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WATER RUNOFF AND SOIL EROSION, REGISTERED IN DIFFERENT CROPS, ON 16% SLOPE LANDS

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ABSTRACT – The goal of the experiments carried out at the Podu-Iloaiei Agricultural Research Station, Iaşi County, was the study of water runoff and soil losses, caused by erosion, in different crops and the influence of water and soil erosion on the losses of organic matter and mineral elements from soil. The results on water runoff and soil losses in different crops from the Moldavian Plateau have shown that in the last seven years, of the total amount of 608.4 mm rainfall, 387.5 mm (63.7%) produced water runoff, which was between 8.5 mm in perennial grasses, in the second year of vegetation, and 34.9 - 36.8 mm, in maize and sunflower crops. The annual soil losses due to erosion, recorded at the same period, were between 0.190 t/ha/year in perennial grasses, and 4.079 - 4.451 t/ha/year in maize and sunflower crops. Erosion has affected soil fertility by removing once with eroded soil, high amounts of organic carbon and mineral elements, which reached 10.71 - 11.26 kg/ha nitrogen, 0.56 – 0.64 kg/ha phosphorus and 0.98 - 1.11 kg/ha potassium, in maize and sunflower crops. The crop structure, which determined the diminution in mean soil losses by erosion until 1.383 t/ha included 20 % straw cereals, 20% annual legumes, 20% row crops and 40 % perennial grasses and legumes. On land with a slope of 16%, lowering the percentage of weeding plants from 60% to 20% has reduced the amount of eroded soil by 49%.

Key words: Slope land; Water erosion; Cropping systems; Organic carbon; Nutrient losses.

REZUMAT – Scurgerea apei şi eroziunea solului, înregistrate la diferite culturi, pe terenurile cu panta de 16%. Experienţele realizate la Staţiunea de Cercetare-Dezvoltare Agricolă Podu-Iloaiei, judeţul Iaşi, au urmarit studiul scurgerilor de apă şi de sol prin eroziune, la diferite culturi, şi influenţa scurgerilor de apă şi a eroziunii solului asupra substanţei organice şi a elementelor minerale din sol. Rezultatele obţinute privind scurgerile de apă şi de sol prin eroziune, la diferite culturi, în Podişul Moldovei, arată că, în ultimii şapte ani, din totalul de 608.4 mm precipitaţii înregistrate, 387.5 mm (63.7%) au determinat scurgeri, care au fost cuprinse între 8.5 mm la

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ierburile perene şi 34.9-36.8 mm la culturile de porumb şi floarea-soarelui. Pierderile anuale de sol prin eroziune au fost cuprinse între 0.190 t/ha la ierburile perene şi 4.079 – 4.451 t/ha la porumb şi floarea-soarelui. Eroziunea influenţează fertilitatea solului prin îndepărtarea, odata cu solul erodat, a unor cantităţi mari de elemente minerale care, la culturile de porumb şi floarea-soarelui, ajung la 10.71 - 11.26 kg/ha azot, 0.56 – 0.64 kg/ha fosfor şi 0.98 – 1.11 kg/ha potasiu. Structura culturilor, care a determinat reducerea pierderilor de sol prin eroziune sub 1.383 t/ha, a cuprins 20% cereale păioase, 20% leguminoase anuale, 20% culturi prăşitoare şi 40% leguminoase şi graminee perene. Pe terenurile cu panta de 16%, scăderea procentului de plante prăşitoare, de la 60% la 20%, a determinat reducerea cantităţilor de sol erodat cu 49%.

Cuvinte cheie: teren în pantă; eroziunea produsă de apă; sisteme de cultură; carbon organic; scurgeri de elemente nutritive.

