ЭРОЗИЯ ПОЧВ

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EFFECT OF IRRIGATION EROSION ON THE FERTILITY OF IRRIGATED DARK BROWN SOIL AND PRODUCTIVITY OF VEGETABLES IN SOUTH-EAST OF KAZAKHSTAN

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Abstract. The results of studying of the effect of irrigation erosion on the fertility of irrigated dark chestnut soils with different methods of irrigation in the foothills of the Trans-Ili Alatau are listed in the article. There was given the estimation of water-stable aggregates of dark chestnut soils, established the quantitative changes in physical and chemical properties of soils under irrigation.

Key words: soil, irrigation erosion, soil fertility, drip irrigation, furrow irrigation, sprinkler irrigation.

INTRODUCTION

One of the most efficient forms of using water resources in arid areas is irrigation. Scientifically justified solution of highly productive use of eroded foothill irrigated land, improving techniques and methods of combating irrigation erosion lays in deep and comprehensive study of composition and features of eroded soils. The surface runoff which occurs in interaction with soil leads to irrigation erosion. Issues of studying soil irrigation erosion in pre-mount area of Trans-Ili Alatau is one of the components of environmental protection and rational use of its resources.

Intensity of soil erosion processes during irrigation depends not only on the combination and interaction of various factors of geographical environment, but also to a large extent on their changes resulted from human activities. Therefore, for the rational use of erosion dangerous lands it is important to determine the optimal interaction in the system "human – water - soil" and identify quantitative and qualitative changes in physical and chemical properties of soils in different methods of irrigation.

MATERIALS AND METHODS

The study of irrigation erosion was carried out on dark chestnut soils (field station of Kazakh Research Institute of Potato and Vegetable Growing). Experimental site is located at an altitude of 1050 m above sea level. Studies have been conducted by expedition, stationary (on experimental and key areas of irrigated fields) and laboratory studies conducted in accordance with the established procedures.

Identified: particle size composition by pipette method with preliminary treatment with sodium pyrophosphate (Grabarov modification); bulk density, specific gravity - by Kaczynski method; humus - by Tyurin method; total nitrogen – by Kjeldahl method; hydrolysable nitrogen - by Tyurin – Konova's method; mobile phosphorus and potassium - by Machigin in modification of Grabarov with further determination of phosphorus on FEC - 56M, potassium on flame photometer FLAPHO 4; CO_2 – by calcium-meter; absorbed bases (Ca, Mg) – by trilonometric method.

The intensity of removal of soil particles in furrow irrigation was taken into account by taking sample of water for turbidity. Turbidity of water was determined from samples taken at the end of the furrow in 5, 15, 30, 60, 120, 240, 1440 min. Sediments were filtered, dried and weighed. By volume of flown off water and average weighted value of solid runoff we determined the amount of soil taken outside the irrigated field.

The analysis of irrigated land erosion processes was conducted in view of interaction features of water flow, the irrigation water drops fallen to the soil. Quantitative characteristics of anti-erosion resistance of dark brown soils has been done. The mechanism of manifestation of irrigation erosion related to the genetic properties of irrigated soils, terrain and irrigation methods has been determined.

To study the changes of water-stable aggregates by elements of the slope in the upper, middle and lower parts, the samples were collected from depths of 0-10, 10-20 and 20-30 cm before and after vegetation irrigation. Water-stability of aggregates was determined by N.I. Savvinov's method.

Developed diagnostic indicators of eroded dark brown irrigated soils can be used during soil erosion studies of irrigated land and designing of soil protection irrigation systems.

RESULTS AND DISCUSSION

An important factor of anti-erosion resistance of soils is water stability of the structure. Anti-erosion resistance of soil basically reflects its potential ability to resist or be washed off under the influence of the energy of moving water in the furrow.

