.

REZUMAT. Sezonul critic pentru eroziunea solului în Podişul Moldovei. Experienţele realizate la Staţiunea de Cercetare-Dezvoltare Agricolă Podu-Iloaiei, judeţul Iaşi, în perioada 2002-2011, au urmărit studiul scurgerilor de apă şi de sol prin eroziune la diferite culturi şi stabilirea sezonului critic de eroziune a solului în aceasta zonă. Stabilirea sezonului critic de eroziune a solului este necesară pentru a satisface nivelul critic de acoperire a solului, în vederea menţinerii unui risc redus de eroziune a acestuia. Pierderile medii anuale de sol prin eroziune, înregistrate la porumb şi floarea-soarelui, au fost (media pe 10 de ani) de 6.753 şi, respectiv, 7.385 t/ha/an. La floarea-soarelui şi porumb, din totalul pierderilor de sol înregistrat în Podişul Moldovei, 19,7-20.4% au avut loc în primăvară, 68.7- 69.2% în lunile de vară şi 6.1-6.6% în lunile de toamnă. Diferenţele de 4.5 până la 4.9%, din totalul pierderilor anuale de sol prin eroziune, au fost înregistrate în timpul iernii, odată cu topirea zăpezii. Sezonul critic de eroziune a solului în Podişul Moldovei, când se înregistrează

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cele mai agresive evenimente pluviale, are loc în lunile iunie şi iulie. Valoarea medie a pierderilor de sol prin eroziune, înregistrate în lunile iunie şi iulie, au fost de 0.424 t/ha la rapiţa de toamnă, 0.291 t/ha la grâul de toamnă şi 0.093 t/ha la ierburile perene, în anul doi de vegetaţie.

Cuvinte cheie: teren în pantă; sisteme de cultură; eroziunea produsă de apă; sezonul critic de eroziune.

INTRODUCTION

The European Union (EU) by way Thematic Strategy for soil protection pursues application adequate measures to combat soil erosion and other soil degradation processes. The Soil Protection Framework Directive of EU (COM (2006) 232 includes the necessary legislative proposals, taken into account by all the Member States concerning the three main threats on the decline in organic matter, soil erosion and contamination and some additional aspects regarding compaction, diminution of biodiversity, salinisation, floods and landslides. In the EU, more than 150 million hectares of soil are affected by erosion and 45% of the European soils have a low content of organic matter (Montanarella, 2008). In all the countries, the quality of environment factors is affected by economic activities, climatic changes and water and soil pollution.

Many investigations conducted in different countries paid a special attention to the technological elements and methods, which determined the recovery of soil physical, chemical and biological characteristics in a shorter time and with lower expenses (Adem *et al.,* 1984; Dârja, 2000; Van der Knijff *et al.,* 2000; Jităreanu *et al.,* 2007; Ailincăi *et al.,* 2011; Bucur *et al.,* 2007, 2011; Gobin *et al.,* 2006; Grimm *et al.,* 2002; Černý *et al.,* 2012; Gobin *et al.,* 2006; Grimm *et al.,* 2002; Kirkby *et al.,* 2008).

Vegetation cover is considered as the most important parameter for soil erosion control. Strip cropping and alternate strips of grasses can be used to control erosion and better water storage or utilization by plants. Soil erosion for the bare fallow was 0.8 t/ha for 1 per cent slope, 4-3 t/ha for 5 per cent and 10 per cent slopes and 29-8 t/ha for 15 per cent slope. Soil erosion from maize was 0-2 t/ha for 1 per cent slope, 0-3 t/ha for 5 per cent slope, 2-6 t/ha for 10 per cent slope (Lal, 2001). Lal estimated yield losses risks due to erosion, on a global scale, 10 per cent in cereals, 5 per cent in soybeans and 12 per cent in root and tubers.

MATERIALS AND METHODS

The climatic conditions in the Moldavian Plain were characterized by a multiannual mean temperature of 9.6^{o}C and a mean rainfall amount, on 80 years, of 542 mm, of which 161.2 mm during September-December and 380.8 mm during January-August. In the last 28 years, the mean annual recorded quantity of rainfall was of 560.7 mm, of which 357.9 mm determined water runoff and soil losses by erosion.

The determination of water runoff, soil and nutrient losses by erosion was done by means of plots for runoff control with the area of 100 m^2 and on the entire area of the watershed, where experiments were set up by means of a hydrological station. When raining, samples are taken for the determination of the partial turbidity and of the content in humus and mineral elements lost by erosion. Investigations conducted on a cambic chernozem at the Moldavian Plateau, followed the influence of different crops on water runoff and nutrient losses, due to soil erosion (*Table 1*).

