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Assessment of soil resistance to erosion of irrigation reclamation

Процена отпорности земљишта на ерозију у процесу наводњавања

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Abstract

In the context of climate aridity increasing economic and environmental importance sustainable high yields while maintaining soil cover. For this purpose it is planned the design and construction of new irrigation systems to ensure the productive soil moisture. However, in each case it is necessary to assess the degree of stability of soil for irrigation reclamation for the possibility of water erosion and nutrient imbalance. Researches were conducted on Grey forest residual-calcareous and Sod-calcareouses soils (Russia, Republic of Bashkortostan, Southern Urals). We studied the following indicators - agrophysical properties (water permeability, categories of soil moisture, density), physico-chemical properties (pH, absorbed Ca, Mg, dry residue of salt), agrochemical properties (humus, mobile forms of nitrogen and phosphorus) and environmental properties (heavy metals). It is shown that the soil has the potential fertility and can be used in irrigated agriculture, subject to the conditions of irrigation, irrigation water quality, the application of organic and mineral fertilizers, in the application of soil conservation tillage systems and use of sloping land for irrigation. Also it was composed of soil-reclamation map with recommendations on the use of soil.

Keywords: Grey forest residual-calcareous soils, Sod-calcareouses soils, soils properties, irrigation, stability

Introduction

In the context of climate aridity increasing economic and environmental importance sustainable high yields while maintaining soil cover. For this purpose it is planned the design and construction of new irrigation systems to ensure the productive soil moisture. However, in each case it is necessary to assess the degree of stability of soil for irrigation reclamation for the possibility of water erosion and nutrient imbalance.

In the Republic of Bashkortostan (Russia, Southern Urals) there are currently 64.7 thousand ha of irrigated land under vegetable crops and perennial grasses. These lands were located in the forest-steppe and steppe zones. Analysis of the irrigated land in this area showed the presence of mild to moderate salinity of 3.4% of the irrigated areas. For example, in irrigation of chernozems ordinary deteriorated agrophysical properties, increased salinity, decrease calcium absorption, reduction of humus content (Suyundukov, 1995).

Long-term irrigation of leached chernozems in the forest-steppe zone with slightly saline water has resulted in considerable changes in the soil properties under vegetable crops: the thickness of the humus horizon decreased by 3-5 cm; the soil texture has not changed considerably, but a tendency for worsening of the soil structural status was observed; erosional processes resulted in a drop in the humus content; the content of exchangeable bases decreased by 27.3% at the expense of calcium, and the soil reaction changed from neutral to slightly and moderately acid values; the soil buffer capacity in the acid range decreased; the portion of humic acids bound to calcium decreased, as well as the nitrogen content in the soil humus and the content of labile nitrogen fractions (first of all, the fraction of easily hydrolyzable nitrogen); the soil was subjected to soda-sulfate salinization of moderate degree in the plow layer and strong degree in the soil layer directly above the illuvial horizon (Gabbasova et al., 2006).

Research carried out in other regions, have also shown that non-compliance with conditions of an irrigation begins to develop reclamation soil degradation, which leads to secondary salinization, waterlogging, destruction of soil structure, dehumification, deterioration of physical, chemical and other regimes in the soil, which greatly complicates the effective use of reclaimed land (Pankova and Novikova, 2004; Minashina, 2009, 2011; Voevodina et al., 2014; Stoma et al., 2015;).

Objects and methods

The research was carried out in the southern forest-steppe zone. The territory on which research is characterized by a typical continental climate with sharp temperature contrasts: cold, harsh, with little snow winters and hot summers, a rapid transition winter to summer, the number of unstable and scarce precipitation during the growing season.

The investigated site is located on a plateau and slopes leveled mainly western and southern exposure with an altitude of 202 to 150 m. In mesorelief allocated little hilly and karst downgrade. Soil-forming rocks are eluvium limestones and deluvial calcareous clay. The main background of the soil cover is represented by grey forest residually calcareous soils. On steep slopes formed sod-calcareous soil typical.

According to the field survey and the results of laboratory tests on the surveyed area following soil marked difference:

1. Grey forest residual-calcareous (Greyic Phaeozems Albic) middle powerful heavy loam a low humus content slightly eroded.

