Original paper DOI 10.5937/ZemBilj2002001T

Salt affected soils under cotton-based irrigation agriculture in southern Kazakhstan

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Abstract

Soil salinity of the irrigated soils in a cotton farm of Kazakhstan was studied aimed to provide background for reconstruction of collection-drainage system of whole region and preventing soil deterioration. The experimental data obtained for 2012-2014 were plotted for the development of the map of soil salinity (1:10000) seasonally and vertically. In spring 2014 the area under medium saline soil in 0-20 cm layer decreased from 79.5 to 57.7%; the area of weakly saline soils increased from 20.5 to 34.6%. In autumn and winter periods the area of strongly saline soils decreased from 25.6 to 14.1%. The area of non-saline soils was 7.7%. The changes in the ions amount, both vertically and seasonally, occur with transport of salts along soil profile driven by temperature gradients and the level of ground water, i.e., in spring from up to down, and in autumn and winter, contrary from down to up.

Keywords: cotton, irrigation, soil salinity, spatial distribution, seasonal distribution, vertical drainage

Introduction

The large-scale irrigation of cotton fields in arid and desert areas of Southern Kazakhstan inevitably leads to the processes of soil salinization. According to Khakimov (1989) due to inappropriate irrigation practices moderately to severely salinized soils in irrigated areas reached 60% to 70% and crop yields decreased by 30% to 33% in Kazakhstan. According to Funakawa et al. (2000) the problems of salt-affected paddy soils might be due to inadequate water management in irrigated areas of Kazakhstan. Farifteha et al. (2006) reported that the salinization process is referred as the most frequently occurring land degradation type in aridic regions. Soil salinization lasting for a longer period causes lower production potential of soil (Szabolcs, 1974; Fauck, 1977).

South-Kazakhstan region is the region growing cotton on an area of 204.1 thousand hectares in 2005 (11.4% of the territory), that was reduced to 99.3 thousand hectares in 2015 due to inappropriate agricultural management that resulted in decrease of soil fertility and cotton yield (http://stat.gov.kz). Due to the deterioration in operating irrigation and drainage systems in South Kazakhstan region, disorders in intensive cotton cultivation technology, reducing water supply both in the growing season, and for soil washing, a sharp increase of the areas subject to secondary salinization was recorded (Bekbayev, 2016; Saparov et al. 2008; Kitamura et al. 2006; Metternicht and Zinck, 2003). Cotton is a water-sensitive crop. Its vegetative growth is intensified when there is sufficient soil water, but can easily become excessive, which increases the plant's water intake that decreases irrigation water use efficiency. However, with a lack of soil moisture, cotton growth is easily suppressed (Li et al 2020). Chhabra (2004) classified salt affected soils as follows: all soils with high pH values (>8.5) as well as high ESP (>15) and high ECe (>4 dS m^{-1}) developed in situ, soils with high pH values (>8.5) as well as high sodium adsorption ratio (SAR > 13) and high ECe (>4 dS m^{-1}) formed due to use of irrigation waters containing high residual sodium carbonate (RSC > 2.5 mol m^{-3}), and those with moderate pH values (7 to 8.5) but high SAR (>13) and high ECe (>4 dS m^{-1}) formed due to shallow saline water table, are classified as saline-alkali soils.

In this respect observation of salt movement and advanced geophysical survey, for detection and prediction of salt-affected areas, considered as promising tools for the evaluation and control of soil ameliorative state of irrigated agricultural lands (Chernousenko et al. 2012; Bhat et al. 2015; Mandal et al. 2009; Weng and Gong, 2006). Repeated salt survey allows to obtain a quantitative characteristic of changes in the salt regime of the soil for a given period (Allbed and Kumar, 2013; Arunachalam et al. 2011). The spatial modeling of salt accumulation regime provides vital information on understanding the dynamic of salt movement regime laterally and vertically (Jury, 1982; Schoups and Hopmans, 2002).

Our research was conducted in the Golodnaya Steppe geological formation that is a vast intermountain drainage basin, bounded on the south by Turkestan range, and on the northeast by Kuramin and Chat Kal ranges (Bekbayev et al. 2015; Micklin et al. 2014; Mueller et al. 2014).

The main goal of the research was establishing the soil salinity state of the irrigated Light Grey soils in cotton farm of Southern Kazakhstan (Maktaaral region) under the vertical drainage, which would provide necessary background for the reconstruction of the collection-drainage system of the whole region, thus contributing to the increasing the net yield and the quality of the row cotton, as well as preventing soil deterioration. Main objectives were studying the dynamics of salts changes seasonally and timely under the vertical drainage and, studying the spatial distribution of salts under the vertical drainage in cotton-based farm in Southern Kazakhstan.

Materials and methods

Study site

Soil and solution samples were collected in 2012 and 2014 from the cotton monoculture experimental station in Maktaaral region in southern Kazakhstan that was established in 1927 (Dzhalankuzov et al. 2011) (40º49′58.03″N and 68º 30′3.07″E) on light grey soil (Zhihareva et al. 1969). Mean annual precipitation is 262 mm; average air temperature is 12.4°C.

Experimental design

To study the effect of vertical drainage on soil amelioration state the 78 ha of the experimental plot was divided into 15 basic sub-plots with each subplot around 5 ha (Figure 1).

