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STUDIES ON THE INFLUENCE OF IRRIGATION ON A CALCIC CHERNOZEM IN THE EASTERN REGION OF ROMANIA

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Abstract

The Romanian strategy in the field of irrigations for the years of 2008-2011 consists of the modernization of the existing works covering about 3.1 mil. ha, while for the years of 2011-2025 the irrigation of additional area of 0.9 mil. ha is expected. In the climate conditions of Romania, the irrigation has a complementary character over the precipitations. Because of this reason, a correct regime of irrigations needs a very good correlation between watering and precipitations in order to achieve both a favorable moisture regime for the growing plants and for the quality protection of soil. Using uncontrolled watering regime or inadequate quality of water, leads in many situations to inappropriate processes for soil evolution. A study regarding the modifications of the soil quality as result of the irrigations was carried out in the district of Bacău, in the East of Romania and its results are presented in this paper. The research objectives were focused on a Calcic Chernozem (FAO-UNESCO) in three areas with different watering conditions and consisted of: analyses regarding the evolutions of porosity and hydro-physical parameters; analyses regarding the dynamic of soil salinity; analyses regarding the dynamic of heavy metals in mobile form; analyses regarding dynamic of nitrogen in the soil; analyses regarding the biologic activity of the soil. The research method consisted in soil sampling at pre-established time periods, their laboratory studying, data processing and interpretation. The conclusions of this study bring new contributions to the development of management for irrigated lands in Romania.

Key words: calcic chernozem, heavy metals, hydro-physical parameters, irrigation, mobile form; soil salinity,; nitrogen in soil, biologic activity of the soil.

1. Introduction

Romania covers a total area of 23,839,139 ha, of which the greatest percentage (61.84%) is agricultural land, followed by forests and other surfaces covered with forestry vegetation (28.28%). Other types of land represents 9.88% of the whole surface of the country (water surfaces, ponds, yards, buildings, communications ways and unproductive land).

The surface of the plough land is 63.9 of the whole agricultural land; the rest is covered by pastures (about 22.82%), hay production land (about 10.28%) vineyards (1.52%) and orchards (1.48%).

In 2007, the total area with irrigation was about 3,200,000 ha. The functional status of the irrigation works is rather poor; some of them missing the working equipment, some other have badly maintained parts, some other missing the necessary exploitation and maintaining funds. In fact, during the years of 2000 - 2007 the irrigated area varied between 45,719 and 754,498 ha (Table 1).

For the years of 2008 – 2011, the Romanian strategy in the field of irrigations takes into account the modernization of the existing works covering about 3.1 mil. ha, and for the years of 2011 – 2025 in the irrigation of an additional area of 0.9 mil. ha.

The irrigations have a complementary character over the precipitations in the climate condition of Romania so that, a correct regime of irrigations needs a very good correlation between watering and precipitations in order to achieve both a favorable moisture regime for the growing plants and for the quality protection of the soil (Gorontiwar and Smout, 2005; Statescu, 2003).

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Uncontrolled watering regimes or inadequate quality of water lead in many situations to the soil degradation as result of the following processes (Acosta-Martinez et al., 2006; Bedano and Cantu, 2006; De Nys et al., 2005; Feyereisen et al., 2007; Guganesharajah et al., 2007; Krishnamoorth et al., 2007; Niklinsca et al., 2006; Salazar et al., 2005; Tafaldar J.C., Gharu A., 2006; Vlek et al., 2007; Wöhling and Schmitz, 2007; Wöhling and Mailhol, 2007):

a) *soil clogging,* due to clay and organic particles from irrigation water, sometimes accompanied by an out of measure increase of nitrogen compounds;
b) *soil salinization,* manifested by the increase of soluble salts over a the critical value;
c) *soil alkalinization,* caused by the saturation of the absorbing complex with Na^+ ions and the increase of carbonates and alkaline bicarbonates;
d) *soil acidification* caused by the use of acid waters or by the neutralization of some easy solving salts;
e) *decrease of soil fertility,* as result of the microelements growth within the soil (Zn, Cu, Al) under a mobile form, in organic acids, amino acids, and other toxic compounds resulted from the decay of organic mater, kalium and iron range wash and of the soil structure degradation;
f) *excess of humidity,* which is causing the lack of oxygen into the soil which is necessary both for the respiration of plants' roots and the intensification of chemical and biochemical anaerobic processes;
g) *soil infection with pathogenic germs,* can appear if waters with a high biologic load are used for irrigations.