A significant factor of dynamics of changing of water stability of topsoil is irrigation. In furrow irrigation the size of water-stable aggregates at the initial moment of irrigation varies depending on the duration of soil moisture, which is actually determined by the rate of movement of irrigation water in the furrow. The latter depends on a variety of different combinations of irrigation technological conditions (water consumption, slope, furrow length) and initial water-resistance feature of the structure. As a result of long-term irrigation of foothill dark brown soils in Almaty region, water stable aggregates content (more than 0,25 mm) in the layer 0-10 cm decreased from 84,8 % in non-washed (virgin) to 49,1-55,4 % in wash off analogue, and content of aggregates >1 mm respectively - from 63,51 % to 2,9-3,2 % (Table 1).

Table 1 – Changing of composition of water-stable aggregates in irrigation, %

Time of determination	Place of sampling along furrow length	Depth, cm					
		0-10			10-20		
		>1,0 mm	0,25-1,0 mm	>0,25 mm	>1,0 mm	0,25-1,0 mm	>0,25 mm
Virgin							
	0-10	63,51	21,28	84,8	39,9	39,9	78,9
Irrigated field, slope 7^0							
Drip irrigation							
Before irrigation	0 m	1,96	43,68	45,64	1,40	50,52	51,92
	40 m	2,08	49,90	51,98	1,38	52,78	54,16
	80 m	2,78	52,56	55,34	1,48	34,88	36,36
After irrigation	0 m	1,90	42,26	44,16	1,20	50,20	51,40
	40 m	1,96	48,18	50,14	1,32	50,40	51,72
	80 m	2,49	51,52	54,01	1,80	33,86	35,66

Table 1 continuation

Sprinkling							
Before irrigation	0 m	2,69	32,33	35,02	1,14	23,57	24,71
	40 m	1,34	24,34	25,68	2,03	19,59	21,62
	80 m	2,58	17,11	19,69	1,38	16,63	18,01
After irrigation	0 m	1,02	18,33	19,35	0,73	10,47	11,12
	40 m	0,97	10,99	11,96	0,99	11,00	11,99
	80 m	0,79	10,75	11,54	1,04	11,54	12,58
Furrow irrigation							
Before irrigation	0 м	2,9	46,2	49,1	1,7	29,8	31,5
	50 м	3,0	47,4	50,4	1,7	48,0	49,7
	100 м	3,2	52,2	55,4	2,1	48,8	50,9
After irrigation, q=1,2 l/s	0 м	2,1	36,5	38,6	1,8	30,4	32,2
	50 м	1,2	22,2	23,4	1,3	24,8	26,1
	100 м	1,2	38,2	39,4	1,5	17,3	18,8

In furrow irrigation method, aggregate composition of the surface soil layer undergoes significant changes. Observations revealed that after irrigation the amount of water-stable aggregates along furrow length decreases. Before irrigation the content of water aggregates (more than 0,25 mm) in the layer of 0-10 cm is as follows: at the beginning of the furrow (0 m) 49.1, in the middle (50 meters) - 50,4 and at the end (100 m) – 55,4% , and after irrigation in rate 1.2 l /s - respectively - 38,6 , 23,4 and 34,0 %. Studies have shown that in irrigation the considerable break of soil aggregates and transport of them along the length of the furrow irrigation are observed.

In drip irrigation of vegetable crops there is a slight brakeage of soil aggregates. Thus, if before irrigation in the layer 0-10 cm at the beginning of the field, composition of soil aggregates was 45,64 %, in the middle - 51,98 %, at the end - 55,34 %, then after irrigation in the beginning of the field - 44,16, mid - 50,14 and end - 54,01 %.

By the nature of changes in water-stability of soil structure in fine disperse sprinkling we can judge on the dynamics of soil physical properties and its permeability. With increase of intensity of rain, water-stable aggregates bigger than 0,25 mm have been destroyed, and the main factor influencing on the reduction of water-resistant structure is adsorbed air, which at high intensity of wetting brakes the aggregates, and raindrops as a result of mechanical impact dispersed them into separate mechanical elements. Dust and silt are carried by the formed runoff, while larger mechanical particles fall as sediment and kolmate the acting porosity. A screen is formed that substantially reduces water infiltration into the soil and facilitates the formation of surface runoff.