Table 1 - The main properties of soils in Iaşi district, depth of 20 cm

Soil type	Area, ha (%)	Clay (%)	pH (H_2O)	Organic carbon (%)	P_2O_5 (mg/kg)
Cambic chernozem	108488 (28.81%)	41.2	6.7	2.01	28
Typical chernozem	60736 (16.13%)	34.1	7.1	2.24	31
Gray soil	50752 (13.48%)	26.3	6.4	1.98	17
Clayey - iluvial soil and brown luvic	35752 (9.31%)	18.1	5.6	1.16	9

RESULTS AND DISCUSSION

In Romania, the land degradation as a whole affects more than 2/3 of the total country area (23,839 sq. km). The *Table 2* summarizes the main entropic factors contributing to land degradation in Romania (Munteanu *et al.,* 2012). From the data of the National Soil Quality Monitoring System and according to SOVEUR methodology, 29.3 percent of the country area is subject to water erosion and landslides, 15.2 percent to soil compaction and crusting, 2.6 percent to salinity, 3.8 percent to severe or moderate pollution and 14.1 percent to reduction in humus and nutrients.

Table 2 - The main restrictive factors for the productive capacity of agricultural soils, 10^3 ha

Kind of restriction area	In Romania	Iaşi district
Water deficit	7 100	313.6
Water erosion	6 300	107.9
Landslides	702	63.6
Salinity	614	55.1
Human induced compaction	6 500	200.0
Strong and moderate acidity	3 437	234.2
Low and very low content of available P	6 258	246.3
Low content of available K	781	38.9
Low content of N	5 088	186.3

Measuring the components of the water flow and soil losses is not an easy task for any type of soil and cropping systems. Soil erosion experimentation in the world uses runoff plots with runoff and soil loss measured at the exit of the plot by collection in a tank. The use models in erosion evaluation are attractive but they offer estimations of potential erosion under specified climatic conditions. Measuring erosion is difficult and expensive and the models use, can reduce very much the investment of measuring erosion. Various methods are available for measuring runoff and soil loss.

A comparison between experimental results and data calculated using the USLE was made by Basso et *al*. (1983) on a vertic soil, in southern Italy, where a 47 min rainfall with an intensity of 71 mm/ hour, simulated by the rain simulator produced a soil loss of 7.9 t/ha, whereas the quantity of eroded soil calculated using the USLE was 10.5 t /ha. Different models and relationships have been proposed to describe and estimate water erosion and sediment production (*Table 3*). The universal soil loss equation is the most widely applied model to estimate soil loss. The Universal Soil Loss Equation (USLE), the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1984), or the Revised Universal Soil Loss Equation (RUSLE) (Renard *et al.,* 1991) are frequently used for the estimation of surface erosion and sediment yield from catchments areas. Soil structure and its stability are important characteristics that influence on water infiltration and runoff volume. The major causes of structural stability are type of clay minerals, organic matter content and type of cations on the complex, and management practice. Crop cover and crop residues reduces raindrop impact, thus reducing disintegration of soil aggregates. Runoff volume and rate depend on rainfall amount and intensity, topography, and soil surface structure.

Table 3 - Models employing empirical equations to evaluate soil erosion

No.	Acronym	Model and reference	*Method
1	EUROSEM	European Soil Eroson Model (Morgan *et al.,* 1998)	RUSLE
2	EPIC	Erosion/Productivity Impact Calculator (Williams *et al.,* 1983, 1984)	RUSLE, MUSLE
3	SHE	Systeme Hidrologique European (Abbott *et al.,* 1986)	RUSLE
4	SWAT	Soil and Water Assessment Tool (Arnold *et al.,* 1993)	USLE

*USLE: Universal Soil Loss Equation; RUSLE: Revised Universal Soil Loss Equation; MUSLE: Modified Universal Soil Loss Equation

Assessment of soil erosion risk is necessary for establish land use and for crop structure planning in critical season of soil erosion. The type of crop or cropping system has a pronounced effect on soil erosion. Critical season of soil erosion in the Moldavia Plateau, when recording the most aggressive rain event is in June and July. In the last 10 years, the mean annual recorded quantity of rainfall was of 579.1 mm, of which 338.5 mm determined water runoff and soil losses by erosion (*Table 4*).

