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SOIL EROSION AND CONSERVATION MEASURES IN MOLDAVIAN PLATEAU

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ABSTRACT. The long-term experiments carried out at the Agricultural Research Station of Podu-Iloaiei, Iaşi County, Romania, tried to establish some fertilization systems for getting efficient yield increases, which maintain or increase the content of organic carbon from soil. These trials were set up on a 16% slope field, with a cambic Chernozem soil, which has a clayey-loam texture, a neuter to weakly acid response and a mean supply in nutrients. Analyzes performed on soil profiles after 44 years, on land with a slope of 16% and slope length of 310 m, shows that the entire length of slope soil fertility were very different, being influenced by processes of erosion and silting. Soil organic carbon, the depth of 0-20 cm, was between 45.94 t / ha, the foot slope and 27.45 t / ha in the mid-slope area with strong erosion. 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 3-4 t/ha/year only in case of 4 year-crop rotations with two reserve fields, cultivated with legumes and perennial grasses, which protect soil. Annual soil losses by erosion, registered during the last 30 years, in the Moldavian Plateau, were between 0.246 t/ha in perennial grasses, on the second year of vegetation, and 8.976 t/ha in sunflower. The fertilization of wheat and maize crops at the rate of $N_{80}P_{80}$ + 60 t/ha manure has determined the increase with 5.5 t/ha (7.8%) in the content of organic carbon from soil, as compared to the rate of $N_{140}P_{100}$.

Key words: Soil erosion; Long-term fertilization; Organic carbon.

REZUMAT. Eroziunea solului şi măsuri de conservare în Podişul Moldovei. Cercetările de lungă durată, efectuate la Staţiunea de Cercetări Agricole Podu-Iloaiei, judeţul Iaşi, au urmarit stabilirea unor sisteme de fertilizare pentru a obţine creşteri eficiente de producţie şi care menţin sau sporesc conţinutul de carbon organic din sol. Aceste studii au fost stabilite pe un teren cu panta de 16%, cu un sol cernoziom cambic, care are o textură luto-argiloasă, un pH neutru spre slab acid şi o aprovizionare mijlocie în substanţe nutritive. Analizele efectuate pe profilurile de sol după 44 de ani, pe un teren cu panta de 16% şi lungimea versantului de 310 m, arată că, pe

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întreaga lungime a versantului, solurile au fertilitate foarte diferită, fiind influențate de procese de eroziune şi colmatare. Cantitatea de carbon organic din sol, pe adancimea de 0-20 cm, a fost cuprinsă între 45.94 t / ha la baza pantei şi 27.45 t/ha la mijlocul pantei, în zona cu eroziune puternică. Din rezultatele obținute privind eroziunea la diferite asolamente s-a constatat că, în condițiile terenurilor cu panta de 16% din Podişul Moldovei, reducerea pierderilor de sol prin eroziune sub limita „tolerabilă" de 3-4 t/ha/an se realizează numai în cazul asolamentelor de 4 ani, cu două sole săritoare cu leguminoase şi graminee perene, care protejează mai bine solul. Pierderile anuale de sol prin eroziune, înregistrate în ultimii 30 de ani în Podişul Moldovei, au fost cuprinse între 0.246 t / ha la ierburi perene, în al doilea an de vegetație, şi 8.976 t / ha la floarea-soarelui. Fertilizarea culturilor de grâu şi porumb, la rata de $N_{80}P_{80}$ + 60 t / ha gunoi de grajd, a determinat creşterea cu 5,5 t / ha (7,8%) în conținutul de carbon organic din sol, în comparație cu rata de $N_{140}P_{100}$.

Cuvinte cheie: eroziunea solului; fertilizare de lungă durată; carbon organic.

INTRODUCTION

The objective of the Thematic Strategy for Soil Protection, COM (2006) 231, is to protect the soil, through the prevention of degradation, the preservation of soil function and the restoration of degraded soils. Since the adoption of the Thematic Strategy for Soil Protection, in European Union has funded various research projects, such as, RAMSOIL which identified a number of risk assessment methodologies for soil degradation processes, ENVASSO has proposed minimum requirements for a gradual harmonisation of soil monitoring activities and soil indicators and LUCAS, which includes studies on land use, land cover and agri-environmental indicators.

