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ARTICLE

General Physical Properties of Gyptic Irrigated Soils Formed in Various Regions

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Abstract

The article presents the general physical properties of irrigated meadow-swamp soils, meadow–sierozem soils, and typical sierozems widely distributed in the Central Fergana area of the Fergana region, the Mirzaobod district of the Syrdarya region, and the Jomboy district of the Samarkand region. The study also outlines the variations in bulk density and total porosity depending on the degree of soil gypsification, as well as their spatial differences across the regions.

Keywords: irrigated meadow–bog soils; meadow–sierozem soils; typical sierozems; particle density; bulk density; total porosity; degree of gypsification.

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1 Introduction

In the republic, almost all soils suitable for irrigation and possessing relatively high fertility have already been brought under cultivation. In recent years, the lands that have been developed, as well as those that may be developed in the near future, mainly belong to the category of soils that are difficult to reclaim, including low-fertility, saline, gypsiferous, and stony soils. The development and utilization of such soils require a comprehensive and carefully planned approach.

In this context, improving the efficiency of using irrigated gypsiferous lands currently utilized in the country's agriculture is of great importance. This involves determining the degree of soil gypsification by taking into account the forms of gypsum, the depth of gypsum occurrence, and the thickness of gypsum-containing layers in these difficult-to-reclaim lands. Furthermore, enhancing the properties and ameliorative condition of such soils in order to restore, increase, and manage their fertility is considered one of the urgent tasks in modern agricultural practice.

In soil science, the study of the general physical, water, technological, and thermal properties of soils occupies a leading position. Therefore, the main aspects of investigating the physical properties of soils have been explained in the scientific works of prominent scholars of the republic, including M. U. Umarov and R. Qurvantayev [1], as well as S. Abdullayev, L. Tursunov, and R. Qurvantayev [2]. The analysis of these studies shows that the general physical properties of irrigated meadow–gray soils with different degrees of gypsum accumulation, widely distributed in Mirzaobod District, have been insufficiently investigated.

2 Research Object

The research objects were irrigated meadow–marsh, meadow–gray, and typical gray soils formed in different regions and characterized by varying degrees of gypsification.

3 Results and Discussion

The particle density of soil is a relatively stable indicator and depends primarily on the chemical and mineralogical composition of soils as well as their humus content. Changes in this parameter are mainly associated with weathering processes occurring in the soil.

Recent studies have shown that in continuously irrigated soils, the decomposition of primary minerals leads to the formation of secondary heavy (clay) minerals, which results in a gradual increase in soil particle density, although the change may be relatively small. Long-term investigations have demonstrated that the presence and weathering of heavy minerals such as magnetite, limonite, hematite, and similar compounds contribute to the increase in particle density in ancient irrigated meadow alluvial soils [2].

In the northwestern part of the Mirzachol region, the mineralogical composition of the soil-forming parent materials is mainly represented by light mineral particles, including quartz, secondary clay minerals, hydromica, and feldspars. Heavy minerals with a particle density greater than 2.75 g/cm^3 occur only in small amounts.

In the irrigated meadow–gray soils distributed within the G. Yunusov massif of Mirzaobod District, Sirdaryo Region, the particle density ranges from 2.55 to 2.77 g/cm^3 regardless of irrigation periodicity. This range is considered characteristic of the meadow–gray soils widely distributed in the Mirzachol area. It should also be noted that although these soils are similar in terms of granulometric composition, they differ in their mineralogical composition. This difference can be explained as follows: studies of the mineralogical composition of coarse-dispersed particles have shown that in the upper and middle horizons of long-term irrigated soil profiles, heavy minerals with a density greater than 2.9 g/cm^3—such as epidote, garnet, hematite, limonite, and magnetite—tend to accumulate. The presence of these minerals in irrigated soils contributes to an increase in particle density.

Soil bulk density is a highly variable parameter that mainly depends on the degree of compaction of soil aggregates. The upper plough layer generally has a lower bulk density because aggregates in this horizon are loosely arranged. In the lower horizons, the number of aggregates decreases and both aggregates and soil particles become more compactly arranged, which reduces pore space and leads to an increase in bulk density (1.5–1.7 g/cm^3). The upper layers of well-structured soils usually have lower bulk density and can maintain favorable physical conditions throughout the vegetation period [6]. In soils with different degrees of gypsification, however, relatively higher bulk density values are often observed even within the plough layer.

In the soils of Uzbekistan, the limited quantity of aggregates and their low water stability cause bulk density to change significantly during the vegetation period. Irrigation water disrupts soil aggregates and promotes further compaction. Newly irrigated lands gradually become more compact and typically exhibit moderate soil density. Although irrigated soils of different types generally have similar density characteristics, soils formed in desert zones and under hydromorphic conditions are usually more strongly compacted. In general, the bulk density of lower soil horizons is higher than that of the upper layers, and the highest bulk density is typically observed in the layer immediately beneath the plough horizon.

According to the studies of U. Norqulov [3], in the Mirzachol region 6–9 kg/m^3 of salts were leached from non-gypsiferous light gray soils with a medium granulometric composition and a bulk density of 1.43–1.57 g/cm^3. In contrast, only 1.5–2 kg/m^3 of salts were removed from gypsiferous soils of Mirzachol with gypsum horizons and from takyr soils of the Sherobod desert when the soil density ranged between 1.65 and 1.76 g/cm^3. In soils with lower compaction (1.43–1.57 g/cm^3), the drainage flow modulus was 1.3–2.7 times higher than in soils with higher compaction (1.65–1.76 g/cm^3).

