Aggregate analysis of dark chestnut soil in irrigated and rain-fed conditions

Svetlana Podovalova [1*], *Natalya* Volkova [1], *Valentina* Popovich[1] and *Vitaly* Terleev[2,3]

[1] Research Institute of Agriculture of Crimea, 150, Kievskaya str., Simferopol, 295043, Russian Federation
[2]Peter the Great St. Petersburg Polytechnic University, St. Petersburg, Russia
[3]St. Petersburg State Agrarian University, St. Petersburg-Pushkin, Russia

Abstract. The soil aggregate composition is influenced by a large number of natural and anthropogenic factors, including irrigation. The question of the effect of irrigation with limited suitable waters on soil aggregate composition is insufficiently studied in the territory of the Russian Federation, although world experience indicates that prolonged use of low- and slightly saline waters entails an increase in the content of soil particles with size of less than 0.25 mm. According to the results of aggregate composition analysis the structural condition of dark chestnut soil in rain-fed conditions and in irrigation with limited suitable waters with similar agricultural techniques for cultivating crops was identified as good. The site–averaged content of soil particles with size of 0.25–10 mm in irrigated conditions was 67.8 %, and in rain-fed conditions – 63.9 %, and content of water resistant aggregates with size of more than 0.25 mm were 57.7 and 49.8 %, respectively.

1 Introduction

Aggregate composition is one of the main morphogenetic features, used in diagnostic of soil condition. Optimal water-air regime of soil, which depends on the content of particles larger than 0.25 mm, is necessary for friendly sprouts formation, sustainable growth of agricultural crops

Aggregate composition is influenced by a large number of natural and anthropogenic factors. The works of many scientists is devoted to assessing the impact of human activity on soil structure. These studies are aimed not only at analyzing different types of anthropogenic impacts, such as urbanization [1–3] and agricultural activities [4–19] on soil structure [9–11], but also at developing a set of measures that contribute to its improvement [4, 5, 7, 8].

The effect of such exposure depends on combination of several factors. The structure of irrigated soil is affected by: method, intensity and rates of water supply, size of raindrops, quality of irrigation water, etc. Some recommended values are established for a number of factors, for example, drizzling rain with a droplet diameter of 0.4–0.9 mm is considered the most favorable for the soil [20], but the issue of irrigation with limited suitable waters

* Corresponding author: podovalovas@list.ru

impact on the aggregate composition has not been sufficiently studied in the Russian Federation. The experience of Chinese researchers shows that long-term use of low- and slightly saline waters entails an increase in the content of soil particles smaller than 0.25 mm in size. For example, during experiments in the fields of the Hengshui Experimental Station in 2006–2015 (China, Hebei Province), the content of aggregates of this size increased by 1.8 times when using water with mineralization increased from 0.7 to 8.9 g/dm^3 [14].

The aim of this work is to conduct an aggregate analysis of dark chestnut soil under rainfed conditions and under irrigation with limited suitable waters with similar agricultural technology for cultivating agricultural crops.

2 Materials and methods

The studies were conducted on the example of a pilot site (Figure 1), located in the Pervomaysky district of the Republic of Crimea, represented by dark chestnut slightly solonetzified soil, in 2023–2024. The cultivated crop is triticale. Planting on irrigated and dryland plots was carried out in the second ten-day period of September 2023, and harvesting was carried out in mid-May. In the first half of 2023, water from the North Crimean Canal system was used for irrigation purposes, from mid-2023 and in 2024, the Vorontsovka River served as the source.