INTRODUCTION

Soil erosion negatively affects crop yields and has a detrimental effect on soil resources. In Europe there is considerable variability, and although productivity in northern Europe is not likely to be significantly reduced by soil erosion, for the southern countries the threat of erosion induced productivity declines is stronger (Bakker *et al.*, 2007). 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). The function soil erosion control addresses two needs, to maintain soil quality and positive balance between soil formation and erosion soil losses and to reduce sediment yield from watersheds (Bazzoffi, 2009). The results obtained concerning erosion in the Coshocton USA, showed that in the areas annual mean soil losses by erosion were of 1.18 t/ha and range, 0.35 in wheat and 7.36 in maize (Izaurralde *et al.,* 2007). In all the countries, the investigations carried out in the last period have followed the establishment of some technological solutions that maintain the productivity of agro ecosystem and the protection of environment factors (Agbenin and Goladi, 1997; Agren and Wetterstedt, 2007; Ailincăi *et al.,* 2011; Alexander, 1988; Alvarez *et al.,* 1998; Lindstrom, 1986). The main problems requiring agro-environment measures in Romania are the degradation degree of fields by erosion (6.3 million ha), deterioration of soil structure and compaction. In Romania, soil erosion is the most expensive degradation process, which affects almost 63% of the total area and 56% of the arable area from Romania. Investigations on the potential erosion, conditioned by geomorphologic, soil and climatic factors, have shown that in NE Romania, the mean soil losses by erosion were of 18.3 t/ha and the effective erosion had a mean value of 4.8 t/ha. In Bulgaria, the investigations showed that the mean annual rate of erosion on the arable lands was of 4.76 t/ha and of 2.69 t/ha on improved arable lands (Totka *et al.*, 2006).

On 8.5% slope fields from Finland, annual soil losses by erosion are of 5-6 t/ha and leached nitrogen and phosphorus amounts are of 15.0 and 1.1 kg/ha/year, respectively (Muukkonen *et al.,* 2007). Soil management practices, with potential for carbon sequestration in soil, comprise conservative tillage methods, use of fertilizers, manure and crop residues, crop rotation and erosion control measures (Singh and Lal., 2005).

In the Republic of Ireland, the 0.89 million ha decrease in the extent of arable lands, from 1851–2000, resulted in the expansion of other land cover types which have a higher SOC density than arable land. The expansion of forests in the Republic of Ireland by 0.53 million ha has led to an increase in the SOC stock (Eaton *et al.,* 2008). The investigations conducted by Lindstrom, in Minnesota, USA, have shown that the amounts of 927, 1853 and 3706 kg/ha of crop residues, applied in maize crops, have determined the decrease of soil erosion to 6.177, 1.730 and respectively, 0.988 t/ha and water runoff to 35.6, 25.4 and respectively, 22.9 mm. The investigations conducted in long-term experiments have shown that only at high fertilizer rates, a significant increase was found in the mass of total organic carbon and stable carbon from soil (Blair *et al.,* 2006). Montagne presents evidence of the sensitivity of soil evolution to climate change in terms of intensity and velocity. Organic carbon concentration is a useful soil property which to guide agricultural applications of chemical inputs.

MATERIALS AND METHODS

Investigations conducted on a Cambic Chernozem at the Agricultural Research and Development Station of Podu-Iloaiei, Iași County, followed the influence of different crop rotations on water runoff and nutrient losses, due to soil erosion. Experiments were conducted on the hydrographical basin of Scobîlțeni, with a reception area of 159 ha, a mean altitude of 119.4 m, and a mean slope length of 250 m. The area of the watershed has been anti-erosion set up since 1983, being used combined cropping systems made of sod rewetting and strip cultivation. The width of cultivated strips is 200-250 m on 5-10% slopes, 100-150 m on 10-15 % slopes and 50-100 m on 15-18 % slopes *(Figure 1).* The determination of runoff and soil losses by erosion was carried out by means of loss control plots with a collecting area of 100 m^2 and by means of a hydrological section equipped with spillway and limn graph and devices for sampling water and soil loss by erosion. Total nitrogen, nitrate, phosphorus and potassium content were determined in soil and water samples, lost by erosion in different crops, thus establishing the losses of nutritive elements. The climate is temperate continental with large thermal amplitude and uneven and commonly torrential rainfall prevalent during the vegetative season. The climatic conditions in the Moldavian Plain were characterized by a mean multiannual temperature of 9.6 ^oC and a mean rainfall amount, on 80 years, of 559.2 mm, of which 161.2 mm during September-December, and 398 mm during January-