This study investigates the modifications of the soil quality as result of the irrigations in several areas of the district of Bacau, in the East of Romania based on a comparative analysis of physical proprieties.

2. Materials and Methods

The researches were carried on in three areas: P.I. – farming with irrigations and organic fertilization, P.II. – farming with irrigations and chemical fertilization, P.III. – farming without irrigations but organic fertilization. A brief description of soils within the research areas are presented in Tables 2, 3 and 4.

The comparative analyze of physical proprieties of the soils within the three areas (Table 5) shows that soils are not compressed and have an average permeability. So the irrigations can be applied without restrictions for this soil. In Table 5, the abbreviations have the following significance: TP - total porosity; K_s - saturated hydraulic conductivity; FC - field capacity; WCO - wilting coefficient; AP - aeration porosity; WHC - water holding capacity; MWC - maximum water holding capacity.

The research method consisted in sampling soil, irrigation water and sedimentation dusts from these areas at precise time ranges, their laboratory analyze, and the data processing and interpretation.

Table 1. The effectively irrigated area (at least one watering) between 2000 and 2007

Area	***Year***						
	2000	2001	2002	2004	2005	2006	2007
ha	85,000	216,100	327,900	569,100	45,719	96,224	754,498
%	100	254	286	670	54	113	888

Table 2. P.I.- Cambic cernozem (The Romanian Taxonomy System), Calcic Chernozem (FAO-UNESCO)

Specification	***Soil horizon***					
	Ap	*Am*	*AB*	*Bv$_1$*	*Bv$_2$*	*Cca*
Depth (cm)	0-30	31-44	45-60	61-104	105-134	135-150
Sand (%)	44.3	44.5	-	46.3	-	50.0
Dust (%)	28.1	27.2	-	25.8	-	29.0
Clay (%)	27.6	28,3	-	27.9	-	21.0
Apparent density (g/cm^3)	1.35	1.38	1.41	1.39	-	-
Humus (%)	2.6	2.1	1.5	-	-	-
pH in water	5.45	6.35	6.85	7.20	7.35	8.25
Ability for cationic exchange (me/100 g sol)	19.5	18.7	19.6	-	-	-
Natrium saturation degree (%)	74.3	86.1	96.9	-	-	-
Nitrogen total (%)	0.125	-	-	-	-	-
Phosphorus (ppm)	54	-	-	-	-	-
Kalium (ppm)	110	-	-	-	-	-
Carbonates (%)	-	-	-	-	-	13.2

Table 3. P.II - Cambic Chernozem (The Romanian Taxonomy System) Calcic Chernozem (FAO-UNESCO)

Specification	*Soil Horizon*						
	Ap	*Am*	*AB*	*Bv$_1$*	*Bv$_2$*	*Cca$_1$*	*Cca$_2$*
Depth (cm)	0-25	26-43	44-55	56-75	76-110	111-130	131-150
Sand (%)	45.1	43.9	46.3	51.8	45.0	51,8	75.1
Dust (%)	27.2	30.6	29.1	26.9	33.4	30,6	15.7
Clay (%)	27.7	25.5	24.2	21.3	21.6	17,6	9.2
Apparent density (g/cm^3)	1.32	1.42	1.44	1.27	-	1,29	-
Humus (%)	2.9	2.8	1.9	1.3	1.3	-	-
pH in water	6.7	6.65	6.70	6.75	8.05	8,15	8.20
Ability for cationic exchange (me/100 g sol)	23.6	23.4	-	-	-	-	-
Causticity saturation degree (%)	96.6	96.1	-	-	-	-	-
Nitrogen total (%)	0.16	0.12	0.12	0.12	0.10	-	-
Phosphorus (ppm)	83	6	13	13	10	-	-
Kalium (ppm)	215	95	95	95	75	-	-
Carbonates (%)	-	-	-	-	5.5	9,6	6.0