2. Sod-calcareouses (Rendzic Leptosols Eutric) low-power a low humus content heavy loam medium eroded.

The soil samples the total content of the humus were determined according to Tyurin's method; the pH of the soil water suspension was determined potentiometrically; the exchangeable Ca^{2+} and Mg^{2+} were determined by complexometric titration; nutrients and agro-physical properties were determined by conventional methods (Arinushkina, 1970; Vadyunina and Korchagina, 1986). Heavy metals were determined in accordance with the «Guidelines…» (1992). The names of soils are listed according to the «Classification…» (Shishov et al., 2004).

Results and discussion

Characteristics of grey forest residual-calcareous soils. Within the surveyed area grey forest residual-calcareous soils formed on flat plateau and fairly steep slopes (i = 0,02-0,05) mainly western and southern exposure, which determined their low power and presence of weak erosion. Humus-accumulation horizon varies in the range of 39-54 cm, in a plowed field involved eluvial horizons of grey forest soils. The soil profile carbonates detected in the illuvial horizons at a depth of 55-60 cm, which is due to carbonate parent rock.

The upper soil horizons are characterized by low- and medium- acidic reaction, which is close to neutral and slightly alkaline in the illuvial carbonate horizon and soil-forming rocks (table 1). The amount of absorbed bases in the upper horizons AU and PU is 44-48 mEq/100g of soil, in podzolized several layers decreases and increases in the lower carbonate horizons. As part of the absorbed bases calcium predominates.

Table 1. Agrochemical soil properties

Horizon, Depth, cm	pH		Humus	Ca^{2+}	Mg^{2+}	N alk.	P_2O_5 tot	P_2O_5 avail.	K_2O avail.	Solids
	H_2O	KCl	%	meq/100 g soil		mg/kg				%
Section 1. The grey forest residual-carbonate moderately heavy loam low-humus slightly eroded										
AU, 0-24	6.19	5.61	3.21	34	14	154	1635	12.1	14.1	0.08
AEL, 24-42	6.18	5.37	2.78	31	14	77	989	5.4	11.3	0.22
BEL, 42-69	6.37	5.22	1.30	38	8	28	348	17.9	n/d	0.001
BTnc, 69-108	7.99	7.14	0.86	41	12	14	471	12.5	n/d	0.06
C, 108-140	8.06	7.34	0.54	40	15	14	327	12.8	n/d	0.06
Section 2. Sod-calcareouses low-power low-humus heavy loam moderately eroded										
AY, 0-24	7.03	6.56	4.18	39	12	133	1553	12.1	13.7	0.24
AYca, 24-31	7.00	6.61	4.37	45	12	91	827	2.4	n/d	0.02
Cca, 39-52	7.09	6.38	1.82	48	11	56	389	2.3	n/d	0.18
Section 5. The grey forest residual-carbonate moderately heavy loam low-humus slightly eroded										
PU, 0-26	6.49	5.77	3.71	39	11	203	n/d	10.8	14.1	0.06
AU, 26-41	6.35	5.12	3.12	n/d	n/d	n/d	n/d	9.4	n/d	0.08
Section 8. Sod-calcareouses low-power low-humus heavy loam moderately eroded										
AY, 0-28	7.41	6.70	4.28	48	12	154	1380	24.6	14.0	0.20
AYca, 28-38	7.35	6.62	4.12	48	12	100	860	19.6	n/d	0.12
Section 9. The grey forest residual-carbonate moderately heavy loam low-humus slightly eroded										
AU, 0-24	5.39	4.58	3.53	30	12	175	n/d	17.5	11.7	0.12
AUe, 24-38	5.72	4.64	3.06	31	13	133	n/d	10.5	n/d	0.04
AEL, 38-45	6.78	5.12	2.14	31	13	98	n/d	6.8	n/d	0.06
n/d - not determined										

On humus content of these soils are a low humus (from 3.21 to 3.97%). Down the profile humus content gradually decreases in the illuvial horizons of less than 1%. Alkali-hydrolysable nitrogen content in the upper horizons is change in a relatively wide range from 130 to 190 mg/kg and indicates the average availability of soil by nitrogen (Kiryushin, 1996).

All studied soils contain a very small amount, both general and mobile phosphorus. Availability of this item is assessed as very low. Exchange potassium content varies from 11 to 14 mg/kg, which defines a very low supply of potassium. Analysis of the water-soluble salt content shows the lack of salinity throughout the soil profile.