The new Rural Development proposal, in the context of the Common Agricultural Policy (CAP) reform to 2020, includes the objectives of sustainable management of natural resources and climate mitigation by means of improved soil management and enhanced carbon sequestration in agriculture and forestry. According to United Nations Environment Programme (UNEP) up to 50.000 km² are lost annually through land degradation due to soil erosion and each year, the planet, loses 24 billion tonnes of topsoil.

Agriculture is dependent on soil fertility and nutrients content from and it use 20-30 million tones of phosphorus annually, which, largely coming from outside the EU.

Large amounts of manure, bio-waste and sewage sludge produced every year contain nutrients and organic matter and a more efficient use of these resources can increase of soil fertility. Acidifying air pollutants, such as, ammonia, sulphur dioxide and nitrogen oxides contributes to soil acidification, mobilising heavy metals and reducing crop yields.

Erosion has an impact on the quality of water, losses of phosphorus exceed 0.1 kg/ha/year across much of Europe, but reach levels in excess of 1.0 kg/ha/year in many areas.

Carbon contents of some soils from Rothamsted, England, varied depending on the use of land, from 0.89% in monoculture wheat unfertilized with manure, at 1.10% at the fertilization with 185 kg $(NH_4)_2SO_4$, 1.52% in old pasture and 2.23% at the dose of 14 tons of farmyard manure applied annually.

Agricultural practices can increase or mitigate soil degradation and makers at EU, introduced restrictions in land use and the set of agro-environmental measures to be offered in a region.

MATERIALS AND METHODS

The determination of water and soil losses by erosion was carried out by means of loss control plots with a collecting area of 100 m^2 (25x4 m) and by means of a hydrological section equipped with spillway and limn graph (an apparatuses for measuring in time the level of the runoff water from the outlet canal of the hydrographical basin) and devices for sampling water and soil lost by erosion. We took samples from drained water for determining runoff turbidity, leached soil amounts and for chemical analyses. The erosion rates were estimated in plots under natural rain.

The climatic conditions from the Moldavian Plain are characterized by a multiannual mean temperature of 9.6^{o}C and a mean rainfall amount on 80 years of 542.6 mm, of which 161.4 mm during September-December and 381.2 mm during January-August. Soil organic carbon (SOC) were evaluate for layer 0-30 cm from soil organic carbon content, gravel content, soil depth and bulk density data. Within the experiment, the following rotation schemes have been followed 2-year rotation (wheat-maize) and 3-year rotation (peas-wheat-maize) + two reserve fields cultivated with legumes and perennial grasses. Bulk density and capillary and total water capacity of soil were determined on soil, sampled in natural sites, in metallic cylinders of 200 cm3, both under moisture and dry condition, according to the method recommended by the National Research and Development Institute for Soil Science, Agrochemistry and Environment Protection of Bucharest.

RESULTS AND DISCUSSION

The investigations conducted on eroded soils have followed the establishment of crop rotations and fertilizing systems, which contribute to maintaining and recovery of soil fertility. Investigations conducted at the Agricultural Research and Development Station of Podu-Iloaiei, Iaşi County, since 1983 have followed the influence of different crop structures and different fertilization methods on crop yield, erosion and soil fertility.

Soil organic matter and nutrient content are most sensitive to soil conservation and management practices such as crop rotation, conservation tillage and organic residue. Soil organic carbon is a key component of the agro system as it prevents soil degradation, reduces the risk of water pollution and enhances physical, chemical and biological soil properties. Soil organic matter influences many soil physical and chemical properties: increases infiltration and water retention, aggregate stability, bulk density, pH and nutrient content, decreases compaction, increases soil aeration and protects soil surface from erosion. Soil loss due to erosion is influence of climate, relief, soil properties, vegetation and land management. Joint Research Centre (JRC) has estimated the surface area affected in EU-27 at 1.3 million km² and almost 20% of these are subjected to a soil loss, more of 10 t/ha in each year. Organic carbon level, in the topsoil, derived from the European Soil Database, shows that is very low (<1,0%), on 13,7% (66 558 238 hectares), low (1,1-2,0%), on 33,8% (163 967 166 ha), medium, on 47,9% (232 325 106 ha) and high (>6%), on 4,6% (22 173 470 ha).

