RESEARCH ON THE EVOLUTION OF THE MAIN SOIL CHEMICAL FEATURES AS INFLUENCED BY CROPPING SYSTEM AND SOIL EROSION

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The experiments carried out at the Podu-Iloaiei Agricultural Research Station, during 1986-2007, had the following objectives: study of water runoff and soil losses by erosion, in different crops; annual rate of erosion processes under the influence of anti-erosion protection of different crops; influence of water runoff and soil erosion on organic matter and mineral element losses from soil. The investigations concerning the potential erosion, conditioned by geomorphologic, soil and climatic factors, have shown that in the NE region of Romania, the mean soil losses by erosion were of 18.5 t ha year^{-1}. The investigations concerning the effective erosion, based on direct determinations, have shown that in the NE region, the effective erosion had a mean value of 4.5 t ha year^{-1}.The mean annual soil losses, caused by erosion, registered during 1986 – 2007, were of 0.286 t ha^{-1} in perennial grasses, on the second growth year, 4.617 t ha^{-1} in beans, 9.268 t ha^{-1} in maize and 9.794 t ha in sunflower. The analysis of results has shown that the erosion process, by decreasing soil fertility, has determined the differentiation of mean wheat yields, according to slope and erosion, from 3632 (100 %) to 2916 kg ha^{-1} (80.3 %). The mean annual yield losses caused by erosion, registered in wheat in the last 10 years, were of 716 kg ha^{-1} (19.7 %).

Keywords: *soil erosion, crop rotation, fertilization, wheat, organic matter*

Erosion is caused by many climatic and human factors, among which the growing system determines a great variability of this process. Erosion affects soil fertility, which decreases gradually at the same time with soil removing from upper horizons, a great amount of organic matter and nutrients. Water runoff caused by erosion diminishes the crop yield, worsening soil water regime; it is an important means of transportation for chemical polluting agents in the hydrographic network.

The main concerns of the European environment are pollution on 20% of the total surface waters, soil erosion that affects 17% of fields and diminution of biodiversity, which affects over 335 species [1]. In all the countries, the quality of environment factors was affected by economic activities, climatic changes and pollution [7, 8, 17]. The North-Eastern region of Romania represents 15.45% (2 131 421 ha) of the farming area of the country (14 836 585 ha) and has large areas with soils affected by erosion (over 56%), acidification, compaction, slides and other forms of degradation (Project of Regional Development for North-East 2007-2013).

On slope farming fields from Big Creek hydrographic basin in Southern Illinois, with mean annual rainfall of 1220 mm, eroded soil reaches 16.35 t ha $year^{-1}$ and organic carbon content from soil varies between 1 and 1.5 kg C m^{-2} [21]. On sandy loam soils from Iowa, in maize-soybean rotation the 20-year average annual SOC (soil organic carbon) change rates were −86 and 415 kg C ha^{-1} for conventional tillage and no-till, respectively. The use of cover crops (clover, winter wheat, oat and barley) for diminishing soil erosion, in 20 years, has resulted in increasing the organic carbon content by 1055 kg C ha $year^{-1}$ in legumes and diminishing the amount of leached nitrates by 9 kg N ha $year^{-1}$ in non-legumes [5].

In maize cultivated under no-till, on clayey soils from Alabama, the losses of NH_4^+ N (3.1 kg ha^{-1}) were in spring by 3-5 times higher than during summer-autumn season, and phosphorus losses caused by erosion were of 2.1 -2.4 kg ha^{-1} [16].

The investigations conducted at Baden-Württemberg, Germany on Gleyic Cambisol have shown that in wheat fertilized with $N_{140}P_{30}K_{60}$, straws and root biomass determined the increase in mineralized carbon content by 12.0 and 9.44%, respectively. In the experimental field from Dummerstorf, North-Eastern Germany, with mean annual rainfall of 665 mm, in the rotation maize-winter wheat-winter rape- and 10% red clover (*Trifolium pratense* L.) and 90% perennial ryegrass (*Lolium perenne* L.), the annual amounts of leached NO_3-N during 2004-2005 were of 15.7 -16.9 kg ha^{-1} [18]. 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 [13]**.** Investigations conducted in the Republic of Moldova by means of loss control plots, placed on weakly eroded Cambic Chernozem with 5-11^0 slope, showed that during 1957-1962, the mean annual amounts of rainfall producing soil losses were of 78.9 mm. They determined water runoff of 10.83 mm ha $year^{-1}$ (runoff coefficient 0.14) and erosion of 37.3 m^3 ha $year^{-1}$ of eroded soil [15].