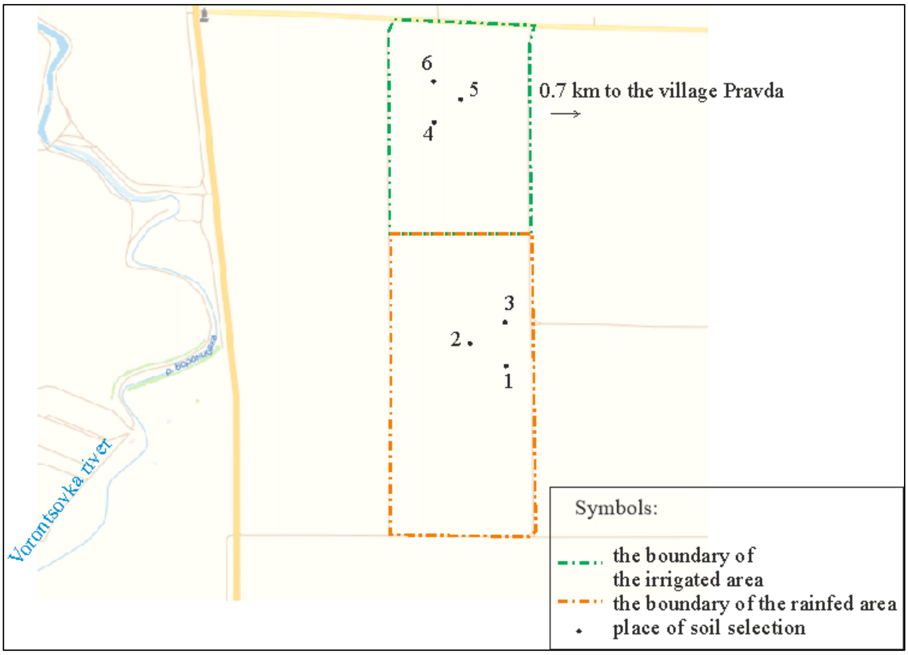

Fig. 1. Layout of the pilot site

The study included the following works:

– sampling of water sources, used for irrigation purposes, their chemical analysis;

– preliminary assessment of possibility of salinization processes development, causing the destruction of water-stable aggregates;

– sampling of soil (depth 0–20 cm) in triplicate and analysis of their aggregate composition using the method of N. I. Savinov [21].

 https://doi.org/10.1051/bioconf/202414102010

The quality of irrigation water was assessed based on the calculation of SAR – coefficient characterizing the sodium adsorption ratio [22]. Statistical processing of the results was performed, based on the determination of the least significant difference at a 5 % significance level (HCP_{05}) [23].

3 Results

During the study, the water of the North Crimean Canal system was classified as sulfate-hydrocarbonate calcium-magnesium, and water of the Vorontsovka River – as chloride calcium-sodium. Detailed information on pH, electrical conductivity, salt composition and content of heavy metals in irrigation water is given in Table 1.

Table 1. Results of chemical analyses of water samples taken from the North Crimean Canal system and the Vorontsovka River.

Indicator	Measurement units	Indicator value depending on the source	
		NCC system	r. Vorontsovka
pH	units	7.6	7.2
ES	mmS	0.8	4.6
HCO3-	mg/dm^3	237.9	207.4
SO_4^{2-}	mg/dm^3	88.6	293.7
Cl^-	mg/dm^3	35.5	1057.9
Ca^{2+}	mg/dm^3	48.0	298.0
Mg^{2+}	mg/dm^3	41.3	131.2
K^+	mg/dm^3	n/d*	15.4
Na^+	mg/dm^3	23.0	685.4
Pb	mg/dm^3	<0.0040	0.0045
Cu	mg/dm^3	<0.0005	0.0007
Cd	mg/dm^3	<0.0005	<0.0005
Zn	mg/dm^3	<0.0005	0.1385
Fe	mg/dm^3	0.1980	<0.0015

* – not determined

The SAR value for the irrigation water sample, taken from the North Crimean Canal system, was 0.6, and from the Vorontsovka River – 8.3.

Below in Table 2 are the results of determining the aggregate composition of dark chestnut slightly solonetzic soil, obtained on the basis of dry sifting.

Table 2. Structural composition of the soil, determined on the basis of dry sifting.

Size of soil particles, mm	Content of soil particles, %	
	under irrigation	in rainfed conditions
>10	27.2	29.5
10–5	16.1	16.3
5–3	10.7	11.0
3–2	7.1	7.0
2–1	13.8	12.2
1–0.5	10.8	8.9
0.5–0.25	9.4	8.5

<0.25	4.9	6.6

The average by site content of soil particles of 0.25–10 mm in size in irrigated conditions was 67.8 %, and in rainfed conditions – 63.9 %.