Characteristics of Sod-calcareouses soils. The sod-calcareous soil typical formed on the steepest slopes of the surveyed area. Perhaps these soils were formed originally as the grey forest and after deforestation they have undergone severe erosion, which brought to the surface carbonate horizons. The subsequent operation in a forb-grass vegetation contributed to the formation of humus sod horizon. Currently, the profile of sod-calcareous soils, as a rule, poorly developed and has a total capacity of about 30-40 cm, contains carbonate gravel and lies on heavy calcareous clays.

The sod-calcareous soils are characterized by typical neutral to slightly alkaline reaction, higher compared to the grey forest content of absorbed bases in the composition of which is also dominated by calcium. The humus content in the upper horizon is 3.64-4.28%, it sharply decreases with depth. The content of alkali-hydrolysable nitrogen average and total and mobile phosphorus - very low. The amount of water-soluble soils in these salts is slightly higher than in grey forest soils, due to their carbonate (table. 1).

Analysis of morphological and agrochemical properties of the soil to determine how typical sod-carbonate low humus loamy medium-eroded, which may not be used for arable land and irrigation.

Water-physical properties of soils. Grain size distribution determines many aspects of the economic use of soil. It determines the water permeability, water-holding capacity of soils and water-lifting. In the field particle size distribution was determined as loam.

In the arable grey forest soil bulk density is estimated as «dense» (1.3-1.4 g/cm^3), in the virgin soil of the upper 0-10 cm layer was evaluated as «compacted» (1.2-1.3 g/cm^3), deeper layers are also dense.

These soils are characterized by relatively low water capacity and water-holding capacity. In the arable horizons lowest moisture content ranges from 29.6 to 33.6%, and total moisture capacity capillary sequentially increased to 30,6-35,6 and 32.2-40.0%, respectively, with the depth of these values are gradually declining (table 2).

Table 2. Water-physical properties of grey forest soils

Horizon, depth, cm	Density	Soil moisture, % by weight of soil				Soil moisture, % by weight of soil			
	g/cm³	Field moisture	FWC	CWC	TWC	Field moisture	FWC	CWC	TWC
Section 1. The grey forest residual-carbonate moderately heavy loam low-humus slightly eroded									
AU, 0-10	1.23	23.90	33.56	35.93	39.97	29.39	41.28	44.19	49.16
AU, 10-20	1.38	21.40	30.51	31.87	32.24	29.53	42.10	43.98	44.49
AEL, 25-35	1.35	21.43	32.14	33.61	34.20	28.93	43.39	45.37	46.17
BEL, 50-60	1.35	29.27	35.94	37.48	37.77	39.51	48.52	50.60	50.99
BTnc, 70-80	1.54	22.01	23.20	24.78	25.16	33.89	35.73	38.16	38.75
C, 110-120	1.59	23.15	23.58	25.38	25.69	36.81	37.49	40.35	40.85
Section 9. The grey forest residual-carbonate moderately heavy loam low-humus slightly eroded									
AU, 0-10	1.32	23.86	33.29	35.33	36.80	31.49	43.94	46.64	48.58
AU, 10-20	1.38	17.60	29.64	30.56	32.88	24.29	40.90	42.17	45.37
AUe, 25-35	1.47	16.79	26.48	28.54	29.00	24.68	38.93	41.95	42.63
FWC - field water capacity; CWC - capillary water capacity; TWC - total water capacity									

Extremely important for the irrigated soils of insufficient moisture zone has its water permeability. Soil permeability was determined in the laboratory by monoliths (Vadyunina and Korchagina, 1986). These studies have shown (table 3), that the grey forest soils are generally good water permeability. The water permeability of the upper layers of the soil arable is 81.4-84.6 mm per hour, and fallow – 92.8-98.2 that comes in a range of 70-100 mm, which is assessed on a scale Kaczynski as «good» (Vadyunina and Korchagina, 1986). In the middle and lower horizons of the profile of water permeability is in the same range.

Thus, water-physical properties of grey forest soils are generally satisfactory for growing vegetables under irrigation, but increased density determines the need for regular loosening of the soil and organic fertilizer.