Table 4. P.III - Cambic Chernozem (The Romanian Taxonomy System), Calcic Chernozem (FAO-UNESCO)

Specification	*Soil Horizon*					
	Ap	*Am*	*AB*	*Bv$_1$*	*Bv$_2$*	*Cca*
Depth (cm)	0-20	21-35	36-50	51-80	81-120	121-140
Sand (%)	43.7	41.1	-	45.0	45.3	45.3
Dust (%)	27.2	28.5	-	25.4	29.2	30.2
Clay (%)	26.7	30.4	-	29.6	25.5	24.5
Apparent density (g/cm^3)	1.33	1.43	1.44	-	-	-
Humus (%)	2.3	1.5	1.0	-	-	-
pH in water	6.5	6.85	7.0	7.20	7.2	8.65
Ability for cationic exchange (me/100 g sol)	20.7	20.1	-	-	-	-
Causticity saturation degree (%)	91.6	90.2	-	-	-	-
Nitrogen total (%)	0.12	0.09	-	-	-	-
Phosphorus (ppm)	2.6	1.4	-	-	-	-
Kalium (ppm)	29.2	10.0	-	-	-	-
Carbonates (%)	-	-	-	-	-	15.8

Table 5. Physical proprieties of the soils within the three areas

Area	*Physical proprieties*						
	TP (%)	*K_s (mm/h)*	*FC (%)*	*WCO (%)*	*AP (%)*	*WHC (%)*	*MWC (%)*
P.I	48.9	3.5	22.95	9.82	10.37	13.13	35.43
P.II	51.48	7.02	22.51	7.38	24.04	15.13	39.30
P.III	48.52	3.3	22.91	9.54	16.67	13.37	34.91

3. Results and discussions

3.1. Evolution of porosity and hydro-physical characteristics

Since the shape of the suction curve is a reasonable and precise base for analyzing the porosity and the hydro-physical characteristics of soil, its variation under the irrigation influence was studied. The suction curves, for the three areas have been experimentally determined at two distinctive moments: at the beginning of the research interval and at its end (after 2.5 years).

The main observations resulted from the shape modification of suction curve were:

a) the total porosity of the soil have dropped with 2.43% to 4% (of the volume) in the irrigated areas and with 2.5% in the un-irrigated area;
b) at the irrigated soils the pore percentage with a diameter of 10 – 0.2 μm dropped significantly and the pores percentage with a diameter smaller than 0.2 μm grew;
c) at the area without irrigations the pore percentage with a diameter of 30 – 10 μm dropped, this explaining the reduction of total porosity;
d) the dynamic of different porosity compounds in the tree areas is presented in Table 6;
e) due to salts and colloidal substances in the irrigation water, the average pores (manly those having a diameter of 10 – 0.2 μm) have clogged up by physical adoption processes, what lead to the decrease of utile water capacity of the soil (Table 7).

