Degradation of the structure of meadow-chernozem soils in different eco-industrial conditions

To cite this article: L L Novykh *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **949** 012099

View the article online for updates and enhancements.

Degradation of the structure of meadow-chernozem soils in different eco-industrial conditions

L L Novykh[1,*], N V Eliseeva[2], S A Tesheva[3], I V Voloshenko[1] and E E Slyusarenko[4]

[1] Belgorod State National Research University, Belgorod, Russia
[2] Academy of Marketing and Social and Information Technologies – AMSIT, Krasnodar, Russia
[3] Federal State Scientific Budgetary Institution «Federal Scientific Rice Centre» Krasnodar, Russia
[4] Branch of the Adygea State University, Belorechensk, Russia

[*] E-mail: novykh@bsu.edu.ru

Abstract. The features of the structure of semi-hydromorphic meadow-chernozem soils in the Central Chernozem region (Belgorod oblast) and in the Krasnodar territory are studied. Both regions are characterized by the dominance of chernozem soils, but with different specialization of grain farming. It was identified that the patterns of changes of the waterproofness of the structure vary considerably in the study soils. Ambiguous results of assessing the quality of the arable soils using classifications by different authors were obtained. It is shown that the determination of the degradation degree of arable soils by the absolute values of the structure parameters is incorrect. The structure of arable and fallow soils for each region was compared. The content of agronomically valuable fractions in the arable horizons of cultivated soils and humus horizons of fallow lands shows that there is no degradation of the structure in rice soils, and in meadow-chernozem there is weak degradation in the «plow sole».

1. Introduction

Soil degradation is one of the urgent problems of our time. According to R Lal [1], there are four types of such degradation: physical, chemical, biological, environmental. Physical degradation is caused by the influence of intensive agricultural technologies and it is clearly revealed in the degradation of the structure. It is determined for different types of soils, including chernozem soils.

A special group is formed by compact soils. On the territory of Russia, they are widely represented in the Krasnodar territory and are characterized by the fact that they have unfavorable physical properties. We considered the features of compact soils in [2, 3], discussed their pedoecological characteristics. According to a number of their properties, compact chernozems are approaching the meadow-chernozem, since the signs of hydromorphism are identified in their profiles.

The presented article is devoted to meadow-chernozem soils. According to the «Unified State Register of Soil Resources of Russia» (USRSRR) [4] their area in the Belgorod oblast is 1%, in the Krasnodar territory - about 5%. The results of the study are discussed on the basis of the traditional factor-genetic classification [5], because despite the development of the substantive-genetic classification of soils in Russia [6] and the introduction of the international system of soil classification [7], factor-genetic classification is still used to account for soil resources in Russia.

Meadow-chernozem soils belong to semi-hydromorphic soils. This means that they are formed with periodic excessive moisture. Currently, according to [8], the classification position of these soils and their nomenclature do not give a sufficiently clear idea of their general properties, characteristics, distinctive features and diversity of such soils. The presented article is devoted to the study of some aspects of the diversity of such soils in Russia.

The aim of the study is to compare the degree of degradation of the meadow-chernozem soils structure under intensive agricultural use in the Central Chernozem region (Belgorod oblast) and Krasnodar territory.

Research hypothesis: during rice sowing, accompanied by periodic flooding of soils, there is a stronger negative impact on the soil structure; therefore, the degradation of the structure of meadow-chernozem soils in the Krasnodar territory will be more expressed than in the Belgorod oblast.

2. Materials and methods.

Figure 1 shows the location of these regions of the Russian Federation on the territory of Russia. The territories are located in the European part of Russia, separated from each other by distance of about 600 km, but their common feature is the dominance of chernozem soils.

Figure 1. Regions where the study was conducted.

The objects of the study were meadow-chernozem arable soils on the territory of the experimental site located in the Belgorod district (Belgorod oblast), and the soils of the rice irrigation system (Belozerny settlement, Krasnodar territory). The experimental site is a stationary field experiment for a comprehensive comparative characteristic of zonal and landscape farming systems, it has been functioning since 1991. On the studied meadow-chernozem soils, the zonal farming system is used here, including a grain-tillage crop rotation. The fallow meadow-chernozem soil was described under similar relief conditions on the slope of the Erik River valley, at the distance of about 2 km from the border of the experiment.