Soil organic matter decline is a threat in Mediterranean areas, where according to the European Soil Bureau nearly 75% of the total area analyzed in Southern Europe has a low (3.4%) or very low (1.7%) soil organic matter content. Researchers consider soils with less than 1.7% organic matter to be in pre-desertification stage.

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 (44% of the total farming area). 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 (over 60%), acidification, compaction, landslides and other degradation forms.

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 (Adams, 1973; Saxton *et al.,* 1986; Aakkula *et al.,* 2000; Albaladejo *et al.,* 2000; Dumitru *et al.,* 2000; Alakukku *et al.,* 2003; Rusu *et al.,* 2006; Ailincăi *et al.,* 2011; Ali *et al.,* 2006; Hiederer and Köchy, 2011).

These are protection crop rotations with annual and perennial legumes, fertilization systems with various biodegradable organic matters, conservation systems of minimum soil tillage, etc. In the organization of the arable field, crop rotation still represents a basic measure of the plant production. In Romania, the main restrictive factors for the productive capacity of agricultural soils, are presented in *Table 1* (Dumitru *et al.*, 2000)

In the past few years a number of projects have attempted to assess the risk of soil erosion at national, European and International level such as PESERA, USLE and INRA and with these models are evaluate soil erosion at the scale of small and medium drainage basins (10-1000 km²). Estimating erosion rates, per several years, in closed or open plots under natural rain conditions, show rates between 0 and 8 t/ha/an in Alicante, Spain (Bautista *et al.,* 1996) and between 0.006 and 2,4 t/ha/an in Murcia (Albaladejo *et al.,* 1991, 2000).

Table 1- The main restrictive factors for the productive capacity of agricultural soils in Romania

No	Kind of restriction	Area, ha
1	Water deficit	7 100 000
2	Water erosion	6 300 000
3	Wind erosion	378 000
4	Human induced compaction	6 500 000
5	Crusting	2 300 000
6	Low or extremely low humus content	8 620 000
7	Strong and moderate acidity	3 437 000
8	Low and very low content of available P	6 258 000
9	Low content of available K	781 000
10	Low content of N	5 088 000

The results derived from rainfall simulation experiments must be used as relative values to compare between different soil and rain conditions and the extrapolation of the erosion rates, to higher spatial and temporal scales, is difficult and not realistic.

Soils were influenced by erosion and silting processes. Analyses conducted on soil profiles, after 44 years, on a slope of 16% and the length of valley side of 310 m, demonstrated that on the entire length of valley side, soils had a very different fertility, being influenced by erosion and silting. In the critical erosion zone on valley side, once with the erosion of the horizon from soil surface, soil degradation processes intensified, even on chernozems, which were more resistant to erosion (*Table 2, Profile 4*). Soil organic carbon, the depth of 0-20 cm, was between 45.94 t / ha, the footslope and 27.45 t / ha in the mid-slope area with strong erosion (*Table 2*).

The results on water runoff and soil losses in different crops from the Moldavian Plateau, determined by control plots, have shown that of the total amount of 570.2 mm rainfall (average on 30 years), 366.1 mm (64.2%) produced water runoff, which was between 6.3 mm in perennial grasses, in the second year of vegetation, and 29.6 - 35.4 mm, in maize and sunflower crops (*Table 3*).

Annual soil losses by erosion, registered during the last 30 years, in the Moldavian Plateau, were between 0.246 t/ha in perennial grasses, on the second year of vegetation, and 8.976 t/ha in sunflower.

