CROPPING SYSTEMS AND FERTILIZATION EFFECTS ON EROSION AND SOIL QUALITY IN MOLDAVIAN PLAIN

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Investigations, set up in 1968, were carried out on a Cambic Chernozem with a slope of 14%. They have shown the influence of different crop rotations and fertilization on soil erosion and fertility. On slope lands from the Moldavian Plain, a good supply in mobile phosphorus for field crops (36-49 mg kg^{-1}) was kept in case of the annual application of a rate of $N_{100}P_{80}$, and a very good supply in mobile phosphorus (71-78 mg kg^{-1}) and mobile potassium (over 200 mg kg^{-1}) was found at a rate of $N_{80}P_{60}$+30 t ha^{-1} of organic manure, applied in 3 or 4 -year crop rotations with legumes and perennial grasses. The total carbon mass on Cambic Chernozem from the Moldavian Plain has registered significant increases at higher than $N_{140}P_{100}$ rates, at organo-mineral fertilization and in 4-year crop rotation + reserve field cultivated with perennial grasses and legumes. The mean yield increases in wheat, during 1998-2009, were between 23 and 27 %, due to crop rotation and between 58 and 104 %, due to applied fertilizer rates. The determination of water runoff, soil, humus and nutritive element losses by erosion in different crops was done by means of loss control plots, 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 analyses of chemical elements. On 16% slope lands, the crop structure, which determined the diminution in mean soil losses by erosion until 2.3 t/ha/year included 20 % straw cereals (winter wheat), 20% annual legumes (pea), 20% row crops (maize) and 40 % perennial grasses and legumes.

Key words: *cropping systems, fertilization, soil erosion, organic carbon, wheat, maize*

Crop rotation will continue to be one of the most important components of the farming technological system, which contributes to rationing the consumption of fuel, water, fertilizers and pesticides and biological preparations for plant protection. Most of investigations have shown that on eroded slope lands, soil should be improved with organic and mineral fertilizers, which restored soil fertility, while crop fertilization assured the stability of yields in the planned crop rotation [2, 10]. The investigations follow the development of conservation technologies, by reducing energy and natural resource consumption, and by observing the requirements of European environment standards for the diminution in environment pollution.

In the last decade, many investigations have shown the special importance of different organic materials (manure, composts, and sewage sludge) on the carbon content from soil, on physical, chemical and biological characteristics and soil erosion [1, 13, 14, 16].

The investigations conducted at Saskatchewan in Canada, on a grey Luvisol with sandy-clayey texture, 5% organic matter and a pH of 7.1 (where the annual mean of rainfall and evapo-transpiration is of 410 and 506 mm, respectively) have shown that the yield of wheat, placed in barley-peas-wheat-rape rotation, was of 2744 kg/ha under unfertilized and of 3786 kg/ha (+38%) at rate of N_{120} P_{30} K_{42} kg/ha. The quantity of straw, chaff and roots (at depth of 0-15 cm) in wheat crop was of 6728 kg/ha, under unfertilized, and 7691 kg/ha (+34.3%), at the rate of $N_{120}P_{30}K_{42}$ kg/ha [8].

In many countries, the most recent research has investigated the diversification of cropping systems by increasing the rate of annual and perennial legumes within crop structure [4, 5, 11, 15] The investigations conducted in long-term experiments at Rothamsted have shown that only at high fertilizer rates ($>N_{192}P_{35}K_{90}Mg_{35}$), a significant increase was found in the mass of total organic carbon and stable carbon from soil [3]. The diminution in the mass of organic carbon from soil, when lower rates than 180 kg N ha^{-1} were applied, was also noticed under long-term experiments carried out on sandy loam Mollisol from Nashua and on clayey-loam Mollisol from Kanawha, in North Iowa, USA. In sandy loam Mollisol from Nashua, applying a rate of 270 kg N ha^{-1} has resulted in increasing the mass of organic carbon, against the unfertilized control, from 18.3 to 20.0 g C kg^{-1} soil, in maize-soybean rotation and from 22.7 to 23.6 g C kg^{-1} soil in maize-maize-oats-alfalfa rotation [14].

On sandy clayey fields from Foulum and Flakkebjerg in Denmark, where in the last 25 years they used mainly spiked cereals rotations, the content of organic carbon diminished by approximately 7% and 15%, respectively [15].

The use of wheat continuous cropping on slope Vertic Cambisols has diminished the content of organic carbon, at depth of 0-40 cm, in comparison with perennial grasses, from 15.0 g kg^{-1} to 8.3 g kg^{-1} in Southern Italy (Catanzaro, Calabria) and from 19.0 g kg^{-1} to 12.7 g kg^{-1} in the centre of Italy (Siena) [12].

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 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, slides and other degradation forms (Project of Regional Development North East 2007-2013).