Table 3 shows the results of determining the aggregate composition of dark chestnut slightly solonetzic soil, obtained on the basis of wet sifting.

Table 3. Content of water-stable aggregates.

Size of soil particles, mm	Content of soil particles, %	
	under irrigation	in rainfed conditions
>3	5.0	2.4
3–2	2.9	1.4
2–1	9.3	5.0
1–0.5	13.5	10.7
0.5–0.25	27.0	30.3
<0.25	42.3	50.2

The average by site content of water-stable aggregates larger than 0.25 mm in irrigated conditions was 57.7 %, while in rainfed conditions it was 49.8 %.

Table 4 presents the results of statistical processing of content comparison of particles from 0.25 to 10 mm in size and water-stable aggregates larger than 0.25 mm in irrigated and rainfed conditions.

Table 4. Statistical processing of data on the content of soil particles and water-stable aggregates in irrigated and rainfed conditions.

Indicator	Calculated values, %			
	by content of soil particles 0.25–10 mm in size		by content of water-resistant particles larger than 0.25 mm in size	
	under irrigation	under rainfed conditions	under irrigation	under rainfed conditions
Arithmetic mean	67.8	63.9	57.7	49.8
Dispersion	65.5	163.3	9.3	6.7
Standard deviation	8.1	12.8	3.1	2.6
Sampling error	4.7	7.4	1.8	1.5
Error of difference	8.7		2.3	
HCP_{05}	24.3		6.4	

4 Discussions

The water of the North Crimean Canal system, which was used for irrigation in the first half of 2023, is characterized as safe for irrigation purposes, based on the SAR value. Its use, according to the preliminary assessment, should not have led to the development of soil salinization. The water of the second source, used for irrigation in 2023 and 2024, is characterized by worse salt composition. Based on the SAR value, it was classified as limitedly suitable. When used for irrigation purposes, the risk of soil salinization is identified as average.

The use of limitedly suitable water for irrigation at the time of the survey did not lead to deterioration in the aggregate composition of the dark chestnut slightly solonetzified soil. No significant difference was recorded between the content of 0.25–10 mm aggregates in rainfed and irrigated conditions (Table 4). The structural state for this soil fertility indicator was identified as good.

With regard to the content of water-stable aggregates larger than 0.25 mm, a significant difference was obtained based on the results of statistical processing. The value of the actual difference between the variants exceeded the HCP_{05} by 1.5 % (Table 4). The structural state for this soil fertility indicator in irrigated and rain-fed conditions was identified as good. The most likely reason for the higher content of water-stable aggregates in the upper layer of the irrigated plot is removal of soil particles by irrigation water into the underlying horizons.

5 Conclusions

Based on the results of this work, at the time of the survey, the aggregate state of the dark chestnut slightly solonetzified soil of the irrigated area, compared to rain-fed conditions, was characterized by a higher content of particles sized 0.25–10 mm and water-resistant aggregates larger than 0.25 mm. This indicates that irrigation with limited suitable waters at a SAR value of 8.3 did not cause significant negative changes in these indicators. According to world experience, long-term irrigation can cause deterioration in the aggregate composition of the soil, but a significant difference was noted when using irrigation water with a content of water-soluble salts of more than 3.5 g/dm^3, which, according to leading scientists, is not recommended for land reclamation purposes.

Acknowledgments

The study was carried out within the framework of the state theme of the Ministry of Science and Higher Education of the Russian Federation, reg. number: FNZW-2022-0002.

