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STUDY OF PEDOGENETIC PROCESSES IN SOILS LONG IRRIGATED - MONITORING AND PROJECTING THEIR EVOLUTION

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Abstract

The soil and water resources of the Republic of Moldova are subjected to an intense anthropogenic press. As a result, such forms of soil degradation such as surface and deep water erosion, landslides, secondary salinisation and secondary salinisation as a result of irrigation, exasinary destructuring and compacting and others have intensified. The rational use of soil resources is based on the detailed knowledge of the main natural and anthropogenic factors that influence effective fertility and their quality status. In order to assess the change of the soil cover structure over the years, it is necessary to use the thematic materials previously elaborated. It should be noted that they do not fully reflect the complexity of the situation at the moment. This finding refers in particular to processes of soil degradation in basin landscapes (Rozloga, 2013; 2015) where pedogenic factors (soil, parental rocks, hydrology, lithology, hydrogeology and vegetation), interacting in various ways, lead to the emergence of extremely complex degradation forms. The anthropic impact on soil and surface waters is largely determined by the activity of the agrarian and industrial sectors. According to the latest estimates, the chemical composition and the soil and surface water quality indices record negative changes. This concerns (Filipciuc, 2007; Simakova et al., 2008), first of all, the agricultural soils (land) that are involved in the irrigation systems and the increase of the degree of mineralization, the ionic reaction and ionic composition of the inland river waters, and to the accumulation basins (lakes, ponds). All these constitute the limiting factor of using soils for irrigation with surface waters. In order to develop complexes of measures to prevent land degradation it is necessary to know the spatial spread and intensity of the manifestation of these processes on a more detailed scale. The achievement of this objective is possible with the use of the Geoinformatics System (GIS), which allows the operative and reasoned approach to inventory, analysis, planning and design issues (Sorokina, 2006). This system creates prerequisites for the development and implementation of measures to combat land degradation at a new quality level aimed at preserving and improving soil fertility.

Key words: *GIS, irrigation, pedogenic processes, soil.*

INTRODUCTION

The agro-industrial complex of the Republic of Moldova operates under risk conditions. By geographic location the territory of the republic falls within the area with insufficient and unstable humidity. The annual amount of atmospheric precipitation varies between 380 and 550 mm. Deposits register a marked decline from Northwest to South East (Rozloga, 2015; Andrieș, 2007). In the northern part of the republic, the volume of rainfall is attested as submijlociu, in the central pedoclimatic zone this indicator is considered to be low and in the south - as very low.

A peculiarity of the republic's climate is the phenomenon of drought. According to the analysis of observations data over the past 100 years, strong and long droughts occur over three years in northern and central areas and over two years in the southern area (Gavrilitsa, 1993). The result of this climate phenomenon is the reduction or compromise of agricultural production.

Through long-term research, it has been established that the main natural limiting factor in obtaining high and stable crops is low availability of affordable water plants (Andrieș, 2007). Under the conditions of the Republic, one of the most effective measures for optimizing the soil moisture regime is irrigation. Obviously, it does not exclude the application of agro-technical processes to water the soil.

Soil irrigation as a method of improving the water regime has been known since ancient times, but to date there are a number of complicated problems related to the reaction of some soil types to the change of the water regime and to the quality of the water used for irrigation. Thus, irrigation of chernozems with mineralized water (> 3000 mg/l) does not cause essential changes in the soil adsorption complex and does not lead to secondary salinisation (Kovda, 1981; Simakova et al., 2008). At the same time, the same author points out that the use of water with a degree of mineralization higher than 1000 mg/l on chernozem soils leads to secondary salinisation and solonization, but also their hydromorphic evolution. Because of the multiannual researches, V.A. Covda (Kovda, 1981; Sorokina, 2006) concludes that the development of water quality indicators for unified irrigation is virtually impossible due to the extremely wide variation in the pedological, geomorphological and geochemical conditions of the irrigated territories.