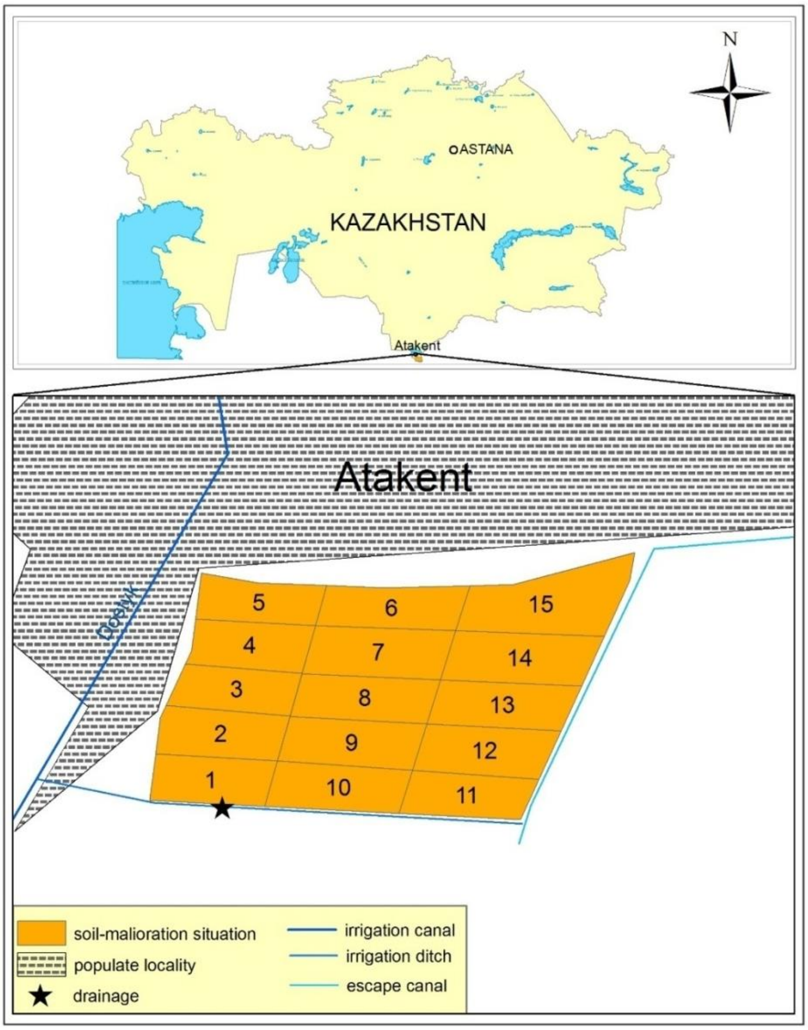

Figure 1. Location of the sampling site

Each subplot was sampled in three replications three times per year: in winter–before washing; in spring–after washing and before sowing; and in autumn– during cotton ripening from three soil depth: 0-20, 20-50 and 50-100 cm. The soil was washed with 5000 m^3 ha^{-1} in winter; irrigation rate was 2000-3000 m^3 ha^{-1} in summer (2nd and 3rd decades of July). Water samples were taken from the irrigation canal, from the vertical drainage and from the discharge canal. The level of ground water was measures seasonally. Salt regime survey was conducted according to the Bazilevich and Pankova (1968) methodology. Soil salinity was determined based on the assessment of "cumulative effect" impact of toxic ions according to the equation: 1 Cl^- = 0,1 CO_3^{2-} = (2,75) HCO_3^- = (5,5) SO_4^{2-} , where 1 mEq. of Cl^- for 10 times less toxic for plants than 1 mEq of CO_3^{2-}; for 2.5-3 times, more toxic than HCO_3^-, and for 5-6 times more toxic than SO_4^{2-}. The obtained results classified sampled soils according to the Table 1.

The experimental data obtained for 2012-2014 years were plotted for the development of the map of soil salinity (1:10 000) seasonally (spring, autumn, winter) and vertically (0-20, 20-50 and 50-100 cm) using MapInfo Professional software.

Table 1. Soil classification on salinity level as "cumulative effect" of toxic ions (Bazilevich and Pankova, 1970)

Salinity level	Cumulative effect of toxic ions (CO_3^{2-}, HCO_3^-, Cl^-, SO_4^2), mEqCl$^-$
Non-saline	<0.3
Weakly saline	0.31-1.0
Medium saline	1.1-3.0
Strongly saline	3.1-7.0
Extremely saline	>7.0

Analytical methods

Soil samples were air-dried and passed through a 1 mm mesh sieve for chemical analyses. Soil samples were analyzed for water-soluble salts by extractions at ratio 1:5. Concentrations of HCO_3^-, CO_3^{2-} were calculated using their ratio determined by solution pH.The$K^+$and Na^+contents were determined by flame photometer FLAPHO 4 (Carl Zeiss Jena); Mg^{2+}, Ca^{2+} content by complexometric titration; Cl^- – by Mohr method with titration ($AgNO_3$ - 0.02N); SO_4^{2-} was calculated as ions (anions and cations) and content of carbonate CO_2 by gas calcimetry method.