References

1. A. A. Puzankov, A. D. Dolgova, N. V. Ivanisova, M. A. Zaprivoda, S. A. Semenova, *Soil size distribution of urbanized areas*, in Proceedings of the IX International Scientific and Practical Conference “Innovative technologies in the agro-industrial complex: theory and practice”, 12–13 March 2021, Penza, Russian Federation (2021).
2. A. A. Vovchok, M. Yu. Shumsky, E. A. Lopin, N. V. Ivanisova, M. A. Zaprivoda, *Soil aggregation analysis on territory of the mine city*, in Proceedings of the LII International Scientific and Practical Conference “World science: problems and innovations”, 30 April 2021, Penza, Russian Federation (2021).
3. E. A. Mamontova, T. A. Chichkina, *Ecological estimation of agrophysical and physicochemical properties of urban soils* , in Proceedings of the X International Scientific and Practical Conference “Innovative trends in the development of Russian science”, 22–23 March 2017, Krasnoyarsk, Russian Federation (2017).
4. N. V. Ivanisova, L. V. Kurinskaya, S. I. Kolesnikov, AgroEcoInfo, **4** (2020).
5. V. P. Belobrov, S. A. Yudin, N. V. Yaroslavtseva, A. V. Yudina, V. K. Dridiger, R. S. Stukalov, N. N. Klyuev, I. V. Zamotaev, N. R. Ermolaev, A. L. Ivanov, V. A. Kholodov, Pochvovedenie, **7**, 880-890 (2020).
6. E. N. Nezhinskaya, S. A. Taradin, International Journal of Humanities and Natural Science, **11**, **1**, 16-19 (2018).

7. N. A. Vakhrushev, L. V. Rudakova, Don Agrarian Science Bulletin, **27**, **3**, 38‑45 (2014).
8. M. A. Nesmeyanova, Perm Agrarian Journal, **9**, **1**, 50‑55 (2015).
9. V. Terleev, W. Mirschel, A. Nikonorov , V. Lazarev, R. Ginevsky, A. Topaj, K. Moiseev, V. Pashtetsky, I. Dunaieva, V. Popovych, A. Melnichuk, M. Arkhipov, J. Advances in Intelligent Systems and Computing, **983**, 462-471, (2019).
10. V.V.Terleev, R.S. Ginevsky, V.A. Lazarev, A.G.Topaj, E.A. Dunaieva, J. Eurasian Soil Sci., 54(6), (2021).
11. V. Terleev, W. Mirschel, A. Nikonorov, R. Ginevsky, V. Lazarev, V. Pavlova, A. Topaj, V. Pashtetsky, I. Dunaieva, V. Popovych, A. Melnichuk, K. Layshev, J. Advances in Intelligent Systems and Computing, 983, 449-461, (2019).
12. A. Tedeschi, M. Menenti, Water Resources Management, **16**, **2**, 89–103 (2002).
13. H. Wang, D. Feng, A. Zhang, C. Zheng, K. Li, S. Ning, J. Zhang, C. Sun, Agricultural Water Management, **262**, 107405 (2022).
14. A. Zhang, K. Li, J. Sun, A. E. Rahma, G. Wang, J. Zhang, D. Feng, Journal of Soil and Water Conservation, **75**, **5**, 629–639 (2020).
15. C. H. Huang, X. Xue, T. Wang, R. De Mascellis, G. Mele, Q. G. You, F. Peng, A. Tedeschi, Environmental Earth Sciences, **63**, **4**, 701–708 (2010).
16. U. K. Mandal, D. N. Warrington, A. K. Bhardwaj, A. Bar-Tai, L. Kautsky, D. Minz, G. J. Levy, Geoderma, **144**, 189–197 (2008).
17. Y. Wu, H. Wang, J. Zhu, Sustainability, **14**, 4390 (2022).
18. P. Adhikari, M. K. Shukla, J. Mexal, Transactions of the ASABE, **55**, **5**, 1711–1721 (2012).
19. N. E. Volkova, S. V. Podovalova, A. M. Dzhaparova, Land Reclamation and Hydraulic Engineering, **14**, **2**, 139–155 (2024).
20. L. A. Voyevodina, Scientific Journal of Russian Scientific Research Institute of Land Improvement Problems, **21**, **1**, 134–154 (2016).
21. I. S. Kaurichev, Workshop on soil Science (Kolos, Moscow, 1980).
22. S. V. Podovalova, N. E. Volkova, V. V. Popovich, V. V. Terleev, Agrophysica, **4**, 57–66 (2023).
23. E. A. Dmitriev, Mathematical statistics in soil science (LIROKOM Book House, Moscow, 2009).