Table 3. Water permeability of grey forest soils

Horizon, depth, cm	Soil water permeability, mm/min						1 hour, mm
	0-10 min	10-20 min	20-30 min	30-40 min	40-50 min	50-60 min	
Section 1. The grey forest residual-carbonate moderately heavy loam low-humus slightly eroded							
AU, 0-10	3.27	2.18	1.64	1.09	1.09	0.55	98.2
AU, 10-20	2.18	1.64	1.64	1.64	1.09	1.09	92.8
AEL, 25-35	3.27	1.64	1.09	1.09	1.09	0.55	87.3
BEL, 50-60	2.18	1.64	1.09	1.09	1.09	1.09	81.8
BTnc, 70-80	2.73	1.64	1.09	1.09	1.09	1.09	87.3
C, 110-120	3.27	1.63	1.09	0.82	0.82	0.55	81.8
Section 9. The grey forest residual-carbonate moderately heavy loam low-humus slightly eroded							
AU, 0-10	3.91	1.30	1.30	0.65	0.65	0.65	84.6
AU, 10-20	3.59	1.30	1.30	0.65	0.65	0.65	81.4
AUe, 25-35	3.26	1.30	1.30	1.08	1.08	0.65	86.7

Ecological characteristics of soils. Together with the major nutrients: nitrogen, phosphorus, potassium and calcium, plants need a certain amount of trace elements, while excessively high concentrations of these elements may be toxic. Food plant micronutrients problem becoming more and more general biological significance because of their excess or deficiency causes adverse consequences not only for the growth and productivity of plants, but also to ensure human and animal food full composition of a certain quality. Analysis of trace elements (table 4) showed that the provision of grey forest soils molybdenum - low, cobalt, zinc and manganese - average, and copper - high. Therefore, crops grown in this area under irrigation, will require introduction of micronutrients, especially molybdenum, to a lesser extent - of cobalt, zinc and manganese.

Analysis of the content of elements of first class toxicity showed that the amount of plumbum, cadmium, mercury and arsenic in all soils, well below the maximum allowable concentrations and can be used for any culture.

Table 4. The content of trace elements and heavy metals in soils, mg/kg

Horizon, depth, cm	Cobalt	Zinc	Copper	Manganese	Molybdenum	Plumbum	Cadmium	Mercury	Arsenic
	Trace elements					Heavy metals			
Section 1. The grey forest residual-carbonate moderately heavy loam low-humus slightly eroded									
AU, 0-24	1,52	1,07	9,39	57,3	0,08	15,0	0,12	0,07	0,9
Section 5. The grey forest residual-carbonate moderately heavy loam low-humus slightly eroded									
PU, 0-26	1,73	0,97	10,0	70,1	0,09	16,1	0,13	0,07	0,8
Section 9. The grey forest residual-carbonate moderately heavy loam low-humus slightly eroded									
AU, 0-24	1,34	1,14	10,18	55,2	0,09	13,6	0,12	0,07	0,9

Agromeliorative characteristics of soils. The soils of the surveyed area are divided into two agromeliorative groups. The first group includes all the grey forest residual-calcareous medium-humus loamy slightly eroded. These soils are characterized by low natural and potential fertility, environmentally friendly, but not resistant to anthropogenic influences. Because the land is located on slopes above the average and large, when plowing may be increased water and wind erosion. Irrigation of these soils is necessary only on the condition of cultivation of vegetable crops.

The second group includes the sod-calcareousess typical low humus loamy medium - eroded soils. These soils are characterized by low fertility, located on very steep slopes and is developing a strong erosion. These soils are not to be irrigation.

Conclusions

Thus, our study on the stability of the soil under irrigation has shown that two types of soils formed in the studied area: Grey forest residual-calcareous (Greyic Phaeozems Albic) and Sod-calcareouses (Rendzic Leptosols Eutric) soils.

The Grey forest residually-calcareous moderately low humus heavy-loamy slightly eroded formed on eluvium limestone and calcareous clay talus characterized by satisfactory agrochemical and water-physical properties, but the insufficient resistance to anthropogenic impacts, erosion-dangerous, suitable for irrigation only when growing vegetable crops. When used these soils in the vegetable crop rotation is recommended to apply 40 t/ha of manure as well as nitrogen, phosphate and potash fertilizers to meet the requirements of specific vegetable crops. To prevent water and wind erosion is necessary to carry out anti-erosion measures, including snow retention, soil tillage and sowing crops across the slope and others.

The Sod-calcareouses (Rendzic Leptosols Eutric) low-power a low humus content heavy loam medium eroded formed on steep slopes prone to erosion and are characterized by low resistance to irrigation. These soils are not to be irrigation.

Also it was composed of soil-reclamation map with recommendations on the use of these soils.

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