August. The content of organic carbon was determined by the Walkley-Black method, to convert SOM into SOC it was multiplied by 0.58. The content in mobile phosphorus from soil was determined by Egner-Riechm Domingo method, in solution of ammonium acetate-lactate (AL) and potassium was measured in the same extract of acetate-lactate (AL) at flame photometer. ANOVA was used to compare the effects of treatments.

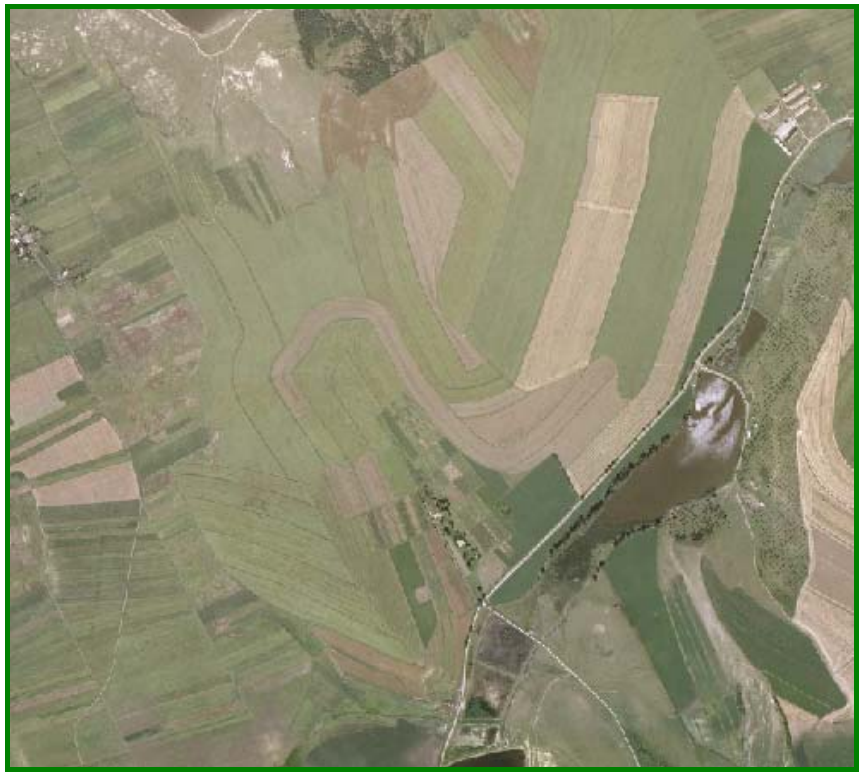

Figure 1 - Geographic presentation of the Scobîlțeni, Iași watershed, set up with anti-erosion works, where the experimental devices were placed

RESULTS AND DISCUSSION

The results on water runoff and soil losses in different crops from the Moldavian Plateau, determined by control plots, have shown that in the last seven years, of the total amount of 608.4 mm rainfall, 387.5 mm (63.7%) produced water runoff, which was between 8.5 mm in perennial grasses, in the second year of vegetation, and 34.9 - 36.8 mm, in maize and sunflower crops *(Table 1).* The annual soil losses due to erosion, recorded at the same period, were between 0.190 t/ha/year in perennial grasses, and 4.079 – 4.451 t/ha/year in maize and sunflower crops *(Table 2).* 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 18.2 t/ha, values corresponding to a moderate erosion risk. The protection degree of soil against erosion, expressed by the ratio between the value of the effective erosion (under specific technological conditions) and of the potential erosion (soil eroded under conditions of uncovered soil, which was not set up with soil erosion control works) is an indicator of erosion risk that shows soil vulnerability to erosion. It is given by the ratio between the value of the effective erosion and that of mean allowable erosion, which corresponds to soils from the studied watershed.