In the last period, the goal of many studies carried out in different countries was to improve the technological elements concerning soil fertilization, tillage and crop rotations with perennial grasses and legumes, which determine the increase in the content of organic carbon from soil and the diminution of soil erosion (Albaladejo *et al.,* 2000; Bautista *et al.,* 1996; Cerhanová *et al.,* 2006; Jităreanu *et al.,* 2006; Antoniadis *et al.,* 2007).

Table 2 - Change of main soil chemical characteristics on a 16% slope, as influenced by soil erosion

Horizon	Depth, cm	pH, (H_2O)	N total %	P-AL mobile ppm	K-AL mobile ppm	Organic carbon %
P1 - Weakly eroded cambic chernozem situated at the lower third of slope						
Ap	0-20	6,8	0,158	49	294	1,75
Am	20-34	6,9	0,129	34	264	1,39
P 2 - Meanly eroded cambic chernozem situated at the mean third of slope						
Am	0-16	6,5	0,145	32	181	1,74
A/B	17-35	7,3	0,123	7	134	1,05
P 3 - Highly eroded cambic chernozem situated at the upper third of slope						
Am	0-15	7,1	0,135	24	156	1,28
A/B	16-28	7,3	0,127	5	125	1,19
P 4 - Highly eroded soil situated at the upper third of slope, in the critical erosion zone						
A/C	0-16	7,3	0,122	14	139	1,03
C1	16-29	7,4	0,112	5	132	0,79

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)
Field	366.1	59.7	18.240
Sunflower	366.1	35.4	8.976
I^{st} year perennial grasses	366.1	18.7	1.914
II^{nd} year perennial grasses	286.5	6.3	0.246
Maize	366.1	29.6	8.425
Peas	366.1	21.3	3.789
Wheat	336.4	11.4	1.662

The analyses carried out on soil profiles, at the beginning of testing period and after 43 years, on a 16% slope, with length of 310 m, have shown that on the entire slope length, soils had a very different fertility (*Table 4*). Soil organic carbon was significantly higher at all slope positions in peas - wheat - maize - sunflower + two reserve fields cultivated with legumes and perennial grasses rotation (*Table 2*). The mean SOC content of the peas - wheat - maize - sunflower + two reserve fields cultivated with legumes and perennial grasses was high (81,27 t/ha), and higher than the wheat - maize rotation with 6,57 t/ha.

By decreasing soil fertility, the erosion process has determined the differentiation of the mean mass of organic carbon, according to slope positions and crop rotation, from 69.43 to 86.99 t/ha (*Table 4*).

On highly eroded soils, the increase in the organic carbon content from soil from 18.8 to 21.6 g/kg soil was recorded by the long-term application of the rate of $N_{80}P_{80}$ + 60 t/ha manure. The fertilization of wheat and maize crops at the rate of $N_{80}P_{80}$ + 60 t/ha manure has determined the increase by 5.5 t/ha (7.8%) in the content of organic carbon from soil, as compared to the rate of $N_{140}P_{100}$.

Table 4 - Mass of organic carbon, in the 0-30 cm soil depth, at Scobâlțeni site (Iaşi county) (t/ha)

Slope	Wheat - maize rotation			Peas – wheat – maize – sunflower + two reserve fields cultivated with legumes and perennial grasses			Difference
	N140P100	N80P80 + 60 t/ha manure	Mean	N140P100	N80P80 + 60 t/ha manure	Mean	
Footslope	75.03	79.12	77.08	83.39	86.99	85.19	8.11 ^{x}
Midslope	64.63	72.21	68.42	73.02	76.21	74.62	6.20 ^{x}
Shoulder	72.62	77.41	75.02	79.02	82.21	80.62	5.60 ^{x}
Average	70.76	76.25	73.50	78.48	81.80	80.14	6.64

x Indicates significance at $P \leq 0.05$

Experiments were conducted on the hydrographic basin of Scobâlțeni (Iaşi county), with a reception area of 159 ha, a mean altitude of 119.4 m, a mean slope of 11 % and a mean slope length of 250 m. The area of the hydrographic basin has been anti-erosion arranged 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.