Data on the quality of environment factors, obtained in 2003, from the monitoring network of the Ministry of Environment and Water have shown a slight improvement in environment quality , due to the retechnologization activities of some economic units. 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 (on 44% of the total of farming area; primary compaction is found on 2 million ha of arable fields-13.59%, and the tendency of crust formation at soil surface, on 2.3 million ha -15.63%), soil chemical pollution (0.9 million ha). Soil erosion affects the production and the safety of dwellings, infrastructure and water quality in affected areas (Source:

Government of Romania - December 2005-National Plan of Development (NPD) 2007-2013, December 2005, National Agency of Cadastre and Estate Publicity, Statistical Year Book of Romania, 2001, 2003, 2004).

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; Statistical Yearbook of Romania (2003). In the last period, many models have been developed for erosion control, for establishing the deposits lost from hydrographic basins. The factors influencing soil erosion are numerous, including climatic, hydrological parameters, topography of land, vegetation and soil characteristics. Their complex interaction at soil surface makes harder the establishment of the erosion rate from hydrographic basins [6, 12].

MATERIALS AND METHODS

These experiments were carried out on a 14% slope 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, 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. 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, 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. Experiments were conducted on the hydrographic basin of Scobalteni, with a catchment 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.

Wheat and maize experiments were carried out based on the method of blocks with split-split plots with six replicates. We have followed the influence of long-term application of different rates of organic and mineral fertilizers and crop residues on wheat and maize yield and on soil agrochemical characteristics.

RESULTS AND DISCUSSIONS

The climatic conditions in the Moldavian Plain were characterized by a mean multiannual 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.

On weakly eroded lands, the mean wheat yields obtained during 1998-2007, were comprised between 1697 kg ha^{-1} (100 %) at the unfertilized control and 4894 kg ha^{-1} (188 %) at rates of 70 kg N + 70 kg P_2O_5 + 60 t ha^{-1} manure *(table 1*). Under these conditions, by applying rates of 100 kg N + 100 kg P_2O_5 or 140 kg N + P_2O_5 100 kg ha^{-1}, the mean yield increases were of 2381 and 2826 kg ha^{-1}, respectively.

On highly eroded soil, the mean wheat yields obtained during 1998-2007 in wheat crop, placed in the peas-wheat-maize rotation, were of 1163 kg ha^{-1} under unfertilized, and of 3665 kg ha^{-1} at high mineral fertilizer rates ($N_{140}P_{100}$). In wheat, the application of mean rates of mineral fertilizers together with 60 t ha^{-1} manure has resulted in getting yield increases of 183 % (2131 kg ha^{-1}), against the unfertilized variant. Applying rates of 100 kg N + 100 kg P_2O_5 determined yield increases of 140 % (2381 kg ha^{-1}) in wheat crop, placed on weakly eroded lands, and 179 % (2085 kg ha^{-1}) in wheat, placed on highly eroded soil, against the unfertilized variant. In wheat placed on weakly eroded lands, the mean yield increases obtained for each kg of a. i. of applied fertilizers varied according to applied fertilizer rates, between 9.15 and 11.8 kg grains ($N_{40}P_{40}$-$N_{140}P_{100}$). On highly eroded lands, mean wheat yields obtained under unfertilized were of 1163 kg ha^{-1} and mean yield increases obtained by applying 40 or 60 t/ha^{-1} manure were of 41.3-35.5 kg grains per ton of manure. By mineral fertilization ($N_{40}P_{40}$-$N_{140}P_{100}$), mean yield increases of 8.1-10.4 kg grains kg^{-1} a. i. of applied fertilizer were obtained. Very close yield results were also obtained by applying, for 42 years, rates of 70 kg N + 70 kg P_2O_5 +3 t ha^{-1} stalk of peas or soybean. At these variants, the yield increases varied, according to soil erosion, between 2313 and 2214 kg ha^{-1} (136-130 %) on weakly eroded lands, and between 2074 and 2001 kg ha^{-1} (178-172 %) on highly eroded lands (*table 1*). The analysis of results has shown that the erosion process, by decreasing soil fertility, has determined the differentiation of mean wheat yields, according to slope and erosion, from 3632 (100 %) to 2916 kg ha^{-1} (80.3 %). The mean annual yield losses caused by erosion, registered in wheat in the last 10 years, were of 716 kg ha^{-1} (19.7 %).