The Analysis of Variance (ANOVA) was done using IBM SPSS statistical analysis package. The Least Significant Difference (LSD) among different treatments was tested individually on triplicate data and collectively by considering the mean values of data for each year as a single replication. The overall significance/effectiveness of treatments (by considering the years and locations as fixed variables) was also evaluated by applying LSD test on grand mean data at the 5% level of probability ($p \leq 0.05$) based on the F-test of the analysis of variance. Correlations between some of the study parameters were also considered by using SPSS 12 for Windows.

Results and discussion

General physicochemical properties of the soils, irrigation water, drainage water and ground water

The parent rocks of Golodnaya Steppe are ancient alluvial that was modified in the upper strata by the secondary processes of lessivage (Rukhovich et al. 2010). Mineralogical composition of these rocks is presented by weakly weathered and re-deposited calcite-quartz-feldspar, which is considered favourable in terms of mineral nutrition of plants (Suleimenov, 2008).

Generally, the soil pH ranged from 8.38 to 8.58 (medium alkali), carbonate CO_2 is 7.02-8.11%. In spring, the medium saline ground waters are located at 0.8-1.0 m depth, while in the autumn and winter they went down to 2.0-3.0 m. Such depths of ground water ensure constant flow of moisture from the lower layers of soil and into root zone. The up moving moisture transports water-soluble salts, which accumulated in upper horizons resulting in salt accumulation in all the experimental plots by the end of vegetation season (Bekbayev et al. 2015).

Spring soil washing allowed significant decrease of the salinity of soil profile at the same time increasing the salinity of ground water up to 11.1 g l^{-1} (Table 2). The total salinity of ground water by autumn was decreased to 3.6 g l^{-1} due to the capillary moving of salts up to the soil surface (Table 3). The salinity of irrigation and drainage waters was not exceeding 1.1 and 1.4 g l^{-1}, respectively (Table 3).

Table 1. Content of cations and anions seasonally and by depth, 2012-2014

Horizon, cm		mEq HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
					Spring				
0-20		0.36a†	-	0.35a	4.91a	2.31a	1.95a	1.24a	0.11a
20-50		0.33ab	-	0.53ab	7.28b	3.75b	2.55ab	1.74ab	0.09ab
50-100		0.29bc	-	1.05b	6.67b	3.00ab	2.54ab	2.45c	0.02c
ground water	g l^{-1}	0.51	-	1.73	5.76	0.96	0.9	1.26	0.002
	mEq	8.39	-	48.8	120.0	48.15	74.25	54.8	0.07
					Autumn				
0-20		0.34a	-	1.46a	7.15a	3.61a	2.35a	2.76a	0.16a
20-50		0.30a	-	1.32a	7.81ab	3.72a	2.65a	3.00a	0.08ab
50-100		0.25b	-	1.54a	8.03ab	3.78a	2.72a	3.27ab	0.04b
ground water	g l^{-1}	0.24	0.02	0.18	2.12	0.37	0.19	0.43	0.006
	mEq	3.96	0.63	5.21	44.3	18.67	15.79	18.8	0.16
					Winter				
0-20		0.35a	-	1.10a	7.31a	2.83a	3.32a	2.49a	0.12a
20-50		0.31a	-	1.52b	9.15ab	3.97ab	3.96a	2.92ab	0.10ab
50-100		0.27a	-	1.35ab	8.46ab	3.64ab	3.56a	2.84ab	0.04c
Irrigation water	g l^{-1}	0.15	0.006	0.08	0.52	0.13	0.05	0.09	0.006
	mEq	2.47	0.2	2.44	10.8	6.87	4.72	4.02	0.15
Drainage water	g l^{-1}	0.17	0.005	0.09	0.72	0.14	0.09	0.12	0.006
	mEq	2.79	0.17	2.66	15.01	7.25	7.94	5.13	0.15

† the letters within a column signify statistically significant differences

During irrigation, the salts brought by irrigation water and the salts from ground water and from soil solution all are involved in the re-distribution both laterally and vertically. The vertical re-distribution of salts under irrigation started at the time when ground waters were still deep. The essence of this process lies in the periodic desalination of flat and low areas, while less wet and more dry micro reliefs is subject to secondary salinization due to the salts migrating from the flat and low relief with film-capillary currents in the soil profile. As a result of such migration the small spots of saline soils are formed on the irrigated fields. Unlike other salt affected soils, in which chloride or sulfate anions absolutely prevails, in our study the Cl^-, HCO_3^- and SO_4^- (the latter estimated by difference) ions along the soil depth (0-20, 20-50 and 50-100 cm) were balanced (Table 2). However, seasonally (spring, autumn and winter), chlorides and sulfates tended to dominate. Na^+ dominated among the ions and its amount increased from 0-20 cm to 1 m depth and from spring to winter, while K^+ decreases with depth during the whole season. Content of Mg^{++} and Ca^{++} generally increased downward the soil profile, except in spring and winter at 20-50 cm where more Mg and Ca cations in upper and deeper layers were recorded. This is explained by the prevalence of Mg^{++} and Ca^{++} as cations and SO_4^- as anion in the composition of water-soluble salts in the soils.