Table 1 - Mean annual water runoff by erosion registered in different crops on 16% slope land (mm)

Years	2004	2005	2006	2007	2008	2009	2010	Mean
Rainfall (mm)	542.0	625.0	681.6	713.5	482.5	652.0	562.3	608.4
Rainfall causing runoff	197.2	349.3	453.2	380.0	402.7	546.0	384.0	387.5
Field	10.8	12.9	94.8	38.6	44.7	49.8	83.2	47.8
Sunflower	9.1	10.2	74.9	25.8	35.4	36.9	65.6	36.8
Ist year perennial grasses	6.9	6.5	51.6	13.3	21.9	35.4	31.9	23.9
IInd year perennial grasses	2.9	2.9	27.4	3.3	5.7	6.5	10.9	8.5
Maize	8.4	9.2	70.2	25.4	34.1	36.1	60.7	34.9
Peas	5.6	8.1	60.7	18.2	14.3	21.1	29.3	22.5
Wheat	6.3	4.9	34.6	6.0	7.2	9.0	16.0	12.0
Beans	8.7	8.0	63.3	20.7	26.6	34.1	53.4	30.7
Winter rape	6.5	5.9	46.8	8.2	9.4	24.8	24.8	18.1

Table 2 - Mean annual of soil erosion registered in different crops on 16% slope land (t/ha)

Years	2004	2005	2006	2007	2008	2009	2010	Mean
Field	2.306	2.678	12.021	5.452	8.362	14.961	16.193	8.853
Sunflower	1.758	1.717	6.872	2.207	4.848	6.243	7.510	4.451
Ist year perennial grasses	0.869	0.870	2.517	0.752	1.305	1.543	1.808	1.377
IInd year perennial grasses	0.186	0.087	0.418	0.029	0.093	0.310	0.209	0.190
Maize	1.527	1.453	5.708	2.199	4.392	5.879	7.392	4.079
Peas	0.982	1.036	3.405	0.915	0.885	1.397	1.684	1.472
Wheat	0.771	0.319	0.708	0.146	0.205	0.451	0.455	0.436
Beans	1.476	1.099	4.303	1.400	2.537	4.089	5.694	2.943
Winter rape	0.868	0.587	0.982	0.351	0.639	1.219	1.074	0.817

Taking into account that the erosion process cannot be avoided and that the tolerance level of soil annual losses is 2 - 3 t/ha/year, which corresponds to the annual rate of soil renewal, the mean annual soil losses due to erosion, recorded in the last seven years, in maize (4.079 t/ha) and sunflower (4.451 t/ha), may result in destructing the fertile soil layer in a few decades *(Table 3).*

Table 3 - Mean annual runoff and soil losses due to erosion, recorded in different crops

Crop	Rainfall causing runoff (mm)	Runoff (mm)	Eroded Soil (t/ha)	Runoff coefficient	Mean turbidity (g/l)
Field	387.5	47.8	8.853	0.12	18.5
Sunflower	387.5	36.8	4.451	0.09	12.1
Ist year perennial grasses	387.5	23.9	1.377	0.06	5.8
IInd year perennial grasses	314.0	8.5	0.190	0.03	2.2
Maize	387.5	34.9	4.079	0.09	11.7
Peas	387.5	22.5	1.427	0.06	6.3
Wheat	387.5	12.0	0.436	0.03	3.6
Beans	387.5	30.7	2.943	0.08	9.6
Winter rape	387.5	18.1	0.817	0.05	4.5