The positive effect of applying crop residues, together with moderate nitrogen rates, on crop yield and soil physical, chemical and biological characteristics was found in many regions with different climatic conditions and soils [3, 4, 9, 14]. The investigations conducted by Campbell (2005) on low slope fields, in the semi-arid zone from Saskatchewan, Canada, on a Chernozem with a pH of 6.5 and a mean texture, have shown that during 36 years, wheat straws have supplied wheat with 37 kg nitrogen ha^{-1}.

Many research works have shown that the additional N application was necessary, when crop residues remained in soil, for avoiding the immobilization of N from soil and increasing the carbon content from soil [4, 19]. Other studies have shown that for determining the rates of crop residues, which had to be applied in order to improve soil characteristics and diminish erosion, one should take into account climatic conditions, soil type and cultural practices [10, 11, 20].

Table 1

Influence of mineral and organic fertilizers on wheat yields, in weakly and highly eroded lands, (F-4 and Gabriela varieties)

Fertilizer rate	Weakly eroded soil		Highly eroded soil	
	Wheat yields, kg ha^{-1}	Differ. kg ha^{-1}	Wheat yields, kg ha^{-1}	Differ. kg ha^{-1}
N_0P_0	1697	0	1163	0
$N_{70}P_{70}$	3192	1495	2478	1315
$N_{100}P_{100}$	4078	2381	3248	2085
$N_{140}P_{100}$	4523	2826	3665	2502
$N_{70}P_{70}K_{70}$	3384	1687	2710	1547
$N_{100}P_{100}K_{100}$	4398	2701	3570	2407
$N_{140}P_{140}K_{140}$	4797	3100	3923	2760
20 t/ha manure	2761	1064	2165	1002
40 t/ha manure	3445	1748	2813	1650
60 t/ha manure	4018	2321	3294	2131
$N_{70}P_{70}$+20 t/ha manure	4102	2405	3304	2141
$N_{70}P_{70}$+40 t/ha manure	4619	2922	3669	2506
$N_{70}P_{70}$+60 t/ha manure	4894	3197	4011	2848
$N_{70}P_{70}$+6 t/ha hashed straw	3770	2073	3041	1878
$N_{70}P_{70}$+6 t/ha stalks of maize	3578	1881	2929	1766
$N_{70}P_{70}$+3 t/ha stalks of pea	4010	2313	3237	2074
$N_{70}P_{70}$+3 t/ha stalks of soybean	3911	2214	3164	2001
Mean	**3632**		**2916**	
LSD 5%		340		310
LSD 1%		450		430
LSD 0.1%		580		570

On 16% slope fields from the Moldavian Plateau, the erosion process has resulted in diminishing the content of humus and nutrients from soil and the mean wheat yield by 19.7% (716 kg ha^{-1}), in 10 years. Both on weakly and highly eroded fields, the mineral fertilization with lower rates than $N_{140}P_{100}$ kg ha^{-1} has resulted in diminishing the humus content from soil until 2.49- 2.91 % (*table 2).* On weakly eroded fields, the humus content was maintained at over 3.2% by annual application of average mineral fertilizer rates ($N_{70}P_{70}$), together with 6 t ha^{-1} of wheat and maize residues, in the annual legumes-wheat-maize rotation. On highly eroded fields, the humus content was kept at values of 3.42-3.49% only by the annual application of a rate of 60 t ha^{-1} manure or $N_{70}P_{70}$+ 60 t ha^{-1} manure. The annual application for 40 years, of 6 t ha^{-1} crop residues, together with 70 kg ha^{-1} nitrogen and 70 kg ha^{-1} P_2O_5, has kept the humus content from soil at values of 3.14-3.28% on weakly eroded fields and of 3.08-3.12% on highly eroded fields.