Rice industry is the important part of the grain agro-industrial complex of the Krasnodar territory: the gross harvest of rice in the Kuban is more than 80% of the all-Russian [9]. Since the beginning of

the twentieth century, hydromorphic soils have been actively used in rice growing. Previously, we considered various properties of meadow-chernozem soils of the Kuban under rice culture [10]; in this study, attention is paid to the structural-aggregate composition of such soils.

The Rice Irrigation System (RIS) has been functioning since 1937. It is located in the old deltaic agro-landscape district of the Krasnodar territory. The soil formation and its properties are strongly influenced by rice production, the cultivation technology of which requires flooding of crops during the growing season. Fallow soils were studied at the «Belozernoye» weather site, created in 1950. Over the past 70 years, no other work has been carried out at the weather site, except for the readout of meteorological data. The studied areas of the Krasnodar territory are characterized by one type of soil – rice meadow-chernozem. This term requires explanation, because there is no such type of soil in the traditional classification. However, the fields keeping under a layer of water during rice cultivation leads to significant changes in oxidizing-reducing conditions in the soil and the associated with it transformations of physical, chemical, biological properties of soils. In such new conditions, the soil-forming process is aimed at bringing together and combining soils of various types into one type of rice soils [10].

The comparison of the profiles of the studied soils shows that in meadow-chernozem soil, local signs of gleization begin in the transitional horizon B from a depth of 30 cm, and obvious gleization can be traced from the depth of 45 cm (BCg horizon), while in rice soil, gleization is expressed of varying degrees throughout the profile, but obvious signs are also determined in the lower part of the profile (horizons B2g and Sg).

To characterize the structural state of soils, there are a large number of indicators. We have used the following in this study:

– content of blocks (B) – fractions > 10 mm in size, %;
– dust content (D) – fractions of < 0.25 mm in size, %;
– content of agronomically valuable fractions (AVF) – sum of fractions ranging in size from 0.25 to 10 mm, %;
– structural coefficient (Sc):

$$Sc= AVF/(B+D) \tag{1}$$

– total waterproofness (Tw) – the sum of fractions > 0.25 mm in size, %, determined by «wet» sifting of the soil;
– most valuable part of aggregates (MVPA) – content of aggregates from 1 to 3 mm in size, %, determined by «dry» sifting of the soil.

The determination of the structural-aggregate composition of soils and the waterproofness of the structure was conducted by the Savvinov method. Cluster analysis was used to identify groups of similar objects in the sample data.

3. Results and their discussion.

Table 1 shows the main indicators characterizing the structural-aggregate composition and water strength of the structure of the studied arable soils.

According to the structural-aggregate composition of the soil, they differ significantly from each other: in general, rice soil has a higher lumpiness, less dispersion of the structure, but higher waterproofness. In all its horizons, the content of the most valuable part of the aggregates is less.

Down the profile, the quality of the structure of rice soil decreases, as evidenced by the decrease in Cs from 1.00 to 0.16, while in the profile of meadow-chernozem soil, the lowest quality of the structure is observed in the middle part of the profile (App and B horizons). Thus, differences in the granulometric composition (medium loam - clay) and the nature of use (presence or absence of flooding) lead to the fact that the structural-aggregate composition of soils differs in all parameters.

Figures 2-3 show the results of cluster analysis. Such analysis was carried out according to the following indicators: the content of ACF, the content of blocks, the content of MVPA, Tw. Below are the graphs illustrating those patterns, that are most clearly visible.

Table 1. The main indicators of structure of the studied soils.

Horizon	Depth, cm	B, %	D, %	AVF, %	Cs	Tw, %	MVPA, %
Meadow-chernozem arable (Belgorod oblast)							
Ap	0-10	16	8	76	3.17	30	32
App	10-30	54	2	44	0.79	57	15
B	30-45	54	2	44	0.79	58	15
BCg	45-60	24	13	63	1.70	69	27
Cg	60-100	39	12	49	0.96	26	15
Meadow-chernozem rice (Krasnodar territory)							
Ap	0-20	49	1	50	1.00	79	14
App	20-40	50	1	49	1.00	96	14
AB	40-77	60	1	49	0.80	89	10
B1	77-100	70	1	29	0.41	89	8
B2g	100-130	84	1	15	0.18	72	4
Cg	130 - ↓	84	2	14	0.16	85	3

