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Change of the content of Soil Water stable Aggregates in a Fallow Field Depending on the Cultivation Level of Albic Glossic Retisols of Long-Term Field Experience

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ABSTRACT: Currently, the most acute problem is the agrophysical degradation of the soil cover with its high cultivation. It is long-term stationary experiments due to the time factor that allow us to assess the direction of trends in the physical properties of the soil. The study of water stable soil aggregates in pure steam showed that over a long period (1958-2015) in the variant without fertilizers, the number of water-bearing aggregates decreased from 14.2% to 2.5%. The introduction of a complete mineral fertilizer N100P150K120 and manure 20 t / ha, as well as their combination, slowed down the processes of destruction of the soil structure, especially in the first periods of operation of the experiment (1958-1991), which later increased (1991-2015) due to the reduction of the structure-forming effect of freezing-thawing during climate warming. Since the aggregate composition of the soil is derived from the mechanical composition and humus content (conservative properties), noticeable changes in 57 years are probably natural. Adverse changes in the content of water stable soil aggregates can occur primarily as a result of erosion, as a result of losses of humus and mineral fine fractions of the soil. The use of organic fertilizers and liming should reduce the development of these processes.

Keywords: cultivation, degradation, long-term experiment, soil, water stability of soil aggregates.

I. INTRODUCTION

Physical properties and physical processes occurring in the soil largely determine the direction of soil formation, conditions for the growth and development of plants. These parameters are taken into account when we develop agrotechnical techniques, land reclamation measures, etc. Physical properties are constantly changing under the influence of natural and anthropogenic factors. Properties change not only along the profile during the transition from one genetic horizon to another, but also in space [1-5].

The change in the soil structure of the experimental plot located on a slope, after a 103-year period of exposure to natural and anthropogenic factors, of varying degrees of intensity, is closely related to the content of water stable soil aggregates.

The content of the water stability of soil aggregates in the soil serves as a criterion for assessing and predicting the stability of the structure of the arable layer, which is a necessary prerequisite for the theoretical justification of various methods of tillage. Studies have shown that on Albic Glossic Retisols, the arable layer will have a stable structure, if it contains at least 40–45% of water stable soil aggregates, if below this level, the soil quickly compacts, its physical properties deteriorate [6, 7].

Soil aggregates, as the main components of the soil, have a significant impact on properties, which are closely related to the processes of water and air movement in the soil, soil erosion capacity, retention and release of nutrients in the soil, soil biological activity [8-11].

Differences in aggregate fractions affect the physical, chemical, and biological properties of the soil. Many studies have shown that soil stability increases with an increase in the number of macroaggregates [8-10,12-15]. Maintaining high aggregate soil stability is important to minimize soil degradation and erosion and preserve soil productivity [3, 16, 17].

According to the agrochemical survey, the soil of the Long-Term Field Experience is classified as cultivated cultured soil [4, 6, 12]. However, the interpretation of the concept cultivated cultured soil is under discussion. What kind of soil and on what grounds should be considered high, medium and poorly improved after cultivation, has not yet been established. And we believe that such signs as, for example, the arable horizon power, the percentage of humus, the degree of saturation of the soil with absorbing complex, etc., cannot serve as a complete objective measure of determination.

In fact, how can the soil of the experimental field be considered highly cultured if, along with enhanced physicochemical properties, by soil structure and soil firmness it can be attributed to structureless soils and then to lose its positive production value.

To give the soil a cultural, lumpy structure, it is necessary to increase the content of water stability of soil aggregates, which is considered optimal for Albic Glossic Retisols in the order of 35-45%. Water stability of soil aggregates is the main factor determining the anti-erosion resistance of the soil.

The content of the water stability of soil aggregates serves as a criterion for assessing and predicting the stability of the arable layer, which is a necessary prerequisite for the theoretical justification of various methods of soil treatment, previously such studies were not conducted.

II. OBJECTS AND METHODS

The object of the study was the soil cover of a fallow field in the long-term experiment, which is represented by sod-podzolic light loamy soil (Fig. 1).

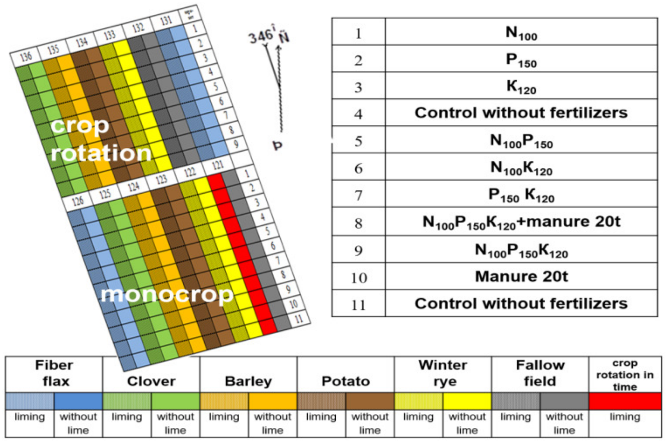


Fig. 1. Long-Term Field Experience scheme.