Erosion has affected soil fertility by removing once with eroded soil, high amounts of organic carbon and mineral elements, which reached 10.71 – 11.26 kg/ha nitrogen, 0.56 – 0.64 kg/ha phosphorus and 0.98 – 1.11 kg/ha potassium, in maize and sunflower crops *(Table 4).* On 16% slope lands, the mean annual nitrogen, phosphorus and potassium leaches, due to erosion, recorded in the last seven years, were comprised between 12.26 and 13.01 kg/ha in row crops (maize and sunflower) and between 2.38 and 5.38 kg/ha/years in wheat and peas crops *(Table 4).* The obtained results on erosion in different crop rotations have shown that under conditions of 16% slope lands from the Moldavian Plateau, the diminution in soil losses below the allowable limit of 2 t/ha/year was done only in 3-4 year crop rotations with two or three outside fields, cultivated with perennial grasses and legumes that protect better soil against erosion *(Table 5).*

From the investigations carried out on effective erosion, based on direct determinations, we found out that the effective erosion in the Moldavian Plateau, in peas-wheat-maize rotation, had a mean value of 1.981 t/ha. At 3 and 4-year crop rotations, which included good and very good cover plants for protecting soil against erosion, the amounts of eroded soil and nutrients lost by erosion were very close to the allowable limit for this area.

Table 4 - Organic carbon and mineral element losses, due to erosion, in the Moldavian Plateau

Crop	Organic carbon and mineral elements lost by erosion, kg/ha						
	Organic carbon	N at water runoff	N in eroded soil	Total N	P-AL	K-AL	Total NPK
Field	181	4.264	12.660	16.924	1.018	2.125	20.066
Sunflower	91	4.894	6.365	11.259	0.641	1.113	13.013
Ist year perennial grasses	28	2.701	2.038	4.739	0.158	0.343	5.240
IInd year perennial grasses	4	0.961	0.279	1.240	0.021	0.047	1.308
Maize	84	4.921	5.792	10.713	0.559	0.983	12.255
Peas	29	2.813	2.126	4.939	0.156	0.285	5.380
Wheat	9	1.584	0.637	2.221	0.049	0.109	2.378
Beans	60	4.052	4.297	8.349	0.324	0.589	9.262
Winter rape	17	2.462	1.193	3.654	0.093	0.178	3.926

Table 5 - Average annual water and soil runoff by erosion registered in different crops rotation

Crop rotation	Water Runoff		Erosion		Organic carbon (kg/ha)	Row plants (%)
	(mm)	%	t/ha/year	%		
[1]Mcc	34.9	100	4.079	100	84	100
BWMSfW	25.3	72	2.469	61	51	60
WM	23.5	67	2.258	55	47	50
PWMSf+G	23.6	68	2.176	63	45	40
PWM	23.1	66	1.981	49	41	33
PWM+2G	18.7	54	1.383	34	29	20
RWM+2G	18.1	52	1.261	31	38	20
PWM + 3G	17.6	50	1.233	30	25	17

[1]Mcc= Maize continuous cropping; BWSfMW = Beans-wheat-sunflower-maize-wheat rotation; WM= Wheat-maize rotation; PWM= Peas-wheat-maize; PWMSf+G = Peas-wheat-maize-sunflower + reserve field, cultivated with legumes and perennial grasses; PWM + 2G = Peas-wheat-maize + two reserve field, cultivated with legumes and perennial grasses; RWM = Rape- wheat-maize + two reserve field, cultivated with legumes and perennial grasses.

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. On slope lands, soil nutrient losses being very high, due to leaching, runoff and element fixing, the establishment of rates and time of fertilizer application must be done differently, according to soil characteristics, cultural practices and climatic conditions. On eroded

slope lands, the growing systems ensure the reduction in soil losses below the allowable limit of 2-3 t/ha/year and allow getting efficient yields from the economic point of view.

The results concerning water runoff, soil and mineral element losses from crops, placed in different rotations, have shown that on 16% slope lands, the use of peas-wheat-maize rotation + two outside fields, cultivated with legumes and perennial grasses, resulted in soil losses, which diminished by 66 % (2.696 t/ha), as compared to maize continuous cropping *(Table 5)*.