Table 3. Content of total salts, CO_2, and pH seasonally and by depth, 2012-2014

Horizon, cm	Sum of salts, %	CO_2 %	pH
	Spring		
0-20	0.374a	7.02a	8.46a
20-50	0.538ab	7.21ab	8.40a
50-100	0.513b	8.11c	8.49a
ground water, g l^{-1}	11.1	-	
	Autumn		
0-20	0.588a	7.03a	8.52a
20-50	0.620a	7.57ab	8.48a
50-100	0.641a	7.83b	8.58a
ground water, g l^{-1}	3.56	-	7.66
	Winter		
0-20	0.570a	7.55a	8.38a
20-50	0.711b	7.42a	8.38a
50-100	0.654b	-	8.46a
Irrigation water, g l^{-1}	1.05	-	8.44
Drainage water, g l^{-1}	1.35	-	8.48

† the letters within a column signify statistically significant differences

Drainage properties of studied soil

The favourable physical characteristics of studied loess loam soils were good permeability, porosity and relatively low conjunction. Negative properties of the parent rocks shown to be high water-lifting capacity (2.5-3.5 m), relatively low infiltration coefficient (an average of 0,003 mm sec^{-}1), which explains the rapid rise in groundwater under irrigation and the slow decline after termination of irrigation.

The secondary re-distribution of salts occurred slower in natural non-drained and weakly drained areas, however, with time passed the secondary re-distribution resulted in a serious salinization. In addition, in non-drained and weakly drained irrigated soils during the re-distribution of salts some areas showed relatively satisfactory reclamation state, while others had lot of hotspots of salt accumulation (Rozanov, 1948; 1951).

Spatial and vertical distribution of the accumulated salts, seasonally

Spatial distribution of the salt accumulation seasonally and annually is shown in the Figures 2-4. The secondary salinization in 2012 was strongly developed covering all the area. However, after the soil washing was undertaken, the salinization process has been reduced, and the gradual desalinization has been recorded.

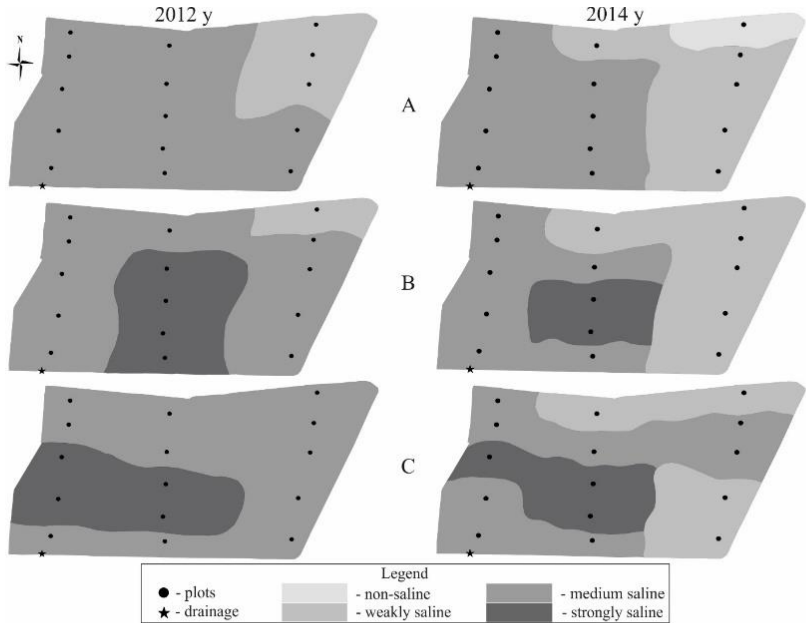

Figure 2. Map of soil salinity spatial distribution in spring (A - 0-20 cm; B – 20-50 cm; C – 50-100 cm).

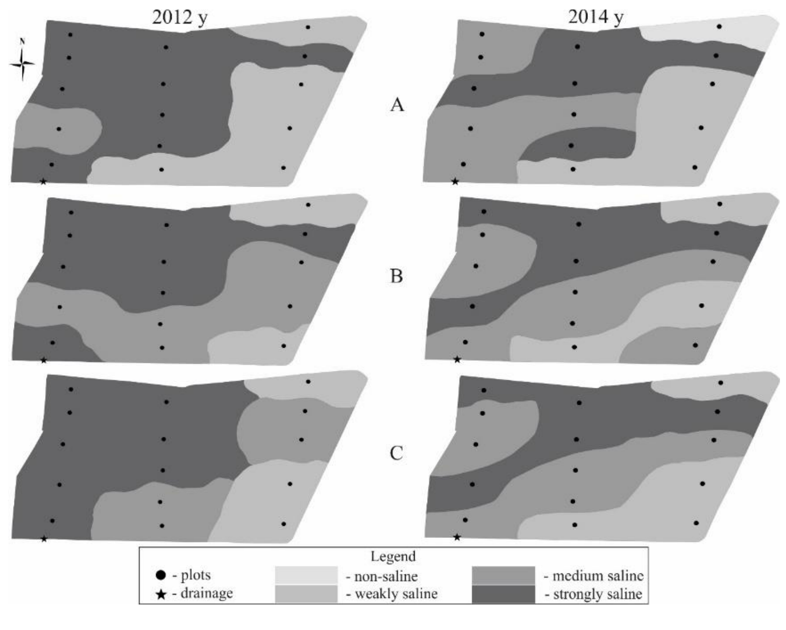

Figure 3. Map of soil salinity spatial distribution in autumn (A - 0-20 cm; B – 20-50 cm; C – 50-100 cm).