The Long-Term Field Experience of the TSHA was founded in 1912 by A.G. Doyarenko. It is located on the territory of the field experimental station of the RSAU-Moscow Agricultural Academy named after K.A. Timiryazeva in Moscow. Coordinates of experience: N 55°50′25″ E 37°33′29″.

Three-factor experience. Factor A – placement of crops (since 1912).

Variants of factor A: 1. Monocrop (fields 121–126); 2. Crop rotation (fields 131–136). On one half of the experimental field, a six-field grain-and-crop crop rotation was developed: 1 – fallow field, 2 – winter rye, 3 – potatoes, 4 – barley with clover seeds, 5 – clover, 6 – flax, and on the other crops are grown permanently.

Factor B – fertilizer (since 1912).

Factor B options: 1. Control (without fertilizers); 2. Manure; 3. NPK; 4. NPK + manure; 5. PK; 6. NK; 7. NP; 8. K; 9. P; 10. N.

From 1973 to 2015 as mineral fertilizers as ammonium nitrate (N – 34.5%), double granulated superphosphate (P_2O_5- 45.0%), potassium chloride (K_2O – 60.0%) are applied at the active substance doses – N – 100, P_2O_5 – 150, K_2O - 120 $kg \cdot ha^{-1}$, organic - manure 20 $t \cdot ha^{-1}$.

Factor C – chemical melioration (since 1949).

Options factor C: 1. Without lime; 2. Lime. Liming is carried out at full hydrolytic acidity once in the rotation of the crop rotation (last time it was made in 2013).

Soil cover of black fallow field of long-term experience considered by WRB (World Reference Base for Soil Resources) classification is presented by Stagnic Cutanic Albeluvisol (Siltic, Eutric, Ruptic)

The content of water stability of soil aggregates was determined by the method of sifting in still water on a Baksheev device [5].

The course of determination. An average sample of an air-dry soil weighing 0.5–2.5 kg, as in the work with the N.I. Savvinov method, is passed through a sieve set and an average sample weighing 25 g is prepared for sifting in still water. To do this, from each fraction we select a portion that is numerically equal to 1/4 of the percentage of this fraction. Aggregates less than 0.25 mm in size are not included in the average sample, but in further calculations they take a sample of 25 g as 100%.

After 12 min. of device operation, we remove the cylinders and put on the stand.

The water from the cylinders is poured into the vessel, the lids are opened, the sets of sieves are removed and disassembled. The soil aggregates remaining on the sieves are washed with a stream of water into pre-weighed porcelain or aluminum cups. After clarification of the water, the excess of it is drained, the plates with the soil are dried in a thermostat or in a water bath to an air-dry state and weighed after cooling.

III. RESULTS AND DISCUSSION

In the absence of vegetation cover (fallow field), the change in the content of water stable soil aggregates depended on the doses and the type of fertilizer (Fig. 2).

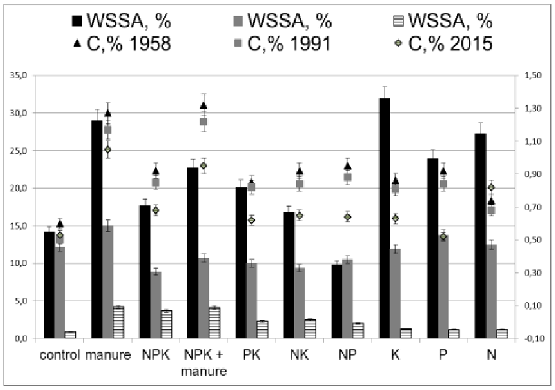
A generalization of data for a long period (1958–2015) showed that in a fallow field in the version without fertilizers, the number of water stable soil aggregates decreased from 14.2% (1958) to 2.5% (2015).

The same pattern, but with large differences, was also noted in the variants of application of one- and two-component mineral fertilizers. The application of full mineral fertilizer $N_{100}P_{150}K_{120}$ and manure 20 $t \cdot ha^{-1}$, as well as their combination, somewhat slowed down the processes of destruction of the soil structure, especially in the first periods of experience (1958–1991), which were further strengthened (1991–2015) due to reducing of the structural effect of freezing - thawing in the period of climate warming.

On average, the structural state of the soil of fallow field is characterized as unsatisfactory in terms of the content of water stable soil aggregates (21.3%).

Lime and manure were used for to improve and recuperate the soil structure. Increased doses of mineral and organic fertilizers did not compensate the degradation of the soil structure [18, 19].

The sifting in still water that we processed in 2015, showed that by the number of water stable soil aggregates of the soil of a fallow field in all fertilization options is characterized as structureless - the content of agronomically valuable aggregates did not exceed 5%. Using the sieves with diameter 0.25-1.00 mm, fractions left only due to the mechanical composition of the soil — sand particles and the fine cartilage of quartz grains, which indicates that the soil of fallow field does not contain almost stable structural aggregates.