Table 6. Soil porosity modification

Area	*Porosity (% v)*								
	>50-10 µm			10-0,2 µm			< 0,2 µm		
	Initial	Final	Dif.	Initial	Final	Dif.	Initial	Final	Dif.
P.I	17.45	16.52	-0.93	21.50	17.50	-4.00	11.00	13.50	+2.50
P.II	28.50	20.00	-1.50	20.50	13.00	-7.50	9.50	14.50	+5.00
P.III	17.50	15.00	-2.50	20.00	20.00	0.00	1.50	11.50	0.00

Table 7. Modification of hydro-physical coefficients

Area	*Hydro-physical coefficients* (% v)								
	FC			WCO			WHC		
	Initial	Final	Dif.	Initial	Final	Dif.	Initial	Final	Dif.
P.I	32.5	31.0	-1.5	11.0	13.5	+2.5	21.5	17.5	-4.0
P.II	30.0	27.5	-2.5	9.5	14.5	+5.0	20.5	13.0	-7.5
P.III	31.5	31.5	0.0	11.5	11.5	0.0	20.0	20.0	0.0

3.2. Soil salinity dynamics

The researches focused on revealing distribution of the total soluble salts content (TSSC) and the results are presented in Figs. 1, 2, and 3.

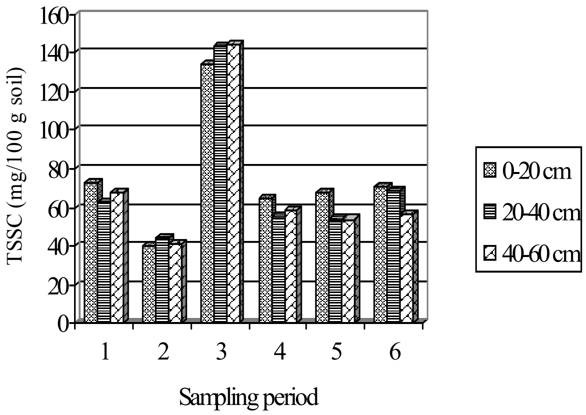

Fig. 1. TSSC evolution in the P.I area

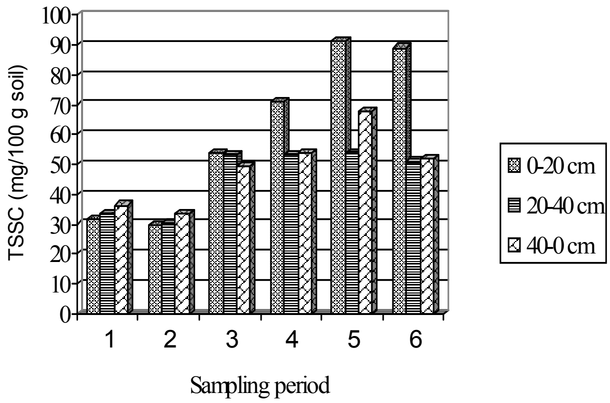

Fig. 2. TSSC evolution in the P.II area

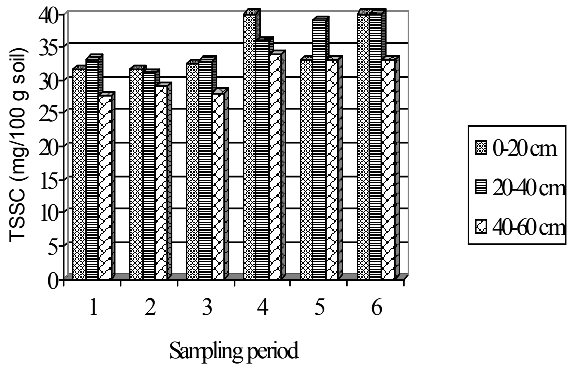

Fig. 3. TSSC evolution in the P.III area

Analyzing these results, the following aspects are revealed:

a) within P.I area, where small amounts of irrigation water with 0.25 – 0.38 g/l fix residuum were used, the TCSS dynamics was especially influenced by the climatic regime and the quantity of irrigation water; the amount of salts added into the soil by the irrigation water varied between 5.612 g/m^2 and 9.147 g/m^2;
b) within P.II area, where grater amounts of irrigation water with 0.21 – 0.32 g/L fix residuum were used, high quantities of salts were added into the 0 – 20 cm soil layer without modifying the salinity class; the quantity of salts brought into the soil by the irrigation water was between 7.742 g/m^2 and 13.890 g /m^2;
c) within P.III area, with no irrigation, the variation of TCSS, for the analyzed period, was insignificant comparing to irrigated areas;
d) the quality of irrigation water were appropriate, the maximal admissible limit of the fix residuum, under the Romanian climate conditions, being 1.2 g/L.