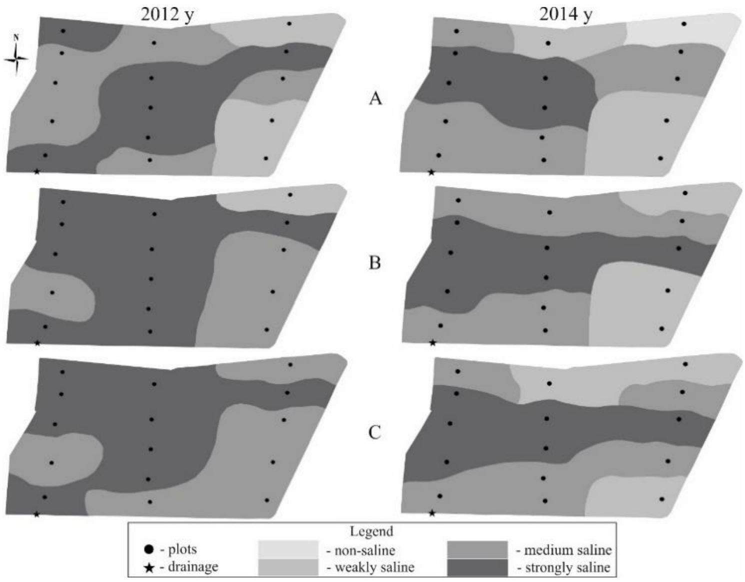

Figure 4. Map of soil salinity spatial distribution in winter (A - 0-20 cm; B – 20-50 cm; C – 50-100 cm)

After winter washing, in spring 2012, in upper layer there were prevailing the medium and weakly saline soils, occupying respectively 79.5 and 20.5% of the studied area. In autumn-winter period of 2012 there were recorded spots with all levels of salinization from weakly saline to strongly saline (weakly saline – 33.3 and 20.5%; medium saline – 9.0 and 39.7% and strongly saline – 57.7 and 39.7%, respectively). Our studies showed that the salinity of most of studied soils significantly differs from spring to winter.

In 2014 there was recorded a positive dynamic of changes comparing to 2012. In spring 2014 the area under medium saline soil in 0-20 cm layer decreased from 79.5 to 57.7%; the area of weakly saline soils increased from 20.5 to 34.6%, and 7.7% of non-saline soil area was recorded (Figures 2 and 5).

In autumn-winter period of 2014 the area under strongly saline soils decreased from 25.6to 14.1%, respectively in 0-20 cm comparing to 2012 (Figures 2, 4 and 5). The areas of medium saline soils increased to 24.3% in autumn and to 6.5% in winter, while areas of weakly saline soils decreased in autumn to 6.4%, and didn’t changed in winter. The area of non-saline soils was 7.7%.

Our studies showed that using the vertical drainage for three years transforms strongly saline soil recorded in 2012 into medium, weakly, and non-saline soils. So, the washing of soil in spring significantly reduces soil salinity due to the moving of salts downward, and in contrary in autumn-winter period increases soil salinity.