In 1987, Scobâlțeni watershed had vegetation coverage of crops, which included wheat 30%, corn 30%, sunflower 10%, perennial grasses 20% and peas 10% (*Table 5; Figs. 1,2*).

In small catchments, with medium slopes of 11%, after seven years from the reclamation, the use of antierosional systems of cultivation in strips, with grassy strips and of the rotation of 3 and 4 years with an adequate structure of cultivation (wheat 30%, maize 30% leguminous plants for grains 30% and perennial herbs 10%) the losses of soil, recorded the most torrential rains were between 0.45 and 0.98 t / ha (*Figs. 3,4,5*).

In Scobâlțeni basin, a culture structure, which contains 30% wheat, 20% corn, 20% soybeans, 15% perennial grasses and 15% sunflower on a single rain, erosion was 940.8-1521 kg/ ha (*Table 5; Figs. 6,7*).

Table 5 - The most erosive events at the Scobâlțeni Study Catchment

The erosive events	Rainfall, mm	Intensity, mm/minute	Runoff, mm	Turbidity, g/l	Erosion, kg/ha
July 4, 1987 (Fig. 1)	65.0	0.118	4.1	14.5	594.50
August 5, 1987 (Fig. 2)	44.9	0.096	4.3	2.98	128.14
June 25, 1989 (Fig. 3)	32.0	1.280	3.1	7.4	229.40
August 15, 1989 (Fig. 4)	48.1	0.295	4.6	12.6	579.61
September7,1989 (Fig. 5)	128.4	0.038	12.9	1.72	221.88
July 1, 2006 (Fig. 6)	57.2	0.264	4.9	19.2	940.8
April 24, 2008 (Fig. 7)	55.1	0.196	6.5	23.4	1521.0

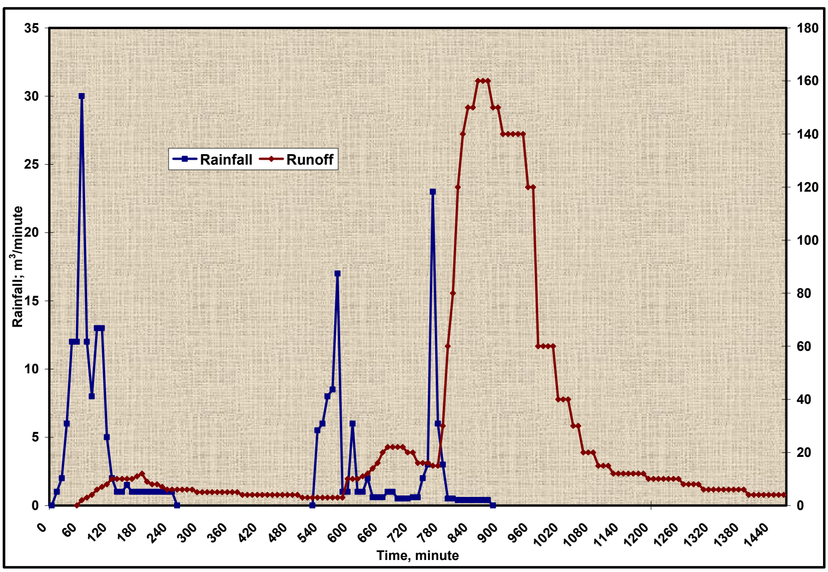

Figure 1 - Runoff (l/minute) hydrograph, on July 4, 1987, in Scobâlțeni watershed, Iaşi county