In the Republic of Moldova, chernozems make over 74% of the surface of irrigated soils (Filipciuc, 2007; 2014). They can be included in the irrigation regime only when using water with low salt content (up to 1000 mg/l) and a favorable chemical composition. Research on different chernozem subtypes shows that changing the natural water regime through the irrigation system, even with the use of good quality water, leads to structural degradation, compaction of the upper horizon and decalcification (Krupenikov et al., 1979; 1981; Podymov, 1976).

The use of highly mineralized water or inappropriate chemical composition in the irrigation of chernozems results in their salinisation and/or secondary solonization (Poznyak, 1997; Filipciuc et al., 1990; Filipciuc, 2014). In this context, it is useful to note that the process of solonization severely affects not only the physical and physico-chemical properties of the soil. It also produces degrading effects on the mineralogical composition by increasing the content of inflatable material in the smectite and illit-smectite group (Gavrilitsa, 1993). Some secondary soil processes induced by irrigation of chernozem with unsatisfactory quality water, such as clay, peptization of fine clay and illitisation, are irreversible and cannot be restored or restored by means of melioration.

Contrary to these findings, some authors argue that chernozem soils can be irrigated with water in which the soluble salts content is 1500-3000 mg/l (Rabochev, 1981; Bezdnina, 1990; Zimovets, 1993; Prikhodko, 1996).

V. Kovda, through the analysis of the global experience of the irrigation consequence, points out that the unification of water quality indicators for irrigation and the setting of limit values presents great difficulties or is impossible due to the diversity of climatic, geomorphological conditions. For the soil and climatic conditions of the Republic of Moldova, water quality indicators used for irrigation regulating the degree of mineralization, the reaction, the sodium adsorption ratio, the magnesium indicator, the chlorine content and the residual sodium carbonate (Filipciuc, 2007) have been established.

MATERIALS AND METHODS

In order to establish and evaluate the impact of irrigation of chernozem soils with water of different quality, land, laboratory and office methods were used.

On the ground, the following works were carried out: the opening of the soil profiles, the morphological and morphometric description; collecting soil samples from genetic horizons for the determination of chemical, physical, hydric and physico-mechanical properties.

Collecting water samples for irrigation in order to determine chemical composition and quality indicators;

The laboratory determined the hygroscopic water content; solid soil phase density; granulometric and microaggregate composition; structurally-aggregate structure and structure's hydrostability; hygroscopicity and cheering coefficients; the content and composition of humus; the content of calcium and magnesium carbonates; nutrient content of nitric nitrogen, mobile phosphorus and exchangeable potassium; the soluble salt content, the reaction and the ionic composition of the aqueous extract; the content of adsorbed cations; chemical composition and water quality indicators for irrigation.

At the office stage the calculations of the field and laboratory determinations were carried out, systematized and analysed the results obtained and elaborated the report for the current year stage.

RESULTS AND DISCUSSIONS

The works covered by the thematic plan were carried out on experimental polygons selected within irrigation systems and their immediate proximity (non-irrigated soils). The soil cover of the polygon in Egoreni commune, Soroca rayon, is represented by deeply humorous, humorous, humorous chernozem. The polygon is located on the first terrace of the Dniester River. The carbonate chernozem is irrigated with this river's water for 47 years. The experimental polygon in Singerei is located on a right slope with an east exposure and with a slope of 2-3%. Soil is a habitually profoundly moderate clay-humus humerus. Irrigated with pond water for 13 years. The experimental polygon in Cozăşti commune Singerei district is situated on a south-eastern slope with a slope of 2%. The soil is presented by the habitus of deeply silky clayey humerus. It has been under irrigation for 9 years. The water used is deep water with unfavorable chemical composition and strong alkaline reaction.

The evolution of secondary pedological processes and changes in physical and chemical properties in irrigated soils were determined by the "pairs profiles" method (irrigated soil - non-irrigated soil). This method is widely used in the pedoameliorative study and is considered practicable in the quantitative determination of soil characteristics (Poznyak, 1997; Ropot, 1991). Field determinations and laboratory analyses performed to determine irrigation-induced changes were performed using the methods.