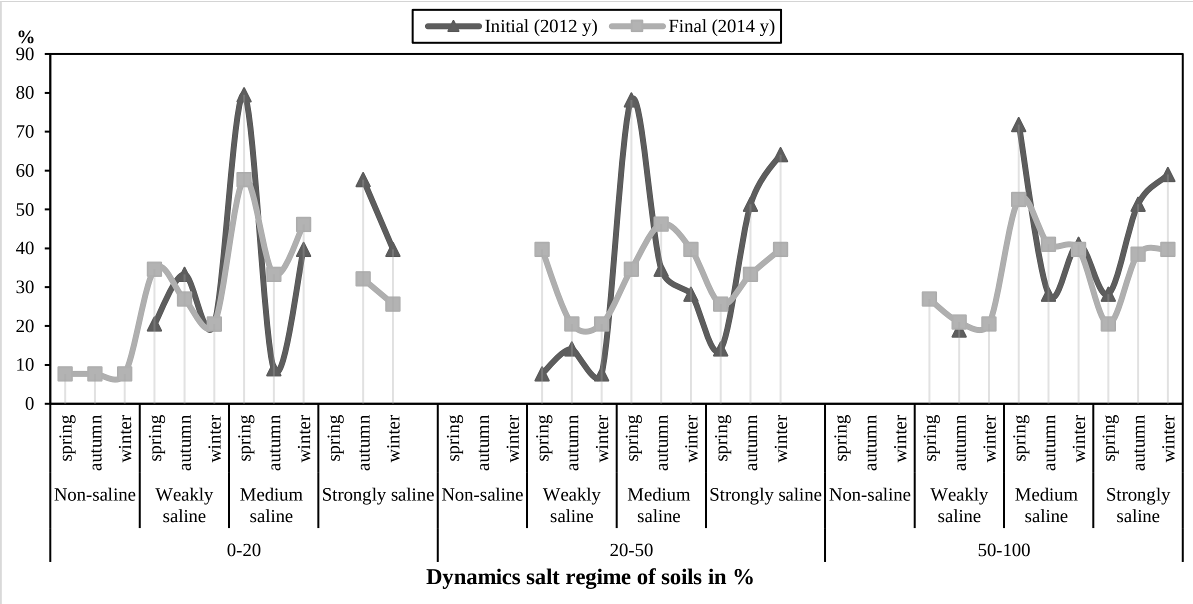

Figure 5. Dynamic of salt regime seasonally and vertically, %

Analysis of vertical distribution of salts allows assuming that the reasons of soil salinity in Light Grey soil of southern Kazakhstan could be one or a combination of the following circumstances: 1. Capillary rise of saline ground water table from shallow water tables to the soil surface. 2. Salt accumulations in plough layer, where subsoil leaching is insufficient to remove the salt. 3. Poor water management and inadequate drainage system subjected to periodic flooding and high evaporation.

The dynamic of ion content seasonally and vertically is presented in Table 4. In the period from 2012 to 2014 the amount of HCO_3^- decreased from 0.36 to 0.25 mEq ($p = 0.0001$), while the amount of SO_4^{2-} increased from 7.06 to 7.75 in 2012 and from 5.85 to 7.7 mEq in 2014 ($p \leq 0.032$); amount of Mg^{2+} increased from 3.1 to 3.31 mEq in 2012 and from 1.97 to 2.57 mEq in 2014 ($p \leq 0.001$) in 1 meter soil layer from spring to winter.

In spring 2012, there was recorded increase of HCO_3^- ($p \leq 0.001$), Cl^- ($p = 0.013$), SO_4^{2-} ($p \leq 0.016$) and Na^+ ($p \leq 0.002$) and K^+ ($p = 0.0001$) from upper to lower layers. In spring 2014 amount of Cl^- ($p \leq 0.013$) and Na^+ ($p \leq 0.002$) also increased, while amount of K^+ ($p = 0.0001$) didn’t change. In autumn and winter 2012 there was recorded decrease of $HCO3^-$ ($p \leq 0.013$) and K^+ ($p = 0.0001$) in 0-20, 20-50, 50-100 cm. In autumn 2014 the amount of HCO_3^- ($p \leq 0.012$) and K^+ ($p = 0.0001$) also decreases with depth. In winter, the decrease was observed only for K^+ ($p = 0.0001$). These results show that changes in the amounts of ions vertically and seasonally occur with transport of salts along soil profile under the influence of temperature gradients and the level of ground water, i.e., in spring from up to down, and in autumn and winter, contrary from down to up.

Table 4. Dynamic of ion content in soil seasonally and vertically, mEq.

Ions	Season	2012	2014	depth, cm	Spring		Autumn		Winter	
					2012	2014	2012	2014	2012	2014
HCO_3^-	Spring	0.37	0.33	0-20	0.33	0.36	0.33	0.34	0.28	0.30

	Autumn	0.33	0.30	20-50	0.38	0.30	0.32	0.28	0.27	0.24
	Winter	0.29	0.25	50-100	0.39	0.32	0.33	0.30	0.32	0.22
Cl^-	Spring	1.04	0.90	0-20	0.29	0.40	0.45	0.61	1.04	1.06
	Autumn	1.14	1.11	20-50	1.67	1.24	1.53	1.12	1.48	1.61
	Winter	1.30	1.33	50-100	1.15	1.04	1.44	1.60	1.37	1.33
SO_4^{2-}	Spring	7.06	5.85	0-20	4.53	5.28	7.05	7.52	5.81	7.53
	Autumn	9.27	6.89	20-50	7.65	6.66	8.94	6.69	8.15	7.92
	Winter	7.75	7.70	50-100	9.01	5.61	11.82	6.47	9.28	7.64
Ca^{2+}	Spring	3.03	2.80	0-20	1.83	2.80	3.60	3.89	2.27	3.72
	Autumn	4.25	3.38	20-50	3.99	3.22	4.37	3.08	4.12	3.45
	Winter	3.24	3.70	50-100	3.28	2.38	4.78	3.16	3.35	3.93
Mg^{2+}	Spring	3.11	1.98	0-20	2.13	1.77	2.68	2.42	2.62	2.46
	Autumn	3.75	2.36	20-50	2.51	2.19	2.99	2.31	2.63	2.82
	Winter	3.31	2.57	50-100	4.68	1.97	5.57	2.35	4.68	2.44
Na^+	Spring	2.22	2.11	0-20	1.12	1.36	1.45	2.03	2.22	2.68
	Autumn	2.67	2.44	20-50	3.06	2.47	3.38	2.61	3.11	3.44
	Winter	2.75	2.97	50-100	2.47	2.52	3.16	2.68	2.91	2.77
K^+	Spring	0.14	0.12	0-20	0.10	0.12	0.10	0.09	0.02	0.03
	Autumn	0.09	0.10	20-50	0.19	0.14	0.09	0.08	0.04	0.03
	Winter	0.03	0.04	50-100	0.12	0.12	0.08	0.13	0.03	0.05

Obtained results assume that after winter washing (5000 m^3 ha^{-1}) in spring the amount of salts in soil decreases, but the level of groundwater approaches the soil surface (to 0.8 m) and the salinity of ground water increases (11.1 g l^{-1}). While in autumn-winter period due to evaporation and transpiration sharp decrease of groundwater level (to 2-3 m) with salinity of 3.6 g l^{-1} is recorded. These processes result in enrichment of salt exchange between the ground water and soil matrix.