Results of determination of water-stability of aggregates indicate that irrigated dark brown soils have very low water stability. Therefore, the structural state of soils by the presence of water-stable aggregates which are larger than 0,25 mm in all investigated samples of arable horizon have been evaluated as unsatisfactory or poor. Unregulated supply of irrigation water to the furrow is the main reason for the reduction of water-stability of the structure.

Permanent erosion and deposition of sediment runoff in irrigated fields in the region during growing season may have impact on the granulometric composition of eroded soil (table 2). Under the influence of irrigation erosion the soil granulometric composition varies in different parts of irrigated field. Granulometric composition of dark brown soil is mainly represented by coarse - dust fraction, which is characteristic of dark chestnut soils of Trans-Ili Alatau formed on loess and loess-like loams. It was revealed that the granulometric composition of the eroded irrigated dark brown soils is strongly affected by lithological features of the parent rocks.

Table 2 – Granulometric composition of irrigated dark brown soils in different irrigation methods, %

Place of sampling	Depth of taking sample, cm,	Sizes of fraction, mm						
		1,0-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
H non-washed (virgin)	0-10	1,6	29,54	34,25	11,17	13,24	10,20	34,61
	10-20	1,1	31,43	34,94	9,51	12,91	10,09	32,52
Irrigated field, slope 7^0								
Furrow irrigation								
Beginning of furrow, 0 м	0-10	2,18	8,19	49,71	10,59	13,03	16,29	39,92
	10-20	2,65	10,22	48,04	10,59	13,03	15,47	39,09
End of furrow, 80 м	0-10	1,20	6,98	45,30	10,20	17,55	18,77	46,52
	10-20	1,22	6,88	44,52	11,03	17,15	19,19	47,37
Post vegetation period								
Beginning of furrow, 0 м	0-10	2,08	68,67	17,71	1,65	6,59	3,3	11,54
	10-20	1,94	69,20	13,60	7,42	4,54	3,3	15,26
End of furrow, 80 м	0-10	2,55	72,37	11,92	4,11	6,17	2,88	13,16
	10-20	1,77	74,79	10,69	5,35	3,70	3,70	12,75
Sprinkling								
Before irrigation								
Upper part of the field	0-10	1,13	12,52	42,15	10,64	14,32	19,23	44,20
	10-20	1,41	8,96	45,02	11,05	15,14	18,41	44,61
Middle part of the field	0-10	1,21	7,58	47,44	12,27	13,50	18,00	43,76
	10-20	1,08	20,35	34,78	9,82	18,00	15,96	43,78
Lower part of the field	0-10	1,53	9,30	45,40	11,45	14,31	18,00	43,76
	10-20	1,51	8,62	47,38	11,44	12,66	18,38	42,48

Table 2 continuation

After irrigation								
Upper part of the field	0-10	1,50	17,94	41,90	10,17	15,05	13,41	38,65
	10-20	1,26	38,10	26,86	7,32	12,62	13,84	33,78
Middle part of the field	0-10	0,51	6,67	52,10	10,99	16,69	13,02	40,71
	10-20	1,38	9,76	45,24	11,41	17,93	14,26	43,61
Lower part of the field	0-10	1,08	18,25	40,33	12,22	16,29	11,81	40,33
	10-20	0,79	5,11	45,62	18,74	17,92	11,81	48,47
Drip irrigation								
Before irrigation								
Upper part of the field	0-10	1,20	4,54	45,70	13,76	17,93	15,88	47,57
	10-20	1,36	16,42	39,07	10,58	18,32	14,25	43,15
Middle part of the field	0-10	1,31	7,77	45,67	12,64	19,16	13,46	45,26
	10-20	1,35	52,19	14,67	4,48	13,04	14,27	31,79
Lower part of the field	0-10	2,01	30,84	34,18	7,73	14,65	10,58	32,96
	10-20	2,30	21,61	33,77	13,84	16,28	12,21	42,33
After vegetation period								
Upper part of the field	0-10	1,12	7,17	45,24	13,86	15,08	17,53	46,47
	10-20	1,22	12,41	41,15	12,22	17,52	15,48	45,22
Middle part of the field	0-10	1,41	39,54	21,18	7,74	17,51	12,62	37,87
	10-20	1,37	11,02	44,83	11,41	18,34	13,04	42,79
Lower part of the field	0-10	1,59	28,7	27,72	10,19	16,31	15,50	42,00
	10-20	1,61	14,66	46,84	10,00	17,63	19,26	46,89