Table 1. The chemical composition of the Dniester (Nistru) river water

Indicators	Unit of measurement	The content		
		minimum	Maximum	Medium
Mineralization	mg/l	240	670	455
The reaction (pH)	Units	7.53	8.45	7.99
CO_3^{2-}	me/l	0.07	0.84	0.46
HCO_3^-	me/l	2.49	4.92	3.71
Cl^-	me/l	0.57	3.10	1.84
SO_4^{2-}	me/l	1.00	3.33	2.16
Ca^{2+}	me/l	2.60	4.50	3.55
Mg^{2+}	me/l	0.58	3.33	1.96
Na^+	me/l	0.70	3.26	1.98

Table 2. The composition and quality indices of the Dniester (Nistru) river (year 2018)

Period	Mineralization, mg/l	pH	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	SAR	P_{Mg}, %
			me/l mg/l							
May	496	8.31	3.42 209	1.60 57	1.40 67	3.72 74	1.20 14	1.50 34	0.9	24
August	240	7.95	2.60 159	1.16 41	0.31 15	3.30 66	0.12 2	0.65 15	0.5	19
September	254	8.05	2.80 171	1.36 48	0.23 11	3.02 61	0.72 9	0.65 15	0.5	17
Admissible values										
	< 1000	< 8.30	-	<3.00	-				<3.0	<50

Depending on the climatic conditions, especially the rainwater regime, the degree of mineralization and the chemical composition of the Nistru river water are marked by significant changes (Table 1).

Soluble salt content ranges from 240 to 670 mg/l over a multi-year cycle. The water reaction is judged to be slightly alkaline with pH values ranging from 7.53 to 8.45 units (Florea, 1976).

One of the main qualitative indicators of surface water in the Republic, used for irrigation, is the magnesia index. For water from the Dniester river, between May and September 2018, it oscillated between 17 and 24%. The calculated values of this indicator show that the possibility of the adsorption process of the magnesium cation by the colloidal soil complex in appreciable quantities is virtually excluded.

By chemical composition and quality indicators the water of the Nistru river is appreciated as good - very good for irrigation (Krupenikov, 1983). It can be used without limitation for irrigating any type of soil.

However, it should be noted that under certain thermal conditions, usually at high temperatures, or during the abundant development of phytoplankton, the water in the Dniester is potentially alkaline, and in its composition appears the CO_3^{2} anion. In such transformations, the water intensifies the decalcification process of the soil and changes the ratio of the exchangeable cations in the adsorbent complex. Such degrading impact of the Nistru river water was recorded at the Caragaşi irrigation system (Orlov, 1980).

During the reference year, the Dniester river water analysis was carried out in three rounds. The determinations show that the total content of soluble salts is low and compose 240-496 mg/l. According to river classification by degree of mineralization, sweet to low salted (Orlov, 1980). By mineralization, water used for irrigation does not pose a risk of secondary salinisation of the soil (Table 2). In the soluble salt composition predominates calcium compounds, which make up 58-71% of the dry residue (Annex 1). Toxic sodium and magnesium salts have a subordinate role.

Table 3. The main agrochemical properties of chernozem carbonate

Deph, cm	Humus, %	Humus reserve, t/ha	$CaCO_3$, %	$N\text{-}NO_3$	P_2O_5	K_2O
				me/100 g sol		
Not irrigated soil						
0-25	2.18	68	3.8	0.45	1.05	19.6
25-50	2.11	67	3.8	0.29	1.19	18.8
50-84	1.88	86	6.1	0.34	0.82	14.6
84-106	1.20	36	8.7	0.26	0.80	14.6
106-130	0.87	25	10.9	0.26	0.75	14.5
130-160	0.62	26	11.8	0.22	0.98	12.9
Irrigated soil						
0-28	2.56	90	2.3	0.45	1.85	20.8
28-48	2.58	71	3.5	0.34	0.89	19.6
48-76	2.16	83	5.4	0.32	1.02	19.6
76-107	1.38	58	8.8	0.36	0.69	14.6
107-138	1.02	43	10.7	0.31	0.65	14.5
138-180	0.81	46	12.0	0.30	0.82	13.8

