Evalution of Degradation of Some Agrophysical properties of the Gray Forest Soils

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Degradation manifests itself both in the decrease in soil productivity as a result of transformation of soil properties and in the total destruction of soil cover and development of rill and gully erosion. Soil degradation tends to increase and spreads over a large area within the agricultural zone. Therefore, investigations aimed at the prevention of physical degradation of soils are of great importance.

The investigations were carried out at the experimental field station of the Institute of Physicochemical and Biological Problems in Soil Science Russian Academy of Sciences in Pushchino. The following variants of soil management were chosen: permanent black fallow (5 years old), uncut grassland (7 years old), cut grassland (12 years old), winter wheat with grasses, and grasses sown for 2 years in the five-field rotation.

The gray forest soils studied have a low humus content and low cation-exchange capacity (Table 1). Agrochemical properties of the soil depend on the type of soil management. The 5-year-old fallow state causes a decrease in humus content by 0.26% (in comparison with virgin soil) and increases the acidity of the arable layer. The addition of lime and mineral fertilizers under field crop rotation is favorable for the soil: humus content and composition of absorbed bases remain constant, and soil pH and the supply of nutrients increase. The grassing of soil results in the formation of a litter horizon and the increase in biomass and humus content.

The water regime of the gray forest soils is defined as periodically percolative. During the spring-summer period (April, May, June), these soils were dried up to a great extent. In the dry period, the moisture content in the upper horizons was reduced to 30-40% of the field capacity, which was equal to 26-28% in the upper soil layers and 24% in the lower ones. A distinguishing feature of the gray forest soils was the presence of a watersaturated layer at a depth of 160-190 cm (ranging from 100 to 300 cm depending on the topographic position). The moisture of these layers often exceeded the field capacity moisture. The strong spring-autumn drying of gray forest soils leads to the formation of a network of polygonal fissures.

The type of soil management affects agrophysical properties of gray forest soil, i.e., bulk density, water retention capacity, and soil macrostructure. Numerous parameters characterize soil as a bio-abiotic body, but the aggregate composition may be among the most reliable parameters that distinguish soil from other natural formations. Changing environmental conditions primarily affect the formation and composition of soil aggregates. The aggregate composition of the soil studied is supporting evidence of this statement (Table 2). We can arrange the types of soil management in order of their decreasing adverse effect on the water-stable properties of soil as follows: fallow, winter crops with grasses, grasses used during two years, cut grassland, and uncut grassland.

Using the indices of water stability, we suggest a scale for estimating the degree of degradation of water-stable properties of macroaggregates (Table 3).

Increasing soil degradation leads to an increase in bulk density and swelling capacity of macroaggregates, a decrease in porosity, and an increase in variability of the water stability of the macrostructure.

In recent years, bulk density has been considered as an integral indicator of physical properties of soil. It was found that field moisture capacity decreases from 0,42 to 0,24 g/g as the bulk density increases from 1,14 to 1,51 g/cm^3 (Fig. 1). Thus, soil compaction causes an abrupt decrease in the supply of available water. The relationship between field capacity (W_{fc}) and bulk density (ρ_i) can be described by the following equation:

$$W_{fc} = 0{,}516 \exp[1.471\,(1.0-\rho_i)],$$

where $1<\rho_i<1.6$.

The mechanical stability increases with increasing bulk density as well. It can be estimated using the value of cohesion forces characterizing both the stability of bonds between elementary soil particles and the stability of interaggregate bonds. The cohesion force was calculated according to [Mirtskhulava, 1980]:

$$C = 16(ud/(H + 20d))^2 \times 10^4,$$

where C is the cohesion force; H is the depth of linear wash-out, m; u is the speed of water ejection from the nozzle, m/s; and $-d$ is the diameter of the nozzle, m.

As can be seen from Fig. 2, the cohesion force increases with increasing bulk density. This increase accelerates when bulk density is above 1.3 g/cm^3. The relationship between the cohesion force and bulk density is described by the following equation:

$$C = 101(\rho_i/\rho_0)^{8.63} \times 10^4,$$

where C is the cohesion force, Pa;

ρ_0 = 1.0 g/cm^3; ρ_i is the bulk density of the soil (ρ_i > 1.0).

The compaction of gray forest soil and the degradation of its macrostructure have caused a change in the water permeability. A model experiment was carried out to determine the relationship between the filtration coefficient and the bulk density of gray forest soil (Fig. 3). There was an almost 100-fold decrease in the filtration coefficient with an increase in bulk density from 1.4 to 1.5 g/cm^3. The strongest decrease was observed when the bulk density was above 1.2 g/cm^3.

The minimum water conductivity measured in the field was in the soil under permanent fallow owing to the low water stability of macroaggregates, despite the fact that the upper layer of soil (0-20 cm) was sufficiently loose (Table 4). An increase in the filtration coefficient of the soil under perennial grasses of the second year was recorded.

Soil degradation can occur on any of the levels of structural organization of the soil. For instance, processes of degradation in the gray forest soil under 5-year fallow are observed at the aggregate and horizon levels of structural organization.