According to the distribution of the AVF, three clusters are isolated, but the patterns are poorly traced. It should be noted that the horizons of the middle and lower parts of the rice soil profile are mergered into one cluster - B1, B2, C.
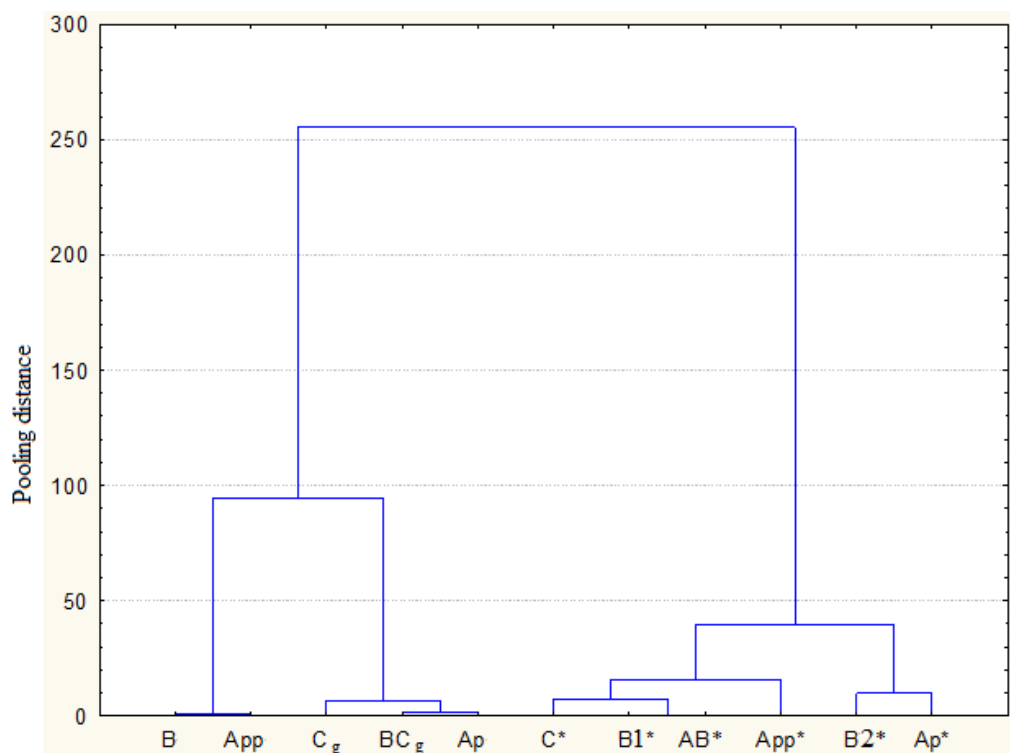
According to the distribution of blocks (Figure 2), the entire data set is also divided into three clusters, one of which has the complex composition.
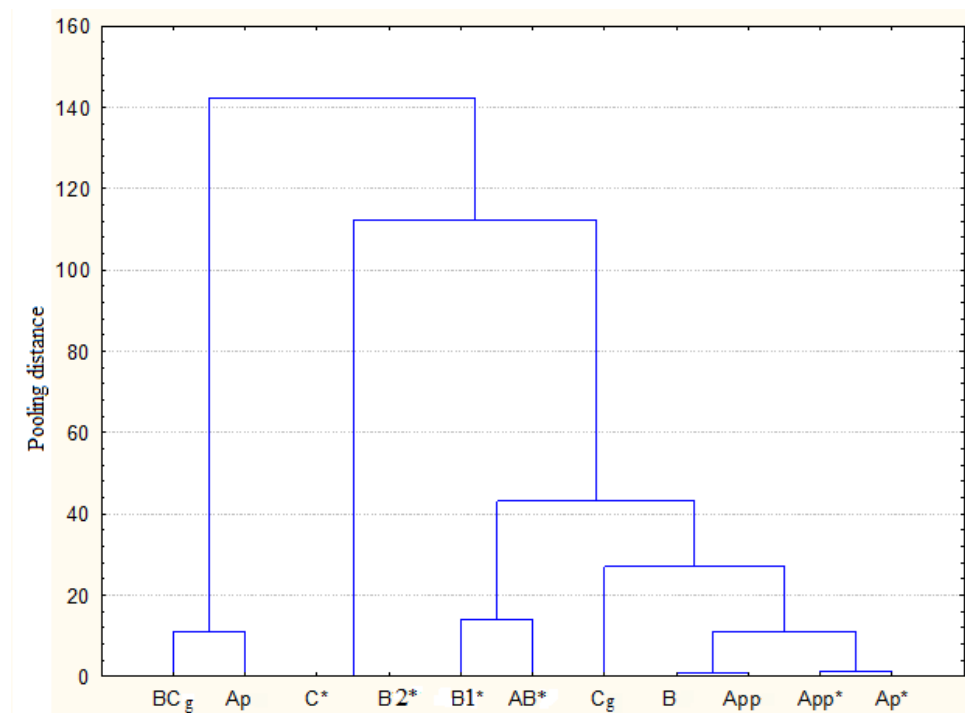
Figure 2. Dendrogram of the distribution of horizons by the content of blocks: the horizons of rice soil are marked with the sign *.