Arable layer of these soils consists of residues of A and AB horizons and it is mixed with the illuvial horizon, characterized by the highest content of clay particles and therefore the granulometric composition of the arable layer becomes heavier. Permanent erosion and deposition of sediment runoff in the irrigated field for many years, has a significant impact on the granulometric composition of the eroded dark brown soil. Under the influence of irrigation erosion, the granulometric composition of soil varies in different parts of the irrigated field.

Thus, in non-eroded soils the content of fine dust in the horizon of 0-10 cm is 13,2 % and physical clay 34,6 %. And the presence of significant amounts of coarse - dust particles (34,25 %) indicates a weak anti-erosion resistance of irrigated dark chestnut soils.

In furrow irrigation a permanent wash off and deposition of sediment runoff in the irrigated field for many years has a significant impact on granulometric composition of soil. In various parts of irrigated field under the influence of irrigation erosion the soil granulometric composition distribution changes.

In the process of irrigation, in the fields occurs sanding of dark brown soils, that is, medium loam turned into sandy loam (physical clay is 9,47-15,26 %).

Drop strike is the main reason for separating of particles under the influence of successive drop strikes. Separating of particles from soil is determined by mechanics of irrigation water drops' strike. However, shortly after the beginning of irrigation, drops fall on the soil which is already saturated with water, or on water layer.

To evaluate the impact of drops on soil in drip irrigation the granulometric composition was determined before and after irrigation. Granulometric composition of dark brown soils varies along the length of irrigated field. Before irrigation the share of physical clay in the 0-10 cm layer is 47,57 % in the upper part of the slope, in the middle- 45,26 % and 32,96 % at the base of the slope, and after vegetation irrigations respectively – 46,47, 37,87 and 42,00 %.

Under the influence of drops, hydrodynamic loads, fine fractions resulting from the destruction of soil aggregates, move deeper into the soil profile to a depth of wetting. Thus, in the layer (10-20 cm) before irrigation, physical clay content in the beginning of the field is 43,15 %, in the middle - 31,79 and in the end - 42,33 %, and after growing season there is an increase of physical clay content accordingly – 45,22 at the beginning of the field and 42,79 % in the middle, and in the end – 46,89%.

Another pattern is observed at sprinkling irrigation, drops of size 10-15 mm falling from a height of 2 m, have high kinetic energy. In the result of mechanical effect on aggregates, they burst, dispersing them into separate mechanical elements. Drops falling on the soil surface are muddying the topsoil, and therefore silt particles are carried off by the formed surface runoff. The stream is unable to move bigger particles, and they are settling down and kolmate the total soil porosity. So, before irrigation the share of physical clay in the layer 0-10 cm is 44,20 % in the upper part of the field, in the middle - 43,76 % and in the lower - 43,76 %, and after vegetation sprinkling respectively - 38,65; 40,71 and 40,33 %.

Analysis of the material of soil study of agrolandscapes allowed to determine that on the degree of erosion, vegetable fields are weak-, medium- and heavy washed off, which steepness of slopes is 3^0—7^0.

The study results showed that irrigation erosion causes a significant change in composition of soil nutrient content. During growing season vegetable crops absorb large amounts of nutrients from soil. Soil used in cropping system, differ from virgin analogues. Dark brown soils in virgin area contain 3,6 % of humus in the upper layer, and in the profile there is its sharp decrease in the depth. Dark brown soil of the experimental irrigated field contains humus almost 2 times less than virgin soil. So, before irrigation humus concentration in the upper (0-10 cm) horizon of dark brown soil on the slope elements (irrigated field) is as follows: in the top: - 2,23, at 40 m - 2,23, in the accumulation zone (80 m) - 2,18 %; and after vegetation respectively - 1,36; 1.3 and 1,18 %. Similarly, concentration of total nitrogen changes, the amount of which decreased in the upper part to 0,042 %, in the middle part to 0,014 %. The sharp decrease in nutrient composition in the soil upper layers is associated with irrigation erosion.