Typical gray forest soil

Table 1. The influence of different types of soil management on some chemical properties of gray forest soil

Soil management	Depth, cm	Humus, %	pH of salt suspension	Absorbed bases, mg-equiv/100 g of soil		Available forms, mg/100 g of soil	
				Ca^{2+}	Mg^{2+}	P_2O_5	K_2O
Permanent fallow (5 years old)	0-12	1.72	4.65	12.7	1.5	6.8	10.1
	12-26	1.59	4.65	12.9	1.6	6.3	11.7
	30-40	0.83	4.87	13.6	2.2	11.5	6.8
Uncut grassland (7 years old)	0-12	2.83	4.95	12.7	1.4	11.0	20.8
	12-26	2.19	4.45	12.0	1.1	9.8	16.0
	30-40	0.79	4.75	15.0	2.2	9.8	9.5
Cut grassland (12 years old)	0-12	2.88	4.80	11.2	1.8	4.5	10.9
	12-26	1.98	4.75	11.7	1.4	4.8	6.7
	30-40	1.28	4.75	12.3	1.8	6.4	6.7
Winter crops with grasses	0-12	1.96	6.75	15.0	1.4	14.0	10.1
	12-26	1.48	6.80	16.0	1.4	9.8	7.6
	30-40	0.74	6.90	16.4	2.6	13.0	8.5
Grasses of the second year	0-12	2.03	6.25	13.3	1.4	7.8	10.1
	12-26	1.65	6.44	13.2	1.5	7.5	6.8
	30-40	1.01	6.50	13.9	2.2	12.5	7.2

Table 2. The influence of the type of soil management on the change in water stability of macroaggregates in gray forest soil

Soil management	Depth, cm	Physical clay, %	Virgin cloddiess D_c, mm	Indices of water stability			
				water-stable aggregates >0,25 mm, %	D_{ad}, mm	D_{cw}, mm	D_{cw}/D_c
Permanent fallow (5 years old)	0-12	35.5	3.03	7.3	0.16	1.82	0.60
	12-26	33.5	3.54	13.1	0.17	2.70	0.76
	30-40	40.3	4.33	16.0	0.17	3.50	0.81
Uncut grassland (7 years old)	0-12	32.9	3.35	64.7	1.75	3.03	0.90
	12-26	34.0	4.11	59.9	1.12	3.93	0.96
	30-40	44.1	3.65	40.3	0.30	3.40	0.93
Cut grassland (12 years old)	0-12	30.9	3.20	68.6	1.68	3.06	0.96
	12-26	30.0	3.52	63.9	1.29	3.30	0.94
	30-40	31.5	3.98	41.2	0.52	3.94	0.99
Winter crops with grasses	0-12	37.6	4.03	28.2	0.31	3.60	0.89
	12-26	39.5	4.07	32.7	0.29	3.91	0.96
	30-40	47.5	4.01	42.8	0.35	3.88	0.97
Grasses of the second year	0-12	35.6	3.00	41.7	0.45	2.75	0.92
	12-26	36.3	3.13	34.8	0.40	2.88	0.92
	30-40	43.7	4.58	45.0	0.35	4.30	0.94

Table 3. Estimation of degradation of water stability of the macrostructure in gray forest soil

Degradation of water stability of macroaggregates	Indices of water stability			
	water-stable aggregates > 0.25 mm, %	D_{ad}	D_{cw}	D_c
		mm		
Strong	30	0.15-0.30	2.40	4.0
Medium	30-40	0.31-0.45	3.84	4.0
Weak	40-65	0.46-1.60	3.68	4.0
Nondegraded	> 65	> 1.60	3.60	4.0

Fig. 1. Relationship between bulk density and field capacity of the gray forest soil.

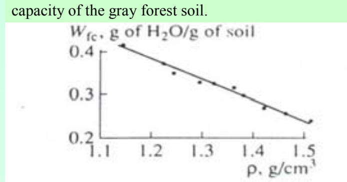

Fig. 2. Relationship between bulk density and the interaggregate cohesion force in the gray forest soil.

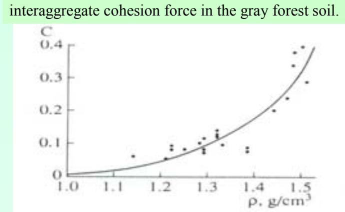

Fig. 3. Relationship between bulk density and the filtration coefficient in the gray forest soil.

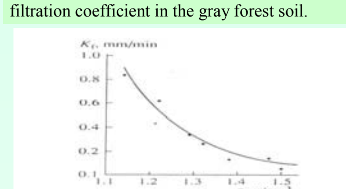

Table 4. Water permeability of gray forest soil

Type of soil management	Infiltration rate, mm/min time, hours						Amount of water infiltrating during one hour, mm	Estimate of water permeability of soil according to Kachinskii
	1	2	3	4	5	6		
Permanent fallow	0.38	0.13	0.11	0.12	0.11	0.11	22.8	Unsatisfactory
Winter crops with grasses	0.43	0.19	0.17	0.16	0.16	0.16	25.8	«
Grasses of the first year	0.55	0.35	0.35	0.33	0.31	0.30	33.0	Satisfactory
Grasses of the second year	1.03	0.49	0.45	0.47	0.43	0.43	61.8	«