3.3. Dynamics of heavy metals in mobile form

Within the studied area, the heavy metals sources for the soil are represented by the irrigation water and the silting dusts. Considering one metal, Zn, a very important microelement for the growth and development of plants the conclusions are:

a) the Zn quantities brought into the soil by the irrigation water varied between 1.9 mg/m^2
b) and 15 mg/m^2 in the P.I area, and respectively 2.8 mg/m^2 and 4.6 mg/m^2 in P.II area;
c) the Zn quantities fell on the soil with the silting particles varied between 7.70 mg/m^2 and 40.47 mg/m^2 in the P.I. area and respectively between 0.47 mg/m^2 and 40.47 mg/m^2 in the P.II. and P.III area.

The dynamics of Zn in the three studied areas are presented in Figs. 4, 5 and 6.

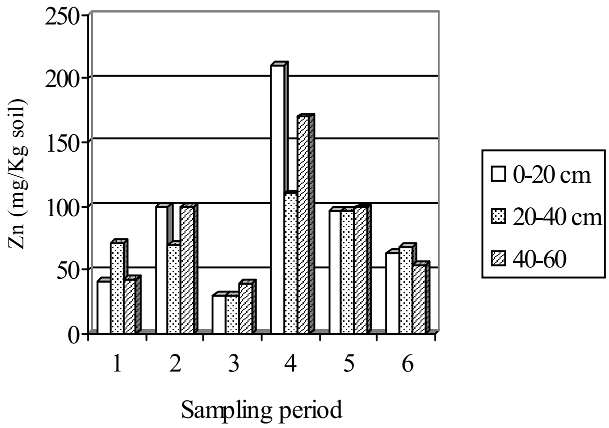

Fig. 4. The dynamics of Zn in the soil cross section of P.I area

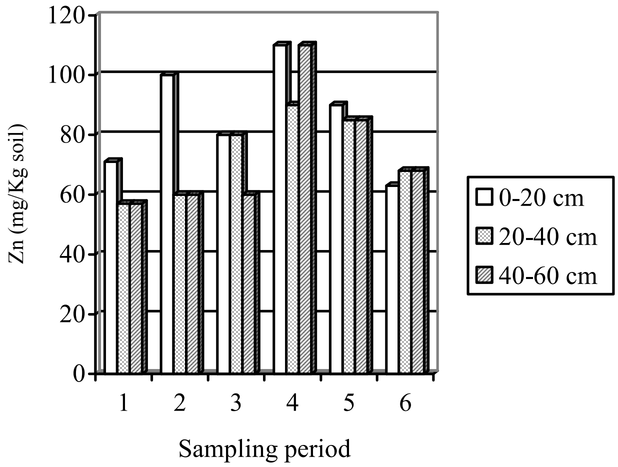

Fig. 5. The dynamics of Zn in the soil cross section of P.II area

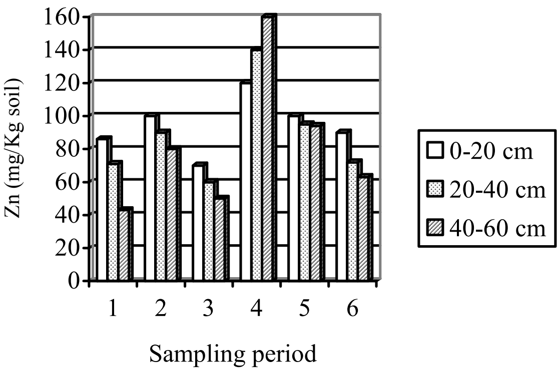

Fig. 6. The dynamics of Zn in the soil cross section of P.III area

3.4. Studies regarding the nitrogen activity in the soil

Starting from the fact that the mineralization of organic mater is a process influenced by the water content in the soil, an equation has been established stating that quantity of nitrogen in the soil in the 0-20 cm layer is growing in logarithm way while the humidity grow. So for the three experimental areas analyzing the results regarding the nitrogen content in the soil and the weather recordings (precipitations and temperatures) and also taking into account the distributed irrigation rations, Eq. (1) results:

$$N = 0.269\left(1 - e^{-0,053 Iu}\right) \quad (1)$$

where: N is the total nitrogen in the soil at 0-20 cm layer (%), and Iu – humidity index, calculated with Eq. (2):

$$Iu = \frac{P + I}{10 + t} \quad (2)$$

where: P- average annual precipitations (mm), I – irrigation ratio (mm), t – annual average temperature (^oC).

The supplementary water by irrigations is generating a smaller mineralization of the organic mater, a humus accumulation is generating into the soil accompanied by an increase of the amount of total nitrogen.

3.5. Studies regarding the biological activity in the soil

When analyzing the soil quality the biological aspect should not be neglected. Studying the results, as regard to CO_2 quantity in the soil, and the total number of germs (TNG), as seen in Table 8, the following conclusions are revealed:

(a) the very small quantities of CO_2 show a weak biological activity in the soil, in all of the studied areas;

Table 8. Biological analyzes

Sample Nr.	***Season***	***P.I***		***P.II***		***P.III***	
		CO_2 (%)	TNG (germ/g)	CO_2 (%)	TNG (germ/g)	CO_2 (%)	TNG (germ/g)
1	Spring	0.036	298,500	0.0202	260,400	0.0194	200,000
2	Summer	0.0162	56,640	0.0168	185,600	0.0220	264,380
3	Autumn	0.0326	182,400	0.0298	328,500	0.0210	226,100
4	Spring	0.0216	255,080	0.0320	258,500	0.0180	224,240
5	Summer	0.0128	248,000	0.0158	105,500	0.0188	283,200
6	Autumn	0.0176	233,200	0.0264	247,500	0.0062	167,000

b) in the P.III area, where a bio agriculture is practiced, a higher level of CO_2 concentration is revealed during summer as comparing with spring and autumn;
c) in the P.I and P.II areas a decrease of CO_2 concentration is revealed during summer, comparing with spring and summer, due to a mobilization by irrigation of the chemical substances spread on the soil, this inhibiting the microbes activity;
d) comparing the value of CO_2 concentration with the microbes number (TNG) into the soil, a very good direct relation can be seen between these two elements.

4. Conclusions

Irrigation is a common technical method for supplementing the water necessary into the soil and mitigating the drafts consequence. For the next period of time, dominated by climate changes, the Romanian strategy in this field, has as purpose the modernization of the existing irrigation works for the existing 3.1 mil ha, and after 2011 the construction of new irrigation systems of 0.9 mil ha.

The sustainable management for irrigated soils cannot be done without a constant monitoring of qualities and a scientific prognosis of their evolution. In the presented context, the experimental researches are very useful, showing both the processes determining both the modification of soil quality and their intensity. Based on these pieces of information, the best technical solutions for a sustainable use and conservation of the soil can be established.

The incorrect use of irrigations, with low quality water, can cause the start of unfavorable processes for soil evolution. Among these, the most frequently meet at the Romanian soils are: silting, salinity, alkalinity, acidification, decrease of fertility, excess of humidity, infestation with pathogenic germs.

It is very useful to find the starting moment of these processes, in order to stop them, since is easily to prevent the soil decay then to apply curative measures. For this purpose the modernization of soil quality monitoring system is necessary; it can be done by a combination of intelligent sensors, programs for data processing and internet technology.

List of acronyms

Am – humus enriched horizon;
Ap – plowing horizon;
AB – transitional horizon;
Bv – cambic horizon;
Cca – horizon of carbonate accumulation.

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