Effects of cropping systems on water runoff, soil erosion and nutrient loss in the Moldavian Plateau, Romania

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ABSTRACT

The experiments carried out at the Podu-Iloaiei Agricultural Research Station, during 1986-2008, had the following objectives: the study of water runoff and soil losses, by erosion, in different crops; the annual rate of erosion processes under the influence of anti-erosion protection of different crops; the influence of water runoff and soil erosion on losses of organic matter and mineral elements from soil. The determination, in different crops, of water runoff, soil, humus and nutritive element losses by erosion was done by the help of plots for loss control, which are isolated from the rest of the area by metallic walls and have basins and devices for division; we took water and soil samples from plots for determining the partial turbidity and for chemical elements analyses. The determination of water runoff, soil, humus and nutritive element losses on fields arranged by anti-erosion was done on the whole area of the retention basin (159 ha), where experiments were conducted, since 1982, bands with grasses and field strips were set up. The erosion control was done by the help of hydrological station with triangular waste weir, rain gauge, recording rain gauge, limnigraph and devices for water and soil samples uptake during rainfalls. Mean annual losses of soil by erosion, registered during 1986-2008 were of 0.298 $t \cdot ha^{-1}$ in perennial grasses on the second growth year, 4.618 $t \cdot ha^{-1}$ in beans, 9.176 $t \cdot ha^{-1}$ in maize and 9.650 $t \cdot ha^{-1}$ in sunflower.
Erosion has affected soil fertility by removing once with eroded soil, high amounts of humus and mineral elements, which reached 17.4-17.7 $kg \cdot ha^{-1}$ nitrogen, 1.1 $kg \cdot ha^{-1}$ phosphorus and 2.3 $kg \cdot ha^{-1}$ potassium, in maize and sunflower crops. 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 4.502 $t \cdot ha^{-1} \cdot year^{-1}$. From the results obtained on erosion in different crop rotations, we have found out that in 16 % slope fields from the Moldavian Plateau, soil losses by erosion were diminished below the allowable limit of 3-5 $t \cdot ha^{-1} \cdot year^{-1}$ only in case of 4 year-crop rotations with one or two reserve fields, cultivated with legumes and perennial grasses, which protect soil. These elements were necessary for establishing the crop structure and dimensioning the ant erosion works, which determine the decrease of soil erosion and water runoff, soil and nutrients losses below the limit corresponding to the natural capacity of annual soil recovering, of 3-5 $t \cdot ha^{-1} \cdot year^{-1}$ of eroded soil.

Keywords: soil erosion, runoffs, nutrient losses, cropping systems, yield, environment quality

INTRODUCTION

In all the countries, the quality of environment factors is affected by economic activities, climatic changes and water and soil pollution. Many studies carried out in different areas with different soil and climatic conditions followed the establishment of the technological elements, which contribute to the diminution of soil erosion and of mineral element losses in

the agricultural environment (Francisco López-Bermúdez et al., 1998, 2006; Bucur D. et al., 2007; Jitareanu G. et al., 2007; Montanarella L., 2008).
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 aim of the normative regulations concerning the environment protection in EC, established by the Nitrate Directive, Pesticide Directive, Water Framework Directive, Biocide Directive and Habitat Directive, is to ameliorate the environment factors and, especially, the protection of water and soil resources. Of the total Italian area, 51.8% is considered to be at potential risk of desertification. Soil erosion is the most relevant soil degradation system that affects at least 19% of the territory at the potential risk of desertification, while aridity is the second desertification risk (19.0%) (Edoardo A. C. Constantini, 2008). In Austria, during 1994-2007, the mean soil losses in three locations dropped from 6.1 $t \cdot ha^{-1} \cdot year^{-1}$. to 1.8 $t \cdot ha^{-1} \cdot year^{-1}$., by using conservation tillage in cover crops, and until 1.0 $t \cdot ha^{-1} \cdot year^{-1}$. with direct drilling. Nitrogen (9.2, 3.7, 2.5 $kg \cdot ha^{-1} \cdot year^{-1}$) and phosphorus (4.7, 1.3, 0.7 $kg \cdot ha^{-1} \cdot year^{-1}$) losses showed similar tendencies (Rosner et al., 2008).
The main problems requiring agro-environment measures in Romania are the degradation degree of fields by erosion (6.3 million ha) and deterioration of soil structure. The primary compaction is found on 2 million ha of arable fields (13.59%), the tendency of crust formation at soil surface, on 2.3 million ha (15.63%) and soil chemical pollution, on 0.9 million ha. The north-eastern region has 15.45% (2,131,421 ha) of the farming area of Romania (14,836, 585 ha) and includes very great areas with soils affected by erosion (60%), acidification, compaction and other degradation forms.