Funakawa et al (2000) studying the rice-based irrigation agriculture in southern Kazakhstan reported that the rate of salt accumulation during the upland cropping phase is rather rapid: salt accumulation in the 1st year of cotton cropping reached 45 kmol ha^{-1} $year^{-1}$ and in the second year it was 15 kmol ha^{-1} $year^{-1}$. In their study the following cropping of rice facilitated the washing down the salt accumulated during the cotton growing, but the leaching effectiveness was influenced by the quality and operational condition of drainage system. Similarly to their study, the Ca ion activity in 20-50 cm soil layer was higher than in surface 0-20 cm and than in 50-100 cm, both in spring of 2012 and 2014. The fact that soluble salts were not washed out into deeper horizons is explained by the effect of proximate of irrigation channels (Funakawa et al. 2000). The water from nearby irrigation channels penetrates into the surrounding soil strata and transports the salt upward due to evapotranspiration from the soil surface that is much greater than precipitation in arid and semi-arid climates (Eynard et al. 2005). This upward transport ceased once the soluble salts were exposed to a lower up to the P_{CO2} condition in the atmosphere than in the subsoil, resulting in a decrease in the solubility of Ca^+2 and HCO_3^-. Thus the subsurface accumulation of soluble salts occurs (Funakawa et al. 2000).

Generally, similarly to our studies Kaledhonkar et al. (2019) reported that ineffective irrigation water management, including losses in the canal network and inappropriately operating drainage system led to waterlogging and secondary salinization the soil. In addition the use of poor quality water for cotton irrigation causes salinization and alkalization of the soil in semi-arid and arid regions.

Conclusions

The reclamation state of studied soils primarily depends on soil physical properties and from the depth of saline ground water. Washing the soil in spring significantly reduces soil salinization due to migration of salts into deeper layers, while in autumn and winter an increase of salinization in upper soil layers occurs due to the high water-lifting capacity of studied Light Grey soil.

The results of the research indicated that reducing soil salinity using vertical drainage allows adjustment of the level of ground water maintaining more optimal use of water (1.4 g l^{-1}) for washing in winter and spring periods and for watering crops.

For improvement of the soil quality and management of irrigated light grey soil in Southern Kazakhstan and for maintaining higher cotton yield it is necessary to apply not only ameliorative and agro-technical measures, but also additional investments for the restoration of vertical drainage wells with systematic cleaning of farm and off-farm drainage networks.

Acknowledgment : This research is a part of doctoral studies financed by the Kazakh National Agrarian University, Almaty and by the Kazakh Research Institute of Soil Science and Agrochemistry, Almaty, Kazakhstan

References

Allbed A, Kumar L. 2013. Soil Salinity Mapping and Monitoring in Arid and Semi-Arid Regions Using Remote Sensing Technology: A Review. Advances in Remote Sensing, 2: 373-385.

Arunachalam S, Maharani K, Chidambaram.S, et al. 2011. A study on the Land use pattern change along the coastal region of Nagapattinam, Tamil Nadu. Inter. Jour. of Geomatics and Geosciences, 1(4): 700-720.

Bazilevich NI, Pankova EI. 1968. Experience on soil salinity classification. Pochvovedenie, 1:32-39.

Bazilevich NI, Pankova EI. 1970. Guidelines for the reclamation of Solonetz and registration of saline soils. Moscow, “Kolos” publishing.

Bekbayev R, Balgabayev N, Zhaparkulova E. et al. 2015. Factors that intensify soil degradation in the Kazakhstan part of the Golodnostepsky irrigation massif. Life Science Journal, 12(1s): 1-4.

Bekbayev RK. (2016). Factors Influencing on the Degradation of Water and Land Resources of Mahtaaral Irrigation Massif. Academia Journal of Agricultural Research, 4(3): 118-122.

Chernousenko GI, Kalinina NV, Rukhovich DI, et al. 2012. Digital Map of Salt Affected Soils of Khakassia. Eurasian Soil Science, 45: 997–1012.

Chhabra R. 2004. Classification of Salt-Affected Soils. Arid Land Research and Management 19:1:61-79, DOI: 10.1080/15324980590887344

Dzhalankuzov TD, Suleimenov BU, Seytmenbetova AT, et al. 2011. History of development of the world's cotton production and particularly in Kazakhstan. Soil Science and Agrochemistry, 1: 92-98.

Eynard A, Lal R, Wiebe K. 2005. Crop response in salt-affected soils. J Sustanable Agriculture 27(1):5-50, DOI:10.1300/J064v27n01_03

Farifteha TA, Farshada R, George J. 2006. Assessing salt-affected soils using remote sensing, solute modelling, and geophysics. Geoderma, 130: 191 – 206.

Fauck R. 1977. Influences of agricultural practices on soil degradation. FAO Soil Bulletin No. 34: Assessing Soil Degradation.