MATERIAL AND METHOD

Investigations conducted during 1980-2009 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. These experiments were carried out on a 14% slope field, on a Cambic Chernozem with clayey loam texture (423 g clay, 315 g loam and 262 g sand), a neuter to weakly acid reaction and a mean nutrient supply.

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. This station contains a triangular spillway, pluviometer, pluviograph, limn graph and devices for sampling soil and water during rainfall. When raining, samples are taken for the determination of the partial turbidity and of the content in humus and mineral elements lost by erosion. The soil on which physical and chemical analyses were done was sampled at the end of plant growing period. Soil response was determined in water suspension by potentiometrical means with glass electrode. 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.

RESULTS AND DISCUSSIONS

The investigations carried out on eroded soil have tried to establish the crop rotations and fertilization systems, which contributed to maintain and restore soil fertility.

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 542 mm, of which 161.2 mm, during September December, and 380.8 mm, during January-August.

On eroded lands, the mean wheat yields obtained during 1998-2009, were comprised between 1753 kg ha^{-1} (100 %) at the unfertilized control and 3574 kg ha^{-1} (204 %) at rates of 80 kg N + 60 kg P_2O_5 + 30 t ha^{-1} manure *(table 1)*.

Applying rates of 160 kg N + 100 kg P_2O_5 determined yield increases of 95 % (1663 kg ha^{-1}) in wheat crop, and 88 % (2794 kg ha^{-1}) in maize crop, against the unfertilized variant. In wheat placed on eroded lands, the mean yield increases obtained for each kg of a. i. of applied fertilizers varied according to applied fertilizer rates, between 6.4 and 6.8 kg grains ($N_{80}P_{60}$-$N_{160}P_{100}$). In maize, by mineral fertilization ($N_{80}P_{60}$-$N_{160}P_{100}$), mean yield increases of 9.5-10.7 kg grains kg^{-1} a. i. of applied fertilizer were obtained.

Placing winter wheat in 3 and 4- year crop rotations with annual and perennial legumes has resulted in getting yield increases of 23 – 27% (555 – 653 kg ha^{-1}), as compared to continuous cropping *(table 2)*. The mean yield increases in maize, during 1998-2009, were between 24 and 27% (1054 – 1176 kg ha^{-1}), due to crop rotation and between 42 and 91% (1326 – 2897 kg ha^{-1}), due to applied fertilizer rates. Applying high fertilizer rates ($N_{160}P_{100}$) in maize has determined, in the last 12 years, an average yield increase of 88% (2794 kg ha^{-1}), while the use of low mineral fertilizer rates ($N_{80}P_{60}$), together with 30 t ha^{-1} of organic manure, resulted in getting an yield increase of 91% (2897 kg ha^{-1}).

In Cambic Chernozem, on the slope lands from the Moldavian Plain, a good supply in mobile phosphorus of field crops (37-72 mg kg^{-1}) was maintained in annual application of a rate of $N_{120}P_{80}$ and a very good supply (72-78) at the rate of $N_{80}P_{60}$+30 t ha^{-1} of manure, applied in crops from 3 or 4 -year crop rotations with perennial grasses and legumes *(table 3*). The mass of total carbon from Cambic Chernozem in the Moldavian Plain has recorded significant increases at higher than $N_{160}P_{100}$ rates, in organo-mineral fertilization and in 4-year crop rotation, which included melioration plants of perennial grasses and legumes *(table 4*).

In maize continuous cropping and wheat-maize rotation, very significant values of the carbon content were found only in the organo-mineral fertilization, in 4-year crop rotations + reserve field cultivated with perennial legumes and under $N_{160}P_{100}$ fertilization. The analyses conducted on soil samples, taken from the field on which wheat-maize rotation had been used for 40 years, pointed out the worsening of some soil chemical characteristics. In comparison with 4-year crop rotations, in wheat-maize rotation with melioration plants (annual and perennial legumes and perennial grasses), the mean carbon content from soil has diminished from 18.6 to 16.4 C**,** g kg^{-1}, and the content in mobile phosphorus decreased from 52 to 37 P-AL, mg kg^{-1}.

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 [6, 9, 11].

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 [9]. 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%) [5]. 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 [13]. On 8.5% slope fields from SW Finland, soil annual losses by erosion are of 5-6 t ha^{-1}, and leached nitrogen and phosphorus amounts are of 15 and 1.1 kg ha year^{-1}, respectively [11, 15].

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 5*). 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 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.