METHODS

Investigations conducted during 1986-2008 on a Cambic Chernozem at the Agricultural Research and Development Station of Podu-Iloaiei, Iasi County, followed the influence of different crop rotations and fertilizers on water runoff and nutrient losses, due to soil 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. Experiments were conducted on the hydrographic basin of Scobalteni, with a reception area of 159 ha, a mean altitude of 119.4 m, a mean slope of 12 % and a mean slope length of 250 m. The area of the watershed has been anti-erosion set up since 1982, 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.
The content of total nitrogen, nitrates, phosphorus and potassium was determined on soil and water samples, lost by erosion, in different crops, thus establishing the losses of nutritive elements on the area of the watershed where experiments are placed. 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.

RESULTS AND DISCUSSION

The climatic conditions in the Moldavian Plain were characterized by a multiannual mean temperature of 9.6 ^oC 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 23 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 results on water runoff and soil losses in different crops from the Moldavian Plateau, determined by control plots, have shown that, during 1986-2008, of the total amount of 560.7 mm rainfall, 357.9 mm (63.8%) produced water runoff, which was between 6.2 mm in perennial grasses, in the second year of vegetation, and 28.4-29.7 mm, in maize and

sunflower crops (Table 1). The annual soil losses due to erosion, recorded at the same period, were between 0.298 t·ha^{-1}·in perennial grasses, in the second year of vegetation, and 9.176 - 9.650 t·ha^{-1}·in maize and sunflower crops. 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 18.8 t·ha^{-1}·year^{-1}, values corresponding to a moderate erosion risk. Taking into account that the erosion process cannot be avoided and that the tolerance level of soil annual losses is 3-5 t/ha, which corresponds to the annual rate of soil renewal, the mean annual soil losses due to erosion, recorded during 1986-2008 in maize (9.176 t ha^{-1}) and sunflower (9.650 t ha^{-1}), may result in destructing the fertile soil layer in a few decades.
Erosion has affected soil fertility by removing once with eroded soil, high amounts of humus and mineral elements, which reached 17.67-17.44 kg ha^{-1} nitrogen, 1.03-1.10 kg ha^{-1} phosphorus and 2.3-2.4 kg ha^{-1} potassium, in maize and sunflower crops (Table 2).

Table 1. Mean annual runoff and soil losses due to erosion, recorded in different crops

Crop	Rainfall causing runoffs (mm)	Runoff Water (mm)	Eroded Soil (t ha^{-1})	Runoff coefficient	Mean turbidity (g l^{-1})	Organic carbon, (kg ha^{-1})
Fallow land	357.9	51.2	18.790	0.14	36.70	365.1
Sunflower	357.9	29.7	9.650	0.08	32.49	187.5
Ist year perennial grasses	357.9	9.8	1.890	0.03	19.29	36.5
IInd year perennial grasses	324.5	6.2	0.298	0.02	4.81	5.7
Maize	357.9	28.4	9.176	0.08	32.31	178.8
Peas	357.9	11.4	2.690	0.03	23.60	52.4
Wheat	357.9	7.9	1.640	0.02	20.76	32.0
Beans	357.9	16.2	4.618	0.05	28.51	90.0

Table 2. Mean annual losses of nitrogen, phosphorus and potassium, due to erosion in different crops, in the Moldavian Plateau, Romania (kg ha^{-1})

Crop	N_t in runoff water	N_t in eroded soil	Total N	P-AL	K-AL	Total NPK
Fallow land	3.779	27.246	31.025	2.161	4.51	37.696
Sunflower	2.768	14.668	17.436	1.11	2.364	20.910
Ist year perennial grasses	0.894	2.797	3.691	0.217	0.471	4.379
IInd year perennial grasses	0.549	0.489	1.038	0.033	0.074	1.145
Maize	2.624	15.049	17.673	1.028	2.294	20.995
Peas	1.051	4.008	5.059	0.245	0.538	5.842
Wheat	0.773	2.69	3.463	0.184	0.41	4.057
Beans	1.51	7.25	8.760	0.411	0.924	10.095

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 4.502 t·ha^{-1}·year^{-1} (Table 3). 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. On 16% slope lands, the mean annual losses of nitrogen due to erosion were comprised, during 1986-2008, between 17.67 kg ha^{-1} in maize continuous cropping and 6.39 kg ha^{-1}in peas - wheat - maize rotation + two outside fields cultivated with perennial grasses. 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 3-4 t·ha^{-1}·year^{-1} was done only in 3-4 year crop rotations with one or two

outside fields, cultivated with perennial grasses and legumes that protect better soil against erosion.