Funakawa S, Suzuki R, Karbozova E. et al. 2000. Salt-affected soils under rice-based irrigation agriculture in southern Kazakhstan. Geoderma, 97: 61-85

http://stat.gov.kz. The official Internet resource of the Kazakh Statistics Committee.

Jury WA. 1982. Simulation of solute transport using a transfer function model. Water Resour Res 18: 363–369

Kaledhonkar MJ, Meena BL, Sharma PC. 2019. Reclamation and nutrient management for salt-affected soils. Indian J fertilizers 15(5):566-575

Khakimov FI. 1989. Soil-reclamation conditions of desert deltas (changes and spatial differentiation). Pushchino, Academy of Sciences USSR, p.216.

Kitamura Y, Yano T, Honna T. et al. 2006. Causes of farmland salinization and remedial measures in the Aral Sea basin—Research on water management to prevent secondary salinization in rice-based cropping system in arid land. Agricultural Water Management 85: 1-14.

Li M, Xiao J, Bai Y, Du Y, Zhang F, Cheng H, Wang H 2020. Response mechanism of cotton growth to water and nutrients under drip irrigation with plastic mulch in Southern Xinjiang. Journal of Sensors, Special Issue: Sensors and Applications in Agricultural and Environmental Monitoring, vol. 2020, Article ID 2575162, 16 pages, 2020, https://doi.org/10.1155/2020/2575162

Mandal AK, Sharma RC, Singh G. 2009. Assessment of salt affected soils in India using GIS. Geocarto International, 24: 437-456.

Metternicht GI, Zinck JA. 2003. Remote sensing of soil salinity: potentials and constraints. RemoteSens. Environ. 85: 1–20.

Micklin P, Aladin N, Plotnikov I. 2014. The Aral Sea-The Devastation and Partial Rehabilitation of a Great Lake. Springer Earth System Sciences, Book, DOI: 10.1007/978-3-642-02356-9.

Bhat MA, Sheoran HS, Dar EA, et al. 2015. Geoinformatics as a Tool for Appraisal of Salt-Affected Soils, A Review. Inter. J. Innovative Science, Engineering & Technology, 2(10): 480-490.

Mueller L, Saparov A, Lischeid G. 2014. Novel Measurement and Assessment Tools for Monitoring and Management of Land and Water Resources in Agricultural Landscapes of Central Asia. Environmental Science, Springer International Publishing Switzerland, Book, DOI: 10.1007/978-3-319-01017-5.

Rozanov AN. 1948. About changes in Serozem under irrigation. Materials of Soil Science Institute after Dokuchaev, Moscow, Vol. XXV11, p. 9.

Rozanov AN. 1951. Serozems of the Central Asia. Moscow, p 168.

Rukhovich DI, Pankova EI, Chernousenko GI. et al. 2010. Long-term salinization dynamics in irrigated soils of the Golodnaya Steppe and methods of their assessment on the basis of remote sensing data. Eurasian Soil Science 43: 682-692.

Saparov A, Dzhalankuzov T, Umbetaev I, Suleimenov B. (2008). Invluence of irrigatioin on saline light Serozems. Soil Science and Agrochemistry, 3: 72-76.

Schoups G, Hopmans JW. 2002. Analytical model for vadose zone solute transport with root water and solute uptake. Vadose Zone Journal 1: 158-171.

Suleimenov BU. 2008. Increase of fertility of irrigated Serozems in cotton growing areas of Southern Kazakhstan. Doctoral thesis, Uspanov Institute of Soil Science and Agrochemistry, Almaty, Kazakhstan.

Szabolcs I. 1974. Salt Affected Soils in Europe. MartinusNijhoff, The Hague, p. 63

Weng YL, Gong P. 2006. A Review on Remote Sensing Technique for Salt-Affected Soils. Scientia GeographicaSinica, 26 (3): 369-375.

Zhihareva GA, Kurmangaliev AB, Sokolov SS. 1996. Soils of Kazakh SSR. Chimkent region. Vol. 12. Almaty, Nauka, p. 410.

Original paper DOI 10.5937/ZemBilj2002001T

Заслањена земљишта у условима гајења памука са наводњавањем у јужном Казахстану

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Извод

Испитиван је ниво сланости наводњаваног земљишта на гајеном памуку у Казахстану како би се осигурала подлога за обнову дренажног-одводног система целог региона и спречила деградација земљишта. Експериментални подаци добијени за 2012-2014. годину приказани су за сезонску и вертикалну израду мапе салинитета земљишта (1:10000). У пролеће 2014. године, површина средње сланог земљишта у слоју од 0-20 cm смањена је са 79,5 на 57,7%; површина слабо сланог земљишта повећала се са 20,5 на 34,6%. У јесењим и зимским периодима површина јако сланог земљишта смањена је са 25,6 на 14,1%. Површина несланог земљишта износила је 7,7%. Промене у количини јона, вертикално и сезонски, настају транспортом соли дуж профила земљишта вођеног температурним градијентима и нивоом подземне воде, тј., у пролеће одозго на доле, у јесен и зиму, супротно од доле горе.

Кључне речи: памук, наводњавање, сланост земљишта, просторна дистрибуција, сезонска дистрибуција, вертикална дренажа

Received 23.07.2020
Revised 13.08.2020
Accepted 24.08.2020