Table 1

Influence of fertilizers on wheat and maize yield during 1998 – 2009, (Gabriela varieties and PI 110 hybrid)

Fertilizer rate	Wheat yield		Dif. kg ha^{-1}	Sign.	Maize Yield		Dif. kg ha^{-1}	Sign.
	kg ha^{-1}	%			kg ha^{-1}	**%**		
N_0P_0	1753	100			3167	100		
$N_{80}P_{60}$	2702	154	949	xxx	4493	142	1326	xxx
$N_{120}P_{80}$	3077	176	1324	xxx	5414	171	2247	xxx
$N_{160}P_{100}$	3416	195	1663	xxx	5961	188	2794	xxx
$N_{80}P_{60}$+30 t ha^{-1} manure	3574	204	1821	xxx	6064	191	2897	xxx
LSD 5%			224				412	
LSD 1%			385				574	
LSD 0.1%			597				768	

Table 2

Influence of rotation on wheat and maize yield during 1998 – 2009, (Gabriela varieties and PI 110 hybrid)

Crop rotation	Wheat yield		Dif. kg ha^{-1}	Sign.	Maize Yield		Dif. kg ha^{-1}	Sign.
	kg ha^{-1}	%			kg ha^{-1}	%		
Continuous cropping	2612	100			4376	100		
Wheat – maize	2574	100	-38		4719	108	343	x
Peas –wheat-maize	3167	123	555	xxx	5430	124	1054	xxx
Peas –wheat-maize– sunflower + reserve field cultivated with legumes and perennial grasses	3265	127	653	xxx	5552	127	1176	xxx
LSD 5%			218				329	
LSD 1%			342				465	
LSD 0.1%			498				643	

Table 3

Influence of long-term fertilization and crop rotation on the content of mobile phosphorus from soil (P-AL, mg kg^{-1})

Treatment	* Wcc	W-M	P-W-M	P-W-M-S+GL	Mean	Differ.	Signif.
N_0P_0	13	10	14	15	13.0	0	
$N_{80}P_{60}$	29	26	35	40	32.5	19.5	xxx
$N_{120}P_{80}$	41	38	49	56	46.0	33.0	xxx
$N_{160}P_{100}$	58	52	63	69	60.5	47.5	xxx
$N_{80}P_{60}$+30 t ha^{-1} manure	67	58	69	78	68.0	55.0	xxx
Mean	41.6	36.8	46.0	51.6	44.0		
Difference	0	-4.8	4.4	10.0			
Significance		0	x	xxx			
	Interaction	Rotation	Fertilizer				
LSD 5%	3.3	3.8	4.3				
LSD 1%	4.4	5.1	5.7				
LSD 0.1%	5.8	6.7	7.5				

Table 4

Influence of long-term fertilization on the content of carbon from soil (C, g/kg^{-1})

Treatment	*Mcc	W-M rotation	P-W-M rotation	*P-W-M-S+GL	Average	%	Differ.
N_0P_0	15.9	15.2	16.5	16.8	16.1	100	0
$N_{80}P_{60}$	15.7	14.8	16.9	17.1	16.1	100	0.0
$N_{120}P_{80}$	16.4	16.2	17.3	18.2^{x}	17.0	106	0.9
$N_{160}P_{100}$	17.2	17.0^{x}	18.5^{xx}	19.7^{xxx}	18.1	112	2.0^{x}
$N_{80}P_{60}$+30 t ha^{-1} manure	19.4^{xxx}	19.0^{xxx}	20.1^{xxx}	21.4^{xxx}	20.0	124	3.9^{xxx}
Mean	16.9	16.4	17.9	18.6			
Difference	0.0	-0.5	1.0	1.7 ^{xx}			
	Interaction	Crop rotation		Fertilizer			
LSD 5%	1.2	1.4		1.5			
LSD 1%	1.6	1.8		2.1			
LSD 0.1%	2.1	2.4		2.7			

*Mcc - Maize continuous cropping; M - maize; W - wheat; P - pea; S - sunflower; *GL - reserve field cultivated with perennial grasses and legumes

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 6*).

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 7*). 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 $t \cdot ha^{-1} \cdot year^{-1}$ 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 5

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 6

Mean annual losses of nitrogen, phosphorus and potassium, due to erosion in different crops, in the Moldavian Plateau (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

Table 7

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

The mineral fertilization with lower rates than $N_{160}P_{100}$ kg ha^{-1} has determined the decrease in carbon content from soil until 15.2- 15.9 g/kg^{-1}.

The combined use of mean rates of mineral fertilizers ($N_{80}P_{60}$), together with 30 t ha^{-1} manure, has resulted in improving soil physical and chemical characteristics and getting yield increases in wheat of 1821 kg ha^{-1} (104 %), and in maize of 2897 kg ha^{-1} (91 %), against the unfertilized control. Mean annual losses of soil by erosion, recorded in 16% slope fields from the Moldavian Plateau, were of 0.298 t·ha^{-1} in perennial grasses in the second growth year, 4.618 t·ha^{-1} in beans, 9.176 t·ha^{-1} in maize and 9.650 t·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·ha^{-1}·$year^{-1}$ 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% (4.17 kg ha^{-1}) in nitrogen leakages, compared with wheat-maize rotation.

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