Table 4 – Mean rainfall and rainfall causing runoff, recorded in Moldavian Plateau

Month	Mean annual rainfall (mm)	Rainfall causing runoff (mm)	Mean annual rainfall (%)	Rainfall causing runoff (%)
January	37.4	3.0	7.0	0.9
February	23.2	3.7	4.4	1.1
March	35.0	29.1	6.6	8.6
April	49.2	36.3	9.3	10.7
Mai	45.9	32.6	8.6	9.6
June	75.2	56.6	14.1	16.7
July	107.5	81.5	20.2	24.1
August	67.6	53.4	12.7	15.8
September	42.9	21.9	8.1	6.5
October	47.6	20.4	9.0	6.0
Total	**531.5**	**338.5**	**100.0**	**100.0**

Mean annual rainfall, recorded during 2002-2011 (January - December) = 579.1 mm

By means of repeated field measurements it may determine accurate erosion losses. Several techniques exist to measure sediment concentration, with advantage is that it would link to the Water Framework Directive but, and disadvantage that not known sediment sources and actual losses of soil on slopes. When sediment transport capacity is reduce and flow velocity declines, as a result of decreasing slope, the sediments are deposition (*Fig. 1*).

Weeding crops (sunflower and maize) of the total soil loss recorded in the Moldavian Plateau (*Fig. 2*), 19.7 -20.4% occurred in the spring, 68.7 - 69.2% in the summer months and 6.1- 6.6% in the autumn months (*Table 5*). Differences of 2.1 to 3% of total annual soil losses by erosion were recorded in winter with snow melting.

Average annual soil loss by erosion, recorded in maize and sunflower were (mean 10 years) of 6.753 and 7.385 t / ha / year (*Table 6*). The obtained results on the potential erosion, conditioned by geo-morphological, soil and climate factors, have shown that on the fields uncovered by vegetation from the Moldavian Plateau, the mean soil losses due to erosion were of 14.326 t/ha/year.

Figure 1 - Deposition from changing flow conditions from an actively eroding hill slope

Figure 2 - Soil erosion from maize, sowing hill-valley, May 19, 2012, 32 mm

Table 5 - Mean annual soil losses due to erosion, recorded in different row crops

Month	Fallow land	Sunflower	Maize	Bean
Soil loss by erosion (t/ha/year)				
January	0.123	0.108	0.109	0.108
February	0.234	0.226	0.223	0.231
March	0.137	0.292	0.186	0.173
April	0.574	0.479	0.519	0.382
Mai	1.230	0.685	0.669	0.699
June	5.072	2.234	2.312	1.696
July	4.726	2.304	1.903	1.756
August	0.919	0.573	0.426	0.206
September	0.735	0.221	0.232	0.149
October	0.576	0.263	0.174	0.096
Total	**14.326**	**7.385**	**6.753**	**5.496**
Soil loss by erosion (%)				
January	0.86	1.46	1.61	1.97
February	1.63	3.06	3.30	4.20
March	0.96	3.95	2.75	3.15
April	4.01	6.49	7.69	6.95
Mai	8.59	9.28	9.91	12.72
June	35.40	30.25	34.24	30.86
July	32.99	31.20	28.18	31.95
August	6.41	7.76	6.31	3.75
September	5.13	2.99	3.44	2.71
October	4.02	3.56	2.58	1.75
Total	**100.00**	**100.00**	**100.00**	**100.00**

Table 6 - Mean annual soil losses due to erosion, recorded in different crops

Month	Ist year perennial grasses	Peas	Winter rape	Winter wheat	IInd year perennial grasses
Soil loss by erosion (t/ha/year)					
January	0.051	0.091	0.032	0.002	0.001
February	0.214	0.224	0.012	0.011	0.008
March	0.247	0.112	0.157	0.138	0.109
April	0.216	0.151	0.112	0.013	0.006
Mai	0.434	0.233	0.061	0.027	0.011
June	0.497	0.412	0.145	0.096	0.036
July	0.415	0.459	0.279	0.195	0.057
August	0.134	0.189	0.189	0.107	0.028
September	0.026	0.081	0.056	0.041	0.005
October	0.073	0.094	0.099	0.052	0.016
Total	**2.307**	**2.046**	**1.142**	**0.682**	**0.277**
Soil loss by erosion (%)					
January	2.21	4.45	2.80	0.29	0.36
February	9.28	10.95	1.05	1.61	2.89

Month	I[st] year perennial grasses	Peas	Winter rape	Winter wheat	II[nd] year perennial grasses
March	10.71	5.47	13.75	20.23	39.35
April	9.36	7.38	9.81	1.91	2.17
Mai	18.81	11.39	5.34	3.96	3.97
June	21.54	20.14	12.70	14.08	13.00
July	17.99	22.43	24.43	28.59	20.58
August	5.81	9.24	16.55	15.69	10.11
September	1.13	3.96	4.90	6.01	1.81
October	3.16	4.59	8.67	7.62	5.78
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table 7 - Mean annual runoff, due to erosion, registered in different rare row crops