On weakly eroded Cambic Chernozem from the Moldavian Plateau, a good supply of mobile phosphorus in wheat and maize crops (37-72 mg kg^{-1}) was done in the annual application of a rate of $N_{100}P_{80}$, while a very good supply (69-78) was achieved at the rate of $N_{70}P_{70}$+60 t ha^{-1} manure. On highly eroded fields, a very good supply of mobile phosphorus and potassium was done by applying manure at amounts of 60 t ha^{-1} or at the rate of $N_{70}P_{70}$ + 60 t ha^{-1} manure.

Table 2

Effect of soil erosion and fertilization system on the humus and mineral element content in 16% slope fields from the Moldavian Plateau

Fertilizer rate	Weakly eroded lands				Highly eroded lands			
	pH (H_2O)	**Humus (%)**	**P-AL (ppm)**	**K-AL (ppm)**	**pH (H_2O)**	**Humus (%)**	**P-AL (ppm)**	**K-AL (ppm)**
N_0P_0	7.2	2.86	18	206	7.1	2.46	9	189
$N_{70}P_{70}$	6.8	2.91	52	189	6.7	2.49	42	162
$N_{100}P_{80}$	6.3	3.05	87	186	6.1	2.66	61	154
$N_{140}P_{100}$	5.8	3.12	89	174	5.6	2.84	59	151
60 t/ha manure	7.3	3.72	79	287	7.1	3.42	62	254
$N_{70}P_{70}$ + 60 t/ha manure	7.1	3.79	94	314	6.9	3.49	79	286
$N_{70}P_{70}$ + 6 t/ha hashed of wheat	6.9	3.28	62	238	6.7	3.12	58	206
$N_{70}P_{70}$+6 t/ha stalks of maize	6.5	3.22	59	246	6.4	3.09	49	187
$N_{70}P_{70}$+3 t/ha stalks of peas	6.8	3.18	48	235	6.7	3.10	52	185
$N_{70}P_{70}$+3 t/ha stalks of soybean	6.8	3.14	49	232	6.7	3.08	49	179
Mean	**6.8**	**3.23**	**64**	**231**	**6.6**	**2.98**	**52**	**195**
LSD 5%	0.25	0.11	4.97	18.08	0.27	0.16	4.52	15.82
LSD 1%	0.36	0.16	7.15	26.00	0.39	0.23	6.50	22.75
LSD 0.1%	0.53	0.24	10.52	38.24	0.57	0.33	9.56	33.46

The goal of the experiments carried out at the Podu-Iloaiei Agricultural Research and Development Station, during 1986-2007, was to study water runoff and soil losses, caused by erosion in different crops; the annual rate of soil losses under anti-erosion protection of various crops; the influence of water runoff and soil erosion on soil organic matter and nutrient losses. The control of water runoff, soil and nutrient losses, caused by erosion was carried out by means of runoff and loss control plots, with an area of 100 m^2, cultivated with various crops. At the same time, the determination of soil, water, humus and mineral element losses, caused by erosion, was carried out on the whole area of the hydrographic basin, where experiments were set up, by means of a hydrometric station equipped with apparatus for measuring flows of water runoff on slopes (limnigraph). The research carried out until now has shown that erosion-affected soils had a lower profile depth, rougher texture, more alkaline reaction, higher carbonate content and lower humus and mineral element content. The investigations concerning the potential erosion, conditioned by geomorphologic, soil and climatic factors, have shown that in the NE region of Romania, the mean soil losses by erosion were of 18.5 t ha year^{-1}, values which corresponded to a moderate erosion risk. The investigations concerning the effective erosion, based on direct determinations and complex analyses, have shown that in the NE region, the effective erosion had a mean value of 4.5 t ha year^{-1} [2,]. The mean annual soil losses, caused by erosion, registered during 1986 – 2007, were of 0.286 t ha^{-1} in perennial grasses, on the second growth year, 4.617 t ha^{-1} in beans, 9.268 t ha^{-1} in maize and 9.794 t ha in sunflower *(table 3)*.