Table 3. Soil and mineral elements losses by erosion in different crop rotations, (kg ha^{-1})

Crop rotation	Eroded Soil	Organic carbon	Nitrogen	Phosphorus	Potassium	Total NPK
*Mcc	9176	178.6	17.673	1.028	2.294	20.995
W - M	5408	105.6	10.567	0.606	1.352	12.525
P - W - M	4502	87.6	8.731	0.215	1.081	10.027
P - W - M - Sf + Rf	4691	91.1	8.934	0.52	1.136	10.59
P - W - M - Sf + 2 Rf	3959	83.5	7.618	0.466	0.959	9.043
P - W - M + Rf	3451	67.3	6.808	0.486	0.829	8.123
B- W - M+ 2 Rf	3206	62.6	6.394	0.338	0.755	7.487

*Mcc= Maize continuous cropping; W= Wheat; B = Bean; P= Pea; M = Maize; Sf = Sunflower; Rf = Reserve fields cultivated with legumes and perennial grasses.

CONCLUSIONS

Mean annual losses of soil by erosion, recorded during 1986-2008, were of 0.298 $t \cdot ha^{-1}$ in perennial grasses in the second growth year, 4.618 $t \cdot ha^{-1}$ in beans, 9.176 $t \cdot ha^{-1}$ in maize and 9.650 $t \cdot ha^{-1}$ in sunflower.

Erosion affects soil fertility by removing together with eroded soil, significant humus and mineral element amounts, which in maize and sunflower crops reach 17.4-17.7 kg ha^{-1} nitrogen, 1.0-1.1 kg ha^{-1} phosphorus and 2.2-2.4 kg ha^{-1} potassium, representing, on the average, 10-12 % of the chemical fertilizers necessary for these crops.

The crop structure, which determined, during 1986-2008, the diminution in mean soil losses by erosion until 3.206 $t \cdot ha^{-1} \cdot year^{-1}$ included 20 % straw cereals, 20% annual legumes, 20% row crops and 40 % perennial grasses and legumes.

On 16% slope fields, the use of bean - wheat - maize rotation + two outside fields, cultivated with perennial grasses, determined the diminution by 40.7% (2.202 kg ha^{-1}) in the mean annual losses of eroded soil and by 39.5% (4.173 kg ha^{-1}) in nitrogen leakages, compared with wheat-maize rotation.

REFERENCES

- Bucur D., Jităreanu G., Ailincăi C., Tsadilas C., Ailincăi Despina, Mercus A., 2007. *Influence of soil erosion on water, soil, humus and nutrient losses in different crop systems in the Moldavian Plateau, Romania*, Journal of Food, Agriculture & Environment, Vol. 5 (2), 84-87, ISSN 1459-0255.
- Edoardo A.C. Constantini, Giovanni L, Abate, Napoli R., Urbano F., Guido Bonati and Pasquale NNO, 2008. *Risk of Deserfication in Italy and Effectiveness of Response Measures,* 5th International Conference on Land Degradation, Bari, Italy, 18-22 Sept. 2008, Ideaprint- Bari, Italy, pp 125-130.
- Francisco López-Bermúdez, Asunción Romero-Díaz, José Martínez-Fernandez and Julia Martínez-Fernandez, 1998. *Vegetation and soil erosion under a semi-arid Mediterranean climate: a case study from Murcia (Spain),* Geomorphology, Volume 24, July 1998, pages 51-58.
- Francisco López-Bermúdez and Jorge García-Gómez, 2006. *Desertification in the Arid and Semiarid Mediterranean Regions. A Food Security Issue*, Springer Netherlands, Volume 3/2006, pp. 401-428.
- Jităreanu G., Ailincăi C. and Bucur D., 2007. *Soil fertility management in North-East Romania*, Journal of Food, Agriculture & Environment Vol.5 (3&4): 349 - 353 . 2007.
- Montanarella L., 2008. *Moving Ahead from Assessments to Actions: Could We Win the Struggle with Soil Degradation in Europe?,* 5th International Conference on Land Degradation, Valenzaro, Bari, Italy, 18-22 September 2008, Ideaprint- Bari, Italy, pp 5-9.
- Rosner, J., Zwatz, E., Klik, A., Gyuricza, C., 2008.*Conservation Tillage Systems - Soil - Nutrient - and Herbicide Loss in Lower Austria and the Mycotoxin Problem*, 15th International Congress of ISCO 18-23 May 2008, Budapest, Published by the Geographical Research Institute, Hungary.