R_{1958} = 0.26, R_{1991} = 0.11, R_{2015} = 0.74

Fig. 2. The change in the content of water stable soil aggregates (WSSA, %) in the fallow field, depending on the level of cultivation (C_{org}, %).

Further studies have established that with an increase in the total amount of applied doses of physiologically acidic mineral fertilizers, the process of acidification of the soil and the destruction of the water-resistant structure is noted, which increases the need for chemical melioration of the soil. Periodic (once in rotation) lime application for complete hydrolytic acidity maintains the response of the environment on optimal level and creates conditions for improving the structural condition of the soil, by increasing the proportion of Ca^{++} and Mg^{++} in the soil absorbing complex [3, 20].

Crops that cultivated continuously or in crop rotation, also had a different impact on the preservation and maintenance of sustainable soil composition thanks to increasing the content of water stable soil aggregates.

Fluctuations in the maintenance of water stable soil aggregates are observed when comparing the effects of the permanent cultivation of winter rye and crop rotation (field 132). In 1958, with low yields of winter rye, the crop rotation contributed to a significant increase in the content of agronomically valuable aggregates compared to monoculture (by 19.5% over the lime-free background and by 12.0% over the lime background), which is associated with the positive role of growing clover and an increase in the number of plant residues in the rotation (Table 1).

Table 1: The influence of the method of using arable land on the dynamics of the maintenance of water stable soil aggregates on the variants without fertilizers (%).

Culture	1958		1991		2015	
	on lime	without lime	on lime	without lime	on lime	without lime
Fallow field	—	14.2	—	12.2	—	0.9
Potatoes	28.9	22.2	20.8	10.4	12.3	6.8
Winter rye	47.9	35.5	42.9	29.7	29.3	31.1
Crop rotation	59.9	55.0	36.0	36.7	21.2	16.4
Minimum	28.9	14.2	20.8	10.4	12.3	0.9
Maximum	59.9	55.0	42.9	36.7	29.3	31.1
The average	45.6	31.7	33.2	22.2	20.9	13.8
Median	47.9	28.9	36.0	20.9	21.2	11.6
Art. reject.	15.6	17.8	11.3	13.0	8.5	13.2

Starting from the 13th rotation of the crop rotation (1991 to the present), the trend has changed, which is associated with the introduction of new high-yielding varieties and with the warming of the climate, causing an increase in the infestation of permanent crops, and, consequently, an increase in the supply of crop residues. The mechanical action of the root systems of weeds and cultivated agrophytocenosis plants also contributed to the formation of agronomically valuable aggregates.

In 2015, the option of permanently cultivating winter rye contained above 14.7% (without lime) and 8.1% (lime) water stable soil aggregates than in crop rotation, which is due to the absence of a destructive effect on the soil structure of a fallow field and potatoes [21].

Strengthening the mechanical effect when using traditional technology of potato cultivation on low-fertile soils (option without fertilizers) exacerbates the degradation of the soil structure, which results in a decrease in the content of water stable soil aggregates from 25.6% (1958) to 9.6% (2015). However, we note the positive role of chemical soil reclamation. Periodic liming, increasing the proportion of Ca^{++} in the soil absorbing complex, increases the content of water stable soil aggregates by 6.1% compared with the no-liming option.

The studied soil of fallow field and areas without crop rotated cultivation with a natural nutritional background within time becomes unstructured under the influence of natural factors and intensive processing.

Thus, the analysis of data on changes in the content of water stable soil aggregates for the studied variants of the Long experience suggests that with the many years of influence of the intensification of field crops (the method of placing crops, fertilizers, liming), the soil of the experimental plot can be characterized as structureless – option without fertilizers, low-structured – option with NPK and medium structured – option NPK + manure.

The established tendencies of changing agrophysical properties in the Long-Term Field Experience under the influence of various methods of cultivation (method of placing crops, organic and mineral fertilizers, liming) have the fundamental importance for improving the technology of cultivation of crops on sod-podzolic light loamy soils of different degrees of cultivation.

IV. CONCLUSION

The speed and degree of degradation of agrophysical fertility indicators of Albic Glossic Retisols are determined by the ratio of multidirectional processes of mineralization and humus accumulation, depending on the method of using arable land, the mass of organic substances entering the soil and the technology of cultivation of field crops. Long-term (over 100 years) soil fallowing leads to a decrease in the content of organic carbon from 2.04% (1912) to 0.65% (2015), which is accompanied by the complete destruction of the water-resistant structure.

In sifting in still water, structural fractions on sieves were obtained only due to the mechanical composition of the soil, i.e., due to the fine cartilage of quartz grains and large sand particles, in other words, sifting in still water shows that the soil of fallow field does not contain any strong structure aggregates in our long-term experience.

Established in Long-term experience, trends in changes in agrophysical properties under the influence of different methods of cultivation (the method of placing crops, organic and mineral fertilizers, liming) are of fundamental importance for improving crop cultivation technologies on sod-podzolic light-loam soils of different degrees of cultivation.

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