Month	Fallow land	Sunflower	Maize	Bean
Mean annual runoff (mm)				
January	3.1	1.8	1.9	1.6
February	3.4	1.9	1.8	1.9
March	9.2	2.3	2.4	3.2
April	5.7	3.2	3.2	3.0
Mai	12.3	4.5	4.2	4.1
June	22.4	9.9	9.6	7.4
July	25.6	11.3	10.2	8.4
August	8.6	2.4	2.1	2.3
September	5.2	2.1	1.9	2.1
October	5.4	2.1	1.9	1.6
Total	**100.9**	**41.5**	**39.2**	**35.6**
Mean annual runoff (%)				
January	3.07	4.34	4.72	4.49
February	3.37	4.58	4.59	5.34
March	9.12	5.54	6.12	8.99
April	5.65	7.71	8.24	8.43
Mai	12.19	10.84	10.62	11.52
June	22.20	23.86	24.49	20.79
July	25.37	27.23	26.02	23.60
August	8.52	5.78	5.36	6.46
September	5.15	5.06	4.93	5.90
October	5.35	5.06	4.91	4.49
Total	**100.00**	**100.00**	**100.00**	**100.00**

Table 8 - Mean annual runoff, due to erosion, registered in different crops

Month	I[st] year perennial grasses	Peas	Winter rape	Winter wheat	II[nd] year perennial grasses
Mean annual runoff (mm)					
January	1.1	0.5	0.3	0.2	0.1
February	1.8	1.8	1.6	0.9	0.5
March	3.2	3.1	2.8	0.6	0.4

Month	I st year perennial grasses	Peas	Winter rape	Winter wheat	II nd year perennial grasses
April	2.7	2.5	2.1	0.7	0.5
Mai	3.2	2.7	2.9	1.1	0.6
June	5.2	4.6	2.8	2.5	1.2
July	5.8	5.4	2.4	2.6	1.4
August	1.7	1.6	0.9	1.2	0.6
September	1.2	1.5	0.5	0.9	0.3
October	0.8	1.6	0.4	0.9	0.4
Total	**26.7**	**25.3**	**16.7**	**11.6**	**6.0**
		Mean annual runoff (%)			
January	4.1	2.0	1.8	1.7	1.7
February	6.7	7.1	9.6	7.8	8.3
March	12.0	12.3	16.8	5.2	6.7
April	10.1	9.9	12.6	6.0	8.3
Mai	12.0	10.7	17.4	9.5	10.0
June	19.5	18.2	16.8	21.6	20.0
July	21.7	21.4	14.4	22.4	23.3
August	6.4	6.3	5.4	10.3	10.0
September	4.5	6.0	3.0	7.8	5.0
October	3.0	6.2	2.4	7.8	6.7
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

The results on water runoff and soil losses in different crops from the Moldavian Plateau, determined by control plots, have shown that, during 2002 - 2011, of the total amount of 579.1 mm rainfall, 338.5 mm (58.5%) produced water runoff, which was between 6.0 mm in perennial grasses, in the second year of vegetation, and 39.2 - 41.5 mm, in maize and sunflower crops (*Tables 7 and 8*). In June and July at weeding crops, the amount of water drained by erosion accounts for 44 -51% of the annual average flow (*Table 7*). Average annual water runoffs by erosion (mean on 10 years) were 35.6 mm in beans, 41.5 mm in sunflower and 100.9 mm in uncultivated plot.

Wheat and canola crops volumes of water drained by erosion, recorded in June and July were 2.4 to 2.8 mm (*Table 8*). These elements were necessary for establishing the crop structure and dimensioning the anti-erosion works, which determined the diminution of soil erosion and water runoff, soil and nutrient losses below the limit corresponding to the natural capacity of annual soil recovery, of 2-3 t/ha/year of eroded soil.

CONCLUSIONS

Establish critical season of soil erosion is necessary to satisfy the critical level of ground cover, which is required to maintain a low risk of soil erosion.

Average annual soil loss by erosion, recorded in maize and sunflower were (mean on 10 years) of 6.753 and 7.385 t / ha / year.

In sunflower and maize of the total soil loss recorded in the Moldavian Plateau, 19.7-20.4% occurred in spring, 68.7 to 69.2% in summer and 6.1-6.6% in the autumn. Differences of 4.5 to 4.9% of the total annual soil losses by erosion were recorded in winter, with snow melt.

Season critic of soil erosion in the Moldavian Plateau, when recording the most aggressive rain event occurs in June and July. Mean soil loss due to erosion, recorded in June and July were 0.424 t / ha for winter rape, winter wheat 0.291 and 0.093 t/ha the perennial grasses in the second year of vegetation.

In winter wheat and winter rape volumes of water drained by erosion, recorded in June and July were 2.4 to 2.8 mm.

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