Table 3

Mean annual erosion losses of humus and mineral elements from various crops

Crop	Runoff water (mm)	Eroded soil (kg ha^{-1})	Humus and mineral element losses, caused by erosion, kg ha^{-1}					
			Humus	N, in runoff water	N, in eroded soil	Total N	P-AL	K-AL
Fallow land	43,8	18460	652	3.311	20.174	23.485	1.632	3.668
Sunflower	17.1	9794	349	1.438	14.887	16.325	1.126	2.400
Grasses, I year	8.0	1864	66	0.709	2.610	2.532	0.214	0.464
Grasses, II year	5.3	286	10	0.470	0.469	0.939	0.032	0.071
Maize	16.3	9268	329	1.444	15.200	16.644	1.038	2.317
Peas	8.7	2680	95	1.037	3,216	4,253	0.244	0.536
Wheat	7.1	1574	56	0.846	2.581	3.428	0.176	0.394
Beans	10.7	4617	164	1.081	6.926	8.006	0.517	1.154

CONCLUSIONS

On soils from the Moldavian Plateau, most of them situated on slope fields, poor in organic matter and nutrients, the proper use of different organic resources may replace a part of rich technological consumption (mineral nutrients), determine the improvement in the content of organic matter from soil and ensure better conditions for the valorisation of nitrogen fertilizers.

The combined use of mean rates of mineral fertilizers ($N_{70}P_{70}$), together with 40 t ha^{-1} manure or 6 t ha^{-1} crop residues from wheat and maize crops, has resulted in improving soil physical and chemical characteristics and getting yield increases in wheat of 2313-2214 kg ha^{-1} (136-130 %), on weakly eroded lands, and 2074-2001 kg ha^{-1} (178-172 %) on highly eroded lands, against the unfertilized control.

Both on weakly and highly eroded lands, the mineral fertilization with lower rates than $N_{140}P_{100}$ kg ha^{-1} has determined the decrease in humus content from soil until 2.49- 3.05 %. On highly eroded lands, the humus content was kept at values of 3.42-3.49% only by the annual application of the rate of 60 t ha^{-1} manure or $N_{70}P_{70}$+ 60 t ha^{-1} manure.

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 were diminished below the allowable limit of 3-4 t ha $year^{-1}$ only in 4 year-crop rotations with one or two reserve fields, cultivated with legumes and perennial grasses, which protect soil.

Among all the processes of soil degradation, in the Moldavian Plateau, erosion is the most damaging, causing the loss of mean annual soil amounts of 1.574 t ha^{-1} in wheat, 4.617 t ha^{-1} in beans, 1.864 t/ha^{-1} in perennial grasses, in the first growth year, 9.268 t ha^{-1} in maize and 9.794 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, can reach 16.32 – 16.64 kg ha^{-1} of nitrogen, 1.04 – 1.13 kg ha^{-1} of phosphorus and 2.32 – 2.40 kg ha^{-1} of potassium, representing, on the average, 12 - 14 % of the need of chemical fertilizers for these crops.

BIBLIOGRAPHY

1. Alexander, Kaptein, 2006 - *European Land Monitoring - Progress & Next Steps - Europe's environment under pressure*, Infoterra GmbH, Medias-France.
2. Bucur, D., Jitareanu, G., Ailincai, C., Tsadilas, Ch., Ailincai, Despina and Mercus, Ad., 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): 261-264. 2007.
3. Campbell, C. A., Zentner, R. P., Selles, F., Jefferson, P. G., McConkey, B. G., Lemke, R. and Blomert, B. J., 2005 - *Long-term effect of cropping system and nitrogen and phosphorus fertilizer on production and nitrogen economy of grain crops in a Brown Chernozem*. Canadian Journal of Plant Science 85: 81–93.
4. Clapp, C.E., Allmaras, R.R., Layese, M.F., Linden, D.R. and Dowdy, R.H., 2000 - *Soil organic carbon and 13C abundance as related to tillage, crop residue, and nitrogen fertilization under continuous corn management in Minnesota*. Soil and Tillage Research 55: 127-142.
5. Farahbakhshazada, Neda, Dinnes, Dana L, Li, Changsheng,.Jaynes, Dan B. and Salas, William, 2008-*Modeling biogeochemical impacts of alternative management practices for a row-crop field in Iowa*, Agriculture, Ecosystems & Environment, Vol. 123, Pages 30-48.
6. Klik, A., Frauenfeld, B., Hollaus, K., 2002. Experiences with conservation tillage and no till in Austria. In: van Santen, E. (Ed.), Making Conservation Tillage Conventional: Building a Future on 25 Years of Research. Proceedings of the of 25th Annual Southern Conservation Tillage Conference for Sustainable Agriculture. Auburn, AL 24–26 June 2002.