Table 4. Changing the humus composition as a result of irrigation (plowing horizon)

C total, %	C, %			$\frac{C_{AH}}{C_{AF}}$	C faction AH,%		C in the residue, %
	Extract with $Na_4P_2O_7$+NaOH	AH	AF		free and bonded with R_2O_3	bonded with Ca	
Not irrigated soil							
1.73	0.88 / 50.9	0.63 / 36.4	0.25 / 14.4	2.5:1	3.2	96.8	0.85 / 49.1
Irrigated soil							
1.75	0.83 / 47.4	0,57 / 32.6	0.26 / 14.9	2.2:1	6.0	94.0	0.92 / 52.6

The water reaction is slightly alkaline with pH variations from 7.95 to 8.31 units.

Chlorine content is well below the maximum permissible limit of this element in irrigation water, being only 1.16-1.60 me/l.

The sodium adsorption ratio is very low with values ranging from 0.5 to 0.9, so the water does not pose a risk of soil degradation by secondary solonization.

The effect of long-term irrigation on the chemical and physico-chemical properties of carbon black chernozem

The main agrochemical properties of the non-irrigated carbon black chernozem and of the irrigation regime were determined on the genetic horizons of the soil profiles. The obtained results show that both soil variants are characterized by a medium content of organic matter in the plowed and substrate layers, this being 2.11-2.58%. In the transition horizons the humus content decreases slowly to 1.20-2.88%, being appreciated as low. The chernozem curing gradient contains 0.62-0.81% humus, a very low value. It should be noted that the distribution of humus on the irrigated soil profile is more uniform and its content is slightly higher compared to the non-irrigated soil. Reserves of organic matter in irrigated soil are also higher.

The investigated soil variants contain calcium and magnesium carbonates from the surface in average quantities of 2.3-3.8%. In depth the carbonate content gradually increases, reaching maximum values of 11.8-12.0% in the rock (Table 3).

By determining the available nutrients it was found that in the upper horizons of the non-irrigated soil the nitric nitrogen is contained in small amounts of 0.29-0.40 mg/100 g of soil and slowly decreases to 0.22 mg/100 g in depth. The distribution of N-NO3 on the irrigated soil profile is much more uniform. Thus, in the humus-accumulative horizon the nitric nitrogen content is 0.34-0.45 mg/100 g of soil. In the transition horizons and in the parental rocks he recorded an insignificant decrease of up to 0.30 mg/100 g of soil.

Table 5. The salt content, the reaction and the ionic composition of the aqueous extract of the carbonate chernozem

Depth, cm	Dry residue, %	pH	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	$\frac{Ca+Mg}{Na}$	K_{SO}
			me/100 g soil							
Not irrigated soil										
0-25	0.046	8.30	0.51	0.06	0.17	0.63	0.07	0.04	18	0.7
25-50	0.044	8.25	0.54	0.07	0.14	0.63	0.08	0.04	18	0.8
50-84	0.043	8.15	0.55	0.07	0.14	0.66	0.06	0.04	18	0.8
84-106	0.040	8.05	0.55	0.06	0.10	0.56	0.09	0.06	16	0.8
106-130	0.051	8.10	0.52	0.16	0.15	0.58	0.17	0.08	9	0.8
130-160	0.053	8.15	0.60	0.11	0.18	0.60	0.15	0.14	5	0.8
Irrigated soil										
0-28	0.045	8.20	0.56	0.08	0.16	0.60	0.16	0.04	19	0.7
28-48	0.048	8.10	0.65	0.09	0.15	0.70	0.12	0.07	12	0.8
48-76	0.038	8.15	0.62	0.07	0.05	0.60	0.10	0.04	18	0.9
76-107	0.046	8.20	0.55	0.07	0.22	0.58	0.20	0.06	13	0.7
107-138	0.046	8.25	0.60	0.08	0.12	0.58	0.14	0.08	9	0.8
138-180	0.053	8.25	0.54	0.13	0.23	0.64	0.16	0.10	8	0.7