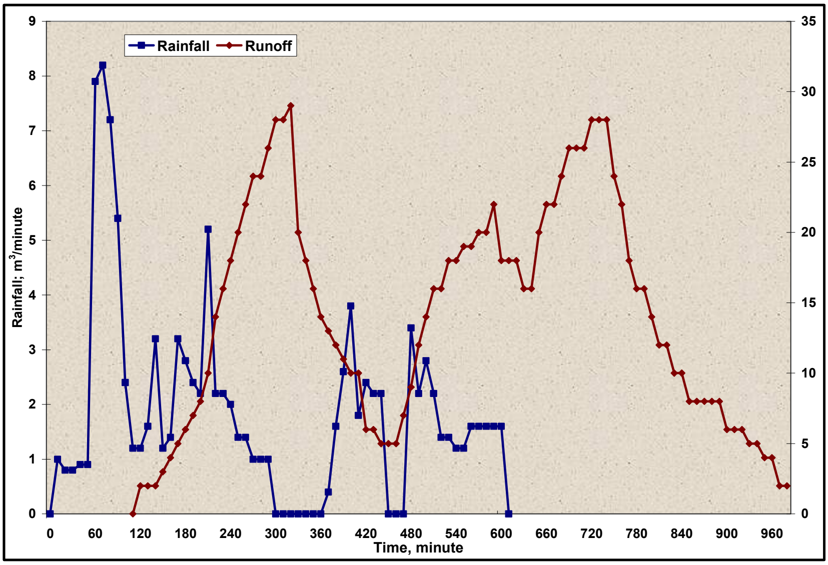

Figure 2- Runoff (l/minute) hydrograph, on August 5, 1987, in Scobâlțeni watershed

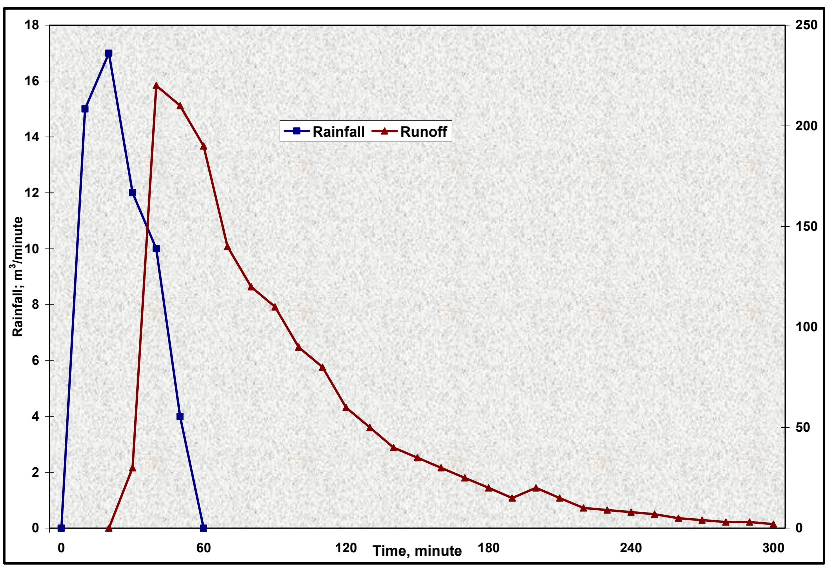

Figure 3- Runoff (l/minute) hydrograph, on June 25, 1989, in Scobâlțeni watershed