CONCLUSIONS

During soil survey of irrigated areas of the foothills of dark brown soils, the diagnostics of soils subjected to irrigation erosion was done. According to that, for irrigated soils the physical and chemical properties of old irrigated soils were determined. Preliminary research results showed that irrigation erosion changes chemical properties of soil in different parts of irrigated field, in particular, enhances the increase at the end of the furrow. In irrigation there is a reduction of composition of total and mobile forms of phosphorus and potassium in washable area and their increase in accumulation area. When water flow into the furrow increases, content of water stable aggregates in arable and sub-arable layer reduce, the value of bulk density increases, content of exchangeable bases reduces.

Drop strike is the main reason for separating particles under the influence of successive drops' strike. Separation of particles from soil is determined by mechanics of irrigation water drops' strike. However, shortly after the beginning of irrigation, drops fall on the soil saturated with water.

In drip irrigation method on dark brown soils, the character of changes of water-stable aggregates is almost the same, and there is a slight degradation of soil aggregates.

In fine disperse sprinkling we can judge on the dynamics of changing of water-stability of aggregates bigger than 0,25 mm. Water-stable aggregates bigger than 0,25 mm are destroyed, the main factor influencing on reduction of water-resistant structure is adsorbed air, which at high intensity of wetting bursts aggregates. Silt is taken away by formed flow, while larger particles settle down and kolmate the acting porosity. A screen if formed which substantially reduces water infiltration into the soil and enhances formation of surface runoff.

The study of soil erosion in irrigated plots reveals qualitative aspect of this development process. Therefore, the efforts of specialists in agriculture should be aimed at preservation and improvement of irrigated lands by conducting a set of anti-erosion measures.

ТҮЙІН

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ОҢТҮСТІК ШЫҒЫС ҚАЗАҚСТАННЫҢ СУАРМАЛЫ КҮҢГІРТ ҚАРА-ҚОҢЫР ТОПЫРАҒЫНЫҢ ҚҰНАРЛЫҒЫНА ЖӘНЕ КӨКӨНІС ДАҚЫЛДАРЫНЫҢ ӨНІМДІЛІГІНЕ ИРРИГАЦИЯЛЫҚ ЭРОЗИЯНЫҢ ӘСЕРІ

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Іле Алатауы бөктері жағдайында суарудың әр түрлі тәсілдері кезінде суармалы күңгірт қара-қоңыр топырақтың құнарлығына ирригациялық эрозияның әсерін зерттеу нәтижелері баяндалған. Күңгірт қара-қоңыр топырақ агрегаттарының суға төзімділігі бағаланып, суару кезінде топырақтың физикалық және химиялық құрамдарының сандық көрсеткіштерінің өзгерістері анықталды.

Түйінді сөздер: топырақ, ирригациялық эрозия, топырақ құнарлығы, тамшылатып суару, арықпен суару, жаңбырлатып суару.

РЕЗЮМЕ

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ВЛИЯНИЕ ИРРИГАЦИОННОЙ ЭРОЗИИ НА ПЛОДОРОДИЕ ОРОШАЕМОЙ ТЕМНО-КАШТАНОВОЙ ПОЧВЫ И ПРОДУКТИВНОСТЬ ОВОЩНЫХ КУЛЬТУР ЮГО-ВОСТОКА КАЗАХСТАНА

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Изложены результаты изучения влияния ирригационной эрозии на плодородие орошаемых темно-каштановых почв при различных способах полива в условиях предгорий Заилийского Алатау. Дана оценка водопрочности агрегатов темно-каштановых почв, установлены изменения количественных показателей физических и химических свойств почв при орошении.

Ключевые слова: почва, ирригационная эрозия, плодородие почв, капельное орошение, бороздковый полив, дождевание.