Table 6. The content of cation exchangeable in carbonate chernozem

Depth, cm	Ca^{2+}	Mg^{2+}	Na^+	Sum	Ca^{2+}	Mg^{2+}	Na^+
	me/100 g soil				% from sum		
Not irrigated soil							
0-25	21.17	2.11	0.55	23.83	89	9	2
25-50	21.06	2.11	0.19	23.36	90	9	1
50-84	19.16	2.21	0.36	21.73	88	10	2
84-106	17.92	2.58	0.36	20.86	86	12	2
106-130	15.76	3.97	0.19	19.92	79	20	1
130-160	12.85	4.85	0.36	18.06	71	17	2
Irrigated soil							
0-28	21.85	2.00	0.48	24.33	90	8	2
28-48	21.50	1.50	0.48	23.48	92	6	2
48-76	19.75	2.00	0.48	22.23	89	9	2
76-107	18.00	1.50	0.48	19.98	90	8	2
107-138	15.50	2.00	0.54	18.04	86	11	3
138-180	15.00	3.35	0.48	18.83	79	17	4

The content of mobile phosphorus is small to medium. After the exchangeable potassium content both soil variants are appreciated as moderately insured.

It is worth mentioning that irrigation of carbonate chernozem with water from the Dniester River influences the composition of humus (Table 4). It has been found that the irrigated soil reduces the carbon content in the humic acids fraction. This led to a reduction in the ratio of CAH: CAF from 2.5: 1, the humus type being the humatic one. Another change in the composition of organic matter refers to the increase in the fraction of free humic acids or bound to iron and aluminum sequestrants.

Therefore, the irrigation of the carbonated chernozem with water from the Dniester is increasing humus mobility.

This trend has been observed in other irrigation facilities (Poznyak, 1997; Novikova, 2009; Novikova et al., 2007).

Irrigation use of good quality water for 47 years does not essentially alter the saline indices of carbon black chernozem. From the results we can see that the anionic composition is clearly predominated by HCO_3^- (0.51-0.64 me), followed by SO_4^{2-} (0.12-0.23 me). Chlorine content is small and accounts for 0.06-0.13 me/100 g of soil. It is important to emphasize that in soil solution (irrigated and non-irrigated) prevails Ca^{2+} with a content of 0.56-0.70 me.

Annex 1

The composition of the soluble salts of irrigation water

Water source	Collection period	Na_2CO_3	$Ca(HCO_3)_2$	$Mg(HCO_3)_2$	$NaHCO_3$	$CaSO_4$	Na_2SO_4	NaCl	$MgCl_2$	$CaCl_2$
		me/l								
River Nistru	May	-	3.42	-	-	0.30	1.10	0.40	1.20	-
	July	-	2.60	-	-	0.31	-	0.65	0.12	0.39
	September	-	2.80	-	-	0.22	0.01	0.64	0.72	-
Lake	May	2.40	4.60	10.70	-	-	23.60	1.83	1.90	-
	September	4.80	7.34	7.66	-	-	33.92	-	4.41	-
Underground	May	4.80	1.08	2.44	1.30	-	2.87	1.73	-	-
	September	4.80	1.00	2.22	0.60	-	4.85	1.49	-	-

Annex 2

The composition of the soluble salts of carbonate chernozem

Depth, cm	$Ca(HCO_3)_2$	$CaSO_4$	Na_2SO_4	$MgSO_4$	$MgCl_2$
	me/100 g sol				
Not irrigated soil					
0-25	0.51	0.12	0.04	0.01	0.06
25-50	0.54	0.09	0.04	0.01	0.07
50-84	0.55	0.11	0.03	-	0.07
84-106	0.55	0.01	0.06	0.03	0.06
106-130	0.52	0.06	0.08	0.01	0.16
130-160	0.60	-	0.14	0.04	0.11
Irrigated soil					
0-28	0.56	0.04	0.04	0.08	0.08
28-48	0.65	0.05	0.07	0.03	0.09
48-76	0.62	-	0.04	0.03	0.07
76-107	0.55	0.03	0.06	0.13	0.07
107-138	0.58	-	0.08	0.06	0.08
138-180	0.54	0.10	0.10	0.03	0.13