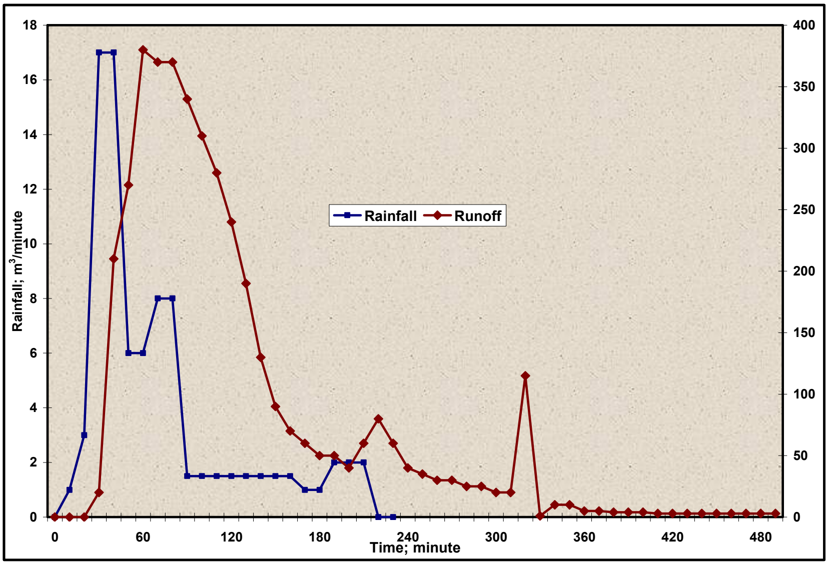

Figure 4 - Runoff (l/minute) hydrograph, on August 15, 1989, in Scobâlțeni watershed

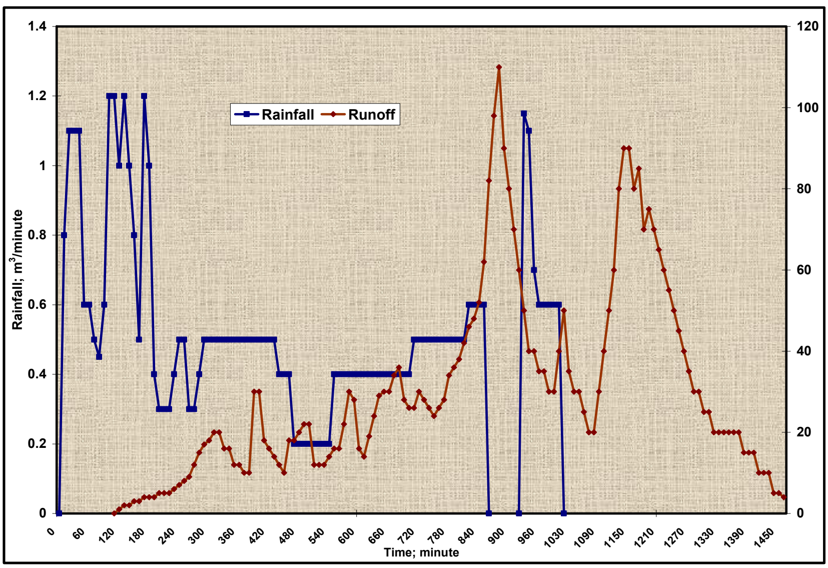

Figure 5 - Runoff (l/minute) hydrograph, on September 7, 1989, in Scobâlțeni watershed

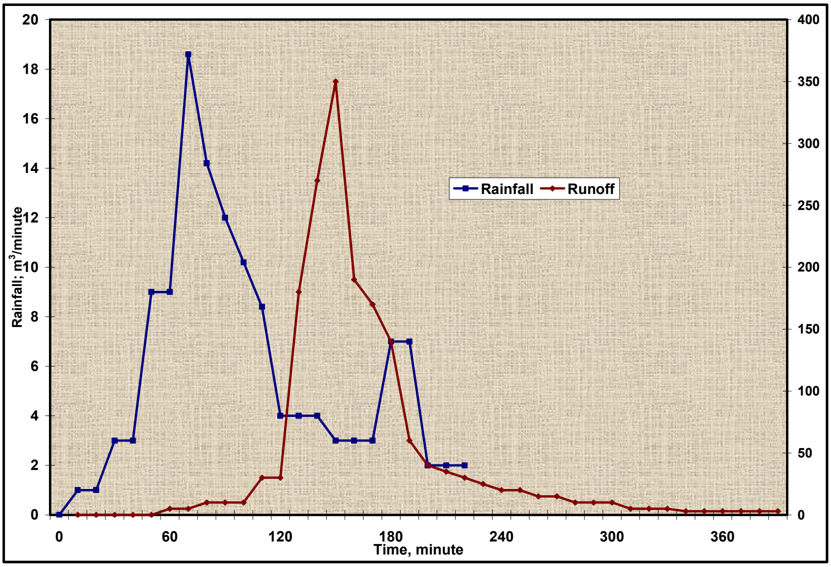

Figure 6 - Runoff (l/minute) hydrograph, on July 1, 2006, in Scobâlțeni watershed