Pairwise clustering of rice soil horizons was determined: Ap-App, AB-B1, B2-C. This fact suggests that in the upper, middle and lower parts of the profile, the patterns of formation of the lumpiness of structure differ. At the same time, the horizons of Ap and App of meadow-chernozem arable soil are at a considerable distance from each other, as the horizons of BCg and Cg are. The last fact may indicate the heterogeneity of the soil-forming rocks in the experimental area under study.

According to the total waterproofness of aggregates (Figure 3), two clusters of complex composition are clearly distinguished, each of which unites the horizons of one of the studied soils. Thus, the regularities of the waterproofness of the structure in the studied soils differ significantly.

Figure 3. Dendrogram of the distribution of horizons according to the total waterproofness of the structure: the horizons of rice soil are marked with a sign *

According to the content of the MVPA, the pairwise unification of the horizons of rice soil is again noted, as with the distribution of lumpiness and a significant distance from each other of the horizons of the Ap and the App of the meadow-chernozem soil.

Based on information from a number of published studies [11-15], the quality of the state of the arable horizons structure of the studied soils was evaluated (Table 2).

The ambiguity of the evaluation results from different sources attracts attention. Thus, according to the content of AVF and the degree of degradation of the parameter, the structure of the arable horizon of meadow-chernozem soil is characterized as good, optimal, undegraded – all these characteristics are close to each other. The structure of the arable horizon of rice soil is satisfactory, the content of AVF reflects a strong decrease from the optimum, and degradation is medium. The evaluation of the content of blocks gives slightly different results: for meadow-chernozem soil, there is a slight decrease in the content of blocks from the optimum, according to other sources; the soil is undegraded or weakly degraded. For rice soil, a strong excess of the content of blocks from the optimum was revealed, degradation is medium or \strong.

Table 2. Evaluation of the state of the arable horizons structure of the studied soils.

№ p/p	Estimated parameter	Result estimated by different authors	
		Meadow-chernozem	Meadow-chernozem rice
1.	Content of AVF	Good structure	Satisfactory structure

2.	Waterproofness of the structure	Unsatisfactory – Satisfactory – Good	Excellent – Excessively high – Very good
3.	Degree of degradation by the content of blocks	Slight decrease from the optimum – Undegraded – Weakly degraded	Strong excess from the optimum – Medium degradation – Highly degraded
4.	Degree of degradation by the AVF content	Optimal – Undegraded	Strong decrease from the optimum – Medium degradation
5.	Degree of degradation by the - total waterproofness	Strong decrease from the optimum	Strong excess from the optimum

According to the waterproofness of the structure, meadow-chernozem soil has an unsatisfactory, satisfactory or good assessment; at the same time, there is a strong decrease in the total waterproofness from the optimum. For rice soil, the waterproofness is characterized as excellent, excessively high or very good; at the same time, there is strong excess of the total waterproofness from the optimum.

We consider that the assessment of the degree of soil degradation by the content of individual fractions blocks, AVF, total waterproofness) is incorrect, since it is not known whether the observed level of fraction content is a consequence of soil degradation or an initial genetic property. In this regard, the properties of arable horizons were compared with fallow variants of similar soils based on the approaches presented in [14]). The results of the comparison are shown in Table 3.

Table 3. Determination of degree of degradation in the studied soils by the content of AVF.