Magnesium cations are contained in 0.06-0.20 meters, and Na^+ does not exceed 0.04-0.14 me/100 g soil. The ratio between bivalent and monovalent cations shows a significant decrease in soil profile at 19: 1 in the 5: 1 horizon in parental rock (Table 5). The sodium ratio in non-irrigated and irrigated soil is very stable on the soil profile, ranging from 0.7 to 0.9. Thus, during 47 years of irrigation in carbon black chernozem, no soda formation conditions are recorded (Krupenikov et al., 1981).

Determination of soluble salt content shows that this indicator does not change when using Dniester water. The profile of both dry soil variants ranges between 0.038 and 0.053%, characteristic for the subtype given by chernozem (Shaimukhamedov et al., 1990).

The actual soil response is estimated to be slightly alkaline with pH values of 8.05-8.30 units. By determining the composition of the soluble salts, it has been established that their main (predominant) components, both in the non-irrigated and the irrigated soil, are represented by Ca $(HCO_3)^2$ and $CaSO_4$. These compounds are harmless to soil and plants and make up 71-84% of dry residue (Annex 2).

One of the main indicators of the irrigated soils' soil condition is the changeable cation content. The impact of water quality on irrigation on the bases of exchange is very defiant. It is reported that when applying freshwater, the main changes refer to the increase in Mg^{2+} content and to the change in cation ratio. The research did not confirm this finding (Table 6).

The content of adsorbed calcium forms in the horizon of 21.17-21.85 me and gradually decreases in the transition horizons. In the rock of solification this cation has values of 12.85-15.00 me.

The magnesium cation distribution on the soil profiles is inverse. Its contents register an increase from 2.00-2.11 me in humus-accumulative horizon up to 3.35-4.85 me/100 g soil in parental rock. Adsorbed salt constitutes 1-2% of the sum of the bases and in the irrigation soil only it increases to 4% of the amount. According to the scale of the degree of irrigation of irrigated soils, the carbonate chernozem is certified as very weakly solonised.

CONCLUSIONS

The obtained results show that both soil variants are characterized by a medium content of organic matter in the plowed and substrate layers, this being 2.11-2.58%. In the transition horizons the humus content decreases slowly to 1.20-2.88%, being appreciated as low. The chernozem curing gradient contains 0.62-0.81% humus, a very low value. It should be noted that the distribution of humus on the irrigated soil profile is more uniform and its content is slightly higher compared to the non-irrigated soil. Reserves of organic matter in irrigated soil are also higher.

The investigated soil variants contain calcium and magnesium carbonates from the surface in average quantities of 2.3-3.8%.

Irrigation use of good quality water for 47 years does not essentially alter the saline indices of carbon black chernozem. From the results we can see that the anionic composition is clearly predominated by HCO_3^- (0.51-0.64 me), followed by SO_4^{2-} (0.12-0.23 me). Chlorine content is small and accounts for 0.06-0.13 me/100 g of soil. It is important to emphasize that in soil solution (irrigated and non-irrigated) prevails Ca^{2+} with a content of 0.56-0.70 me.

It has been found that the irrigated soil reduces the carbon content in the humic acids fraction. This led to a reduction in the ratio of CAH: CAF from 2.5: 1, the humus type being the humatic one. Another change in the composition of organic matter refers to the increase in the fraction of free humic acids or bound to iron and aluminum sequestrants.

The content of adsorbed calcium forms in the horizon of 21.17-21.85 me and gradually decreases in the transition horizons. In the rock of solification this cation has values of 12.85-15.00 me.

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