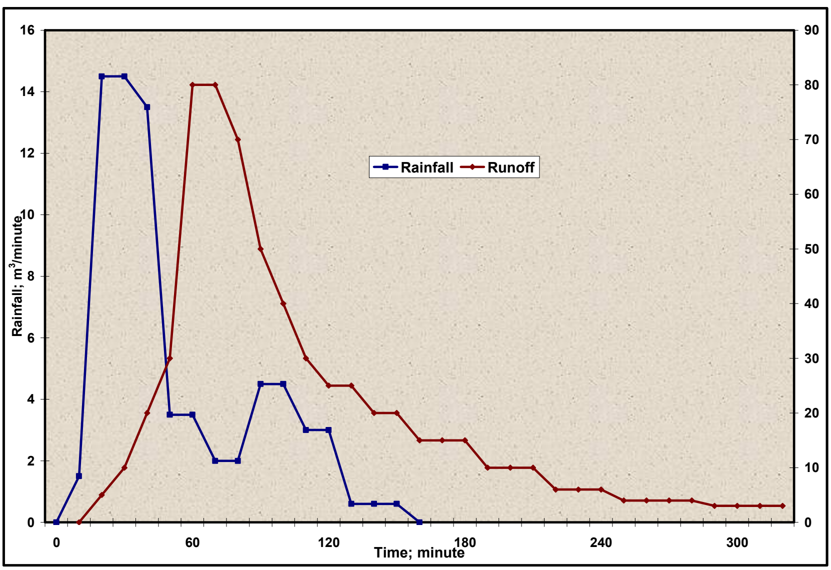

Figure 7 - Runoff (l/minute) hydrograph, on April 24, 2008 , in Scobâlțeni watershed

The processes of erosion with all its seals of forms of superficial leaching, drains, small gullies and torrents are at the most spread in Moldavian Field. Soil loss, recorded the most torrential rains were between 128 and 1521 kg/ha (*Table 5*). Land use management along the contour lines can be promoted and should be considered and used in lands at high erosion risk. Grassy strips, cultures into strips and hydraulic works are major measures to combat soil erosion.

The use of crop rotations leads to soil protection by ensuring plant cover as much as possible, which supports the enrichment of humus in the soil through the incorporation of their organic residue. On slope land, crops that can be considered as low-protection crops should be avoided in a rotation, in case no sufficient erosion controls measures.

CONCLUSIONS

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 3-4 t/ha/year only in case of 4 year-crop rotations with one or two reserve fields, cultivated with legumes and perennial grasses, which protect soil. Annual soil losses by erosion, registered during the last 30 years, in the Moldavian Plateau, were between 0.246 t/ha in perennial grasses, on the second year of vegetation, and 8.976 t/ha in sunflower.

The introduction of rotations peas - wheat - maize rotation + two outside fields cultivated with perennial grasses, which include in the crop structure 20% maize and plants for the protection against erosion, determined the diminution by 69.3% (4.415 t /ha) in mean annual losses of eroded soil and by 64.4% (12.888 kg/ ha) in losses of mineral elements, in comparison with maize continuous cropping.

Mean annual losses of soil by erosion were of 0.246 t /ha, in perennial grasses in the second growth year, 4.519 t /ha in beans, 8.425 t /ha in maize, and, 8.976 t /ha in sunflower.

As the part of small hydrographic basins, with medium slopes of 11%, after twenty five years from the reclamation, the use of antierosional systems of cultivation in strips, with grassy strips and of the rotation of 3 and 4 years with an adequate structure of cultivation (wheat 30%, maize 30% leguminous plants for grains 30% and perennial herbs 10%) the losses of soil were diminished with 79%, in comparison with unarranged surfaces.

The fertilization of wheat and maize crops at the rate of $N_{80}P_{80}$ + 60 t/ha manure has determined the increase by 5.5 t/ha (7.8%) in the content of organic carbon from soil, as compared to the rate of $N_{140}P_{100}$.

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