On 16% slope lands, the mean annual losses of nitrogen due to erosion were comprised between 10.713 kg/ha in maize continuous cropping and 4.036 kg/ha/year in peas - wheat - maize rotation + three outside fields cultivated with perennial grasses *(Table 6)*. If phosphorus and potassium losses are low (0.55-3.13 kg/ha/year), the nitrogen losses should be diminished by using rotations with crop structures that protect soil against erosion. The highest losses of nutrients were recorded in 2-year rotation (wheat-maize) (6.467 kg/ha nitrogen and 7.317 kg/ha total NPK). These amounts decreased very much at the same time with the increase in the rotation structure of cover crops, such as peas, wheat, alfalfa and perennial grasses. Data are very important for establishing and regulating the fertilizer rates applied in crops and for controlling the environment pollution with nitrogen, phosphorus and potassium. In the last seven years, the use of crop rotations with a percent until 20% of row plants, which also included outside fields cultivated with perennial grasses, has determined the diminution in soil and mineral element losses by 66% and, respectively, 60%, as compared to maize continuous cropping. On 16% slope lands, the crop structure, which determined, in the last seven years, the diminution in mean soil losses by erosion until 1.383 t/ha/year included 20 % straw cereals, 20% annual legumes, 20% row crops and 40 % perennial grasses and legumes *(Table 5)*. This scientific information is a source of creating a database necessary to the elaboration of land improvement projects, to watershed setting up and grounding the methods of protecting soil and water resources.

In the last seven years, on 16% slope fields, the increase from 20 to 40% of the percent of row crops (maize and sunflower) used in rotations determined the increase in mean annual losses of eroded soil by 72.5% and the use of crop rotations with 60% row crops resulted in the increase by 95.7% (1.208 t/ha) of the mean annual quantities of eroded soil. According to these results concerning the contribution of melioration plants to the diminution of soil and mineral element losses due to erosion, the technical elements were established for anti-erosion works, such as width of cultivated strips and of sod rewetting, crop structure, crop rotations and assortment of legumes

and perennial grasses used on slope lands. Crop rotations with annual and perennial grasses and legumes have increased the biodiversity of agro-ecosystems, diminished the quantity of nitrogen-based fertilizers, contributed to the increase in soil fertility and diversified the options of farming management.

Table 6 - Mean annual losses of nutritive elements in different crops rotations

Crop rotation	Total N		Total NPK		Row plants (%)
	kg/ha	%	kg/ha	%	
[1]Mcc	10.713	100	12.255	100	100
BWMSfW	6.953	65	7.857	64	60
WM	6.467	60	7.317	60	50
PWMSf+G	6.249	58	7.063	58	40
PWM	5.958	56	6.671	54	33
PWM+2G	4.420	41	4.919	40	20
RWM+2G	4.163	39	4.628	38	20
PWM + 3G	4.036	38	4.481	37	17

CONCLUSIONS

Mean annual losses of soil by erosion, recorded in the last seven years, were of 0.190 t/ha in perennial grasses in the second growth year, 2.943 t/ha in beans, 4.079 t/ha in maize and 4.451 t/ha in sunflower.

Erosion affects soil fertility by removing together with eroded soil, significant mineral element amounts, which in maize and sunflower crops reach 10.7 - 11.3 kg/ha nitrogen, 0.6 - 1.0 kg/ha phosphorus and 1.0-1.2 kg/ha potassium, representing, on the average, 10-11 % of the chemical fertilizers necessary for these crops.

On 16% slope fields, the use of winter rape - wheat - maize rotation + two outside fields, cultivated with perennial grasses, determined the diminution by 69% (2.818 t/ha) in the mean annual losses of eroded soil and by 61% (6.550 kg/ha) in nitrogen leakages, compared with maize continuous cropping.

From the results obtained on erosion in different crop rotations, we have found that in 16% slope fields from the Moldavian Plateau, soil losses by erosion diminished below the allowable limit of 2-3 t/ha only in case of 3 or 4 year-crop rotations with two or three reserve fields, cultivated with legumes and perennial grasses, which protect soil.

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