Variants	Soil layer, cm	Content of AVF, %	Reduction of AVF content, %	Degree of degradation
Krasnodar territory: RIS	0-20	50	11	Absent
Fallow soil	0-20	56	–	–
Belgorod oblast: experiment	0-20	60	No	Absent
	0-10	76	No	Absent
	10-20	44	21	Weak
Fallow soil	0-20	56	–	–

According to [14], with decrease in the content of AVF in arable soil horizons in comparison with virgin analogues by less than 15%, it is considered that there is no degradation, 15-25% – weak degradation, 26-35% – medium moderate, 36-45% – strong and more than 45% – catastrophic. For rice soil, the analyzed indicator is 11%, i.e. there is no degradation.

For meadow-chernozem arable soil, when assessing the whole layer of 0-20 cm, degradation is also not revealed. However, if we study the arable and sub-arable horizons separately (layers 0-10 and 10-20 cm), then a weak degradation of the soil structure is detected in the «plow sole» (the horizon of the App), since the decrease in the proportion of AVF is 21%.

4. Conclusion
Determining the degree of degradation of arable soils by the absolute values of the structure parameters is incorrect, since it is not known whether the observed level of fraction content is a consequence of soil degradation or an initial genetic property. During degradation of the soil structure, its quality decreases to a certain minimum level. If the soil initially has a good structure, this decrease can be significant. With the initial structure of low quality, the minimum level will be achieved with a

relatively small deterioration in the parameters of the structure. It follows that for soils with an agronomically valuable structure, the degree of their degradation during prolonged plowing can be much more revealed than for soils whose structure quality is lower.

In this regard, the expressed hypothesis about a stronger degradation of meadow-chernozem soils in the conditions of rice sowing has not been confirmed. The reasons for this result may be the following: either due to their genetic properties, rice soils initially show a low level of quality of the structure of the upper horizons, or period of 70 years is insufficient to improve the quality of the soil structure, since in this case the structure of arable soil was compared with the parameters of fallow soil. A weak degradation of the soil structure in the «plow sole» of meadow-chernozem arable soil is revealed.

References

[1]   Lal R 2015 *Sustainability* **7** 5875-5895
[2]   Chekhovich E E and Eliseeva N V 2012 *Materials of the reports of the YI Congress of the Society of Soil Scientists named after V.V. Dokuchaev* **Book 3** 461-462
[3]   Eliseeva N V., Novykh L L, Voloshenko I V, Slyusarenko E E 2019 *Proceedings of the VIII International Scientific Confer* edited by M A Polshina (Belgorod, Belgorod: Publishing House «Belgorod» NRU «BelSU») 214-218
[4]   *Unified State Register of Soil Resources of Russia* 2019 (Moscow)] URL: http://egrpr.esoil.ru (accessed: 08.05.2021)
[5]   Egorov V V, Friedland V M, Ivanova E N, Rozov N N, Nosin V A and Frieev T A *Classification and diagnostics of soils of the USSR* (Moscow: Kolos) 224.
[6]   Shishov L L, Tonkonogov V D, Lebedeva I I and Gerasimova M I 2004 *Classification and diagnostics of soils of Russia* (Smolensk: Oikumena) 342.
[7]   IIS WEB Working Group 2018 scientific ed. of translation: M I Gerasimova and P V Krasilnikov *Reports on world soil resources* (Rome: FAO) **106** 216.
[8]   Romanova T. A, Efimova I A, Ivakhnenko N N and Kapilevich J A 2011 *Soil science and agrochemistry* **1 (46)** 62-70
[9]   Pishchenko D A, Garkusha S V and Tesheva S A 2020 *Oilseeds* **3 (183)** 103-106
[10]   Sidorenko A V and Eliseeva N V 2011 *Bulletin of Orenburg State University* **12 (131)** 143-145
[11]   Derzhavin L M and Bulgakov D S 2003 *Methodological recommendations for conducting comprehensive monitoring of soil fertility of agricultural lands* (Moscow: FSSE «Rosinformagrotech») 240
[12]   Shein E V and Karpachevsky L O 2007 T*heories and methods of soil physics* (Moscow: «Grif and K») 616
[13]   Gordeev A V and Romanenko G A 2008 *Problems of degradation and restoration of productivity of agricultural land in Russia* (Moscow Rosinformagrotech) 67
[14]   Medvedev V V 2013 *Physical degradation of chernozems. Diagnostics. Reasons. Consequences. Warning* (Kharkiv: Publishing house «City printing house») 324
[15]   Trofimova T A, Korzhov S I, Gulevskii V A and Obraztsov V N 2018 *Eurasian Soil* **51** 1080-1085