7. Linden, D.R., Clapp, C.E. and Dowdy, R.H., 2000 - *Long-term corn grain and stover yields as a function of tillage and residue removal in east central Minnesota*. Soil and Tillage Research 56: 167-174.
8. Lindstrom, M.J., 1986 - *Effects of residue harvesting on water runoff, soil erosion and nutrient loss. Agriculture*, Ecosystems and Environment 16: 103-112.
9. Liu, X., Herbert, S.J., Hashemi, A.M., Zhang, X., Ding, G., 2006 - *Effects of agricultural management on soil organic matter and carbon transformation – a review*, Plant Soil Environ., 52, 2006 (12): 531–543.
10. Marhan, Sven , Demin, Dmitry, Erbs, Martin, Kuzyakov, Yakov, Fangmeier, Andreas and Kandeler, Ellen, 2008 – *Soil organic matter mineralization and residue decomposition of spring wheat grown under elevated CO_2 atmosphere*, Agriculture, Ecosystems & Environment, Vol.123, Pages 63-68.
11. McCool, D.K., Hammel, J.E. and Papendick, R.I., 1995 - Surface Residue Management. Crop Residue Management to Reduce Erosion and Improve Soil Quality: Northwest. Papendick, R.I. and Moldenhauer, W.C.,U.S. Department of Agriculture Conservation Research Report 40: 10-16.
12. Mignolet, C., 2004, - Spatial dynamics of agricultural practices on a basin territory. Agronomie, nr. 24,219-236, 2004)
13. Muukkonen, Paula, Hartikainen, Helinä, Lahti, Kirsti, Särkelä, Asko, Puustinen, Markku and Alakukku, Laura, 2007 - Influence of no-tillage on the distribution and lability of phosphorus in Finnish clay soils, Agriculture, Ecosystems & Environment, Vol.120, Pages 299-306.
14. Nelson, R.G., Walsh, Marie, Sheehan, John and Graham, R. L., 2004 -Methodology to estimate removable quantities of agricultural residues for bioenergy and bioproduct use. Applied Biochemistry and Biotechnology, 0013-0026.
15. Nour, Dan, Balteanschi, Dumitru, 2004 – *Eroziunea solului*, Edit. Pontos, Chisinau, Republica Moldova, ISBN 9975-926-73-8.
16. Nyakatawa, E.Z., Mays, D.A., Tolbert, V.R., Green, T.H. and Bingham, L., 2006- *Runoff, sediment, nitrogen, and phosphorus losses from agricultural land converted to sweetgum and switchgrass bioenergy feedstock production in north Alabama*, Biomass and Bioenergy, Volume 30, July 2006, Pages 655-664.
17. Russell, A. E., Laird, D. A., Mallarino, A. P., 2006 - Nitrogen Fertilization and Cropping System Impact on Soil Quality in Midwestern Mollisols. Soil Sci. Soc. Am. J. 70-249-255.
18. Tiemeyer, Bärbel, Lennartz, Bernd and Kahle ,Petra, 2008 - *Analysing nitrate losses from an artificially drained lowland catchment (North-Eastern Germany) with a mixing model, Agriculture, Ecosystems & Environment,* Volume 123, January 2008, Pages 125-136.
19. Wilhelm, W.W., Johnson, J.M.F., Hatfield ,J.L., Voorhees, W.B. and Linden, D.R., 2004 - *Crop and soil productivity response to corn residue removal: A review of the literature.* Agronomy Journal 96:1-17
20. Wilson, G. V., Dabney, S. M., McGregor, K.C., Barkoll, B.D., 2004 - *Tillage and residue effects on runoff and erosion dynamics*. Transactions of the American Society of Agricultural Engineers 47: 119-128.
21. Yadav, Vineet and Malanson, George, 2008- *Spatially explicit historical land use land cover and soil organic carbon transformations in Southern Illinois*, Agriculture, Ecosystems & Environment, Vol. 123, February 2008, Pages 280-292.