According to soil compaction conditions, soils can generally be divided into two types. The first type includes naturally compacted soils characterized by heavy granulometric composition and the presence of carbonate and gypsum horizons. The second type consists of artificially compacted soils formed as a result of anthropogenic activities, such as the use of heavy tractors and agricultural machinery, particularly when soil moisture is high during operations such as ploughing, leveling, cultivation, harrowing, irrigation, and leaching of salts. Naturally compacted soils are widely distributed in the Central Syrdarya region, the Mirzachol area, and in the Jizzakh and Bukhara regions. They are typically heavy-textured soils containing carbonate and gypsum layers, as well as takyr and takyr-like soils of the Karshi and Sherobod deserts. The bulk density of such soils ranges from 1.57 to 1.83 g/cm^3.

Soil bulk density is an important indicator in determining soil fertility, particularly for the normal growth and development of cultivated plants and the formation of crop yield. Soil density (bulk density) is a fundamental physical characteristic that influences soil water, air, and thermal regimes. At the same time, it affects the biological activity of plants and the functioning of soil organisms and fauna.

The bulk density (BD) of the studied soils varied considerably, reflecting the diversity of processes occurring within the soil. These variations depend on several factors, including the content of minerals, organic and organo-mineral substances, soil structure, and most importantly the amount of gypsum, the depth of the gypsum horizon, and the thickness of gypsum layers. The bulk density of the studied soils differed significantly depending on the degree of gypsification and the granulometric composition of the soils.

In the non-gypsiferous irrigated typical gray soils examined in this study, the bulk density ranged from 1.22 to 1.40 g/cm^3, with a slight decrease in the lower horizons (about 1.34 g/cm^3). In meadow–marsh soils, bulk density in the plough and sub-plough layers ranged from 1.25 to 1.52 g/cm^3 and decreased in the lower horizons (approximately 1.28 g/cm^3). In meadow–gray soils, bulk density in the plough and sub-plough layers ranged from 1.42 to 1.50 g/cm^3, while in contrast it slightly increased in the lower horizons (about 1.50 g/cm^3). This pattern can mainly be explained by variations in the granulometric composition of the soils.

In weakly gypsiferous soils, the bulk density in the plough and sub-plough layers ranged from 1.26–1.45, 1.37–1.50, and 1.46–1.58 g/cm^3 in typical gray, meadow–gray, and meadow–marsh soils, respectively. In moderately gypsiferous soils, the corresponding values in the same horizons were 1.30–1.51, 1.51–1.73, and 1.41–1.64 g/cm^3, respectively. It was observed that as the thickness of the gypsiferous horizon increased, the bulk density values also tended to increase. In the plough layer of typical gray soils distributed in the Zarafshan valley, meadow–gray soils of the Mirzachol region, and irrigated meadow–marsh soils of Central Fergana, the optimal soil density was maintained within the range of 1.22–1.42 g/cm^3.

Soil porosity varies depending on the structural condition of the soil, the granulometric composition, and the spatial arrangement of soil particles within the soil profile (e.g., cubic, rhombic, and other configurations). When structural aggregates are arranged in a cubic form, they are loosely packed, and theoretical calculations indicate that the pore space between aggregates accounts for 47.6% of the total system. When aggregates are arranged in a hexagonal configuration, the air-filled pore space decreases to approximately 26%. In general, the greater the number of soil aggregates, the more loosely they are arranged, resulting in higher porosity. Conversely, in structureless soils, granulometric particles are densely packed regardless of their arrangement, leading to a significant decrease in total porosity.

Typically, humus-rich and well-structured soils exhibit the highest porosity. In the upper horizons of such soils, total porosity may reach 60–70%. This high porosity is attributed, firstly, to large pores formed by the burrows of soil fauna and insects as well as cavities left by plant roots, and secondly, to the loose arrangement of soil aggregates of different sizes.

The filling of capillary pores with water and aeration pores with air determines the processes of dissolution, decomposition, and weathering of mineral and organic substances in the soil.

The total soil porosity (TP) depends largely on the granulometric composition and soil density. In soils with a bulk density of 1.4–1.5 g/cm^3, total porosity of 41–43% is considered unsatisfactory. In non-gypsiferous irrigated typical gray, meadow–marsh, and meadow–gray soils (profiles 2–41–37), total porosity varies between 37% and 53% throughout the soil profile. In these soils, porosity values are generally higher in the upper horizons and gradually decrease with depth (Figs. 1, 2, and 3). The relatively high total porosity in the plough layer is mainly associated with soil cultivation practices and the formation of soil aggregates.

In weakly gypsiferous irrigated typical gray, meadow–marsh, and meadow–gray soils, the total porosity ranged from 37% to 55%, whereas in moderately gypsiferous soils this indicator decreased to about 33%. In general, it can be concluded that an

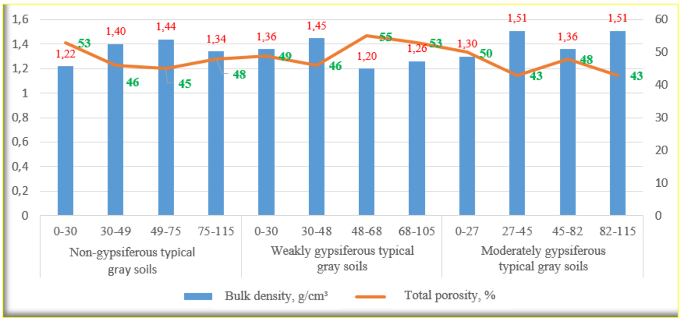

Figure 1. General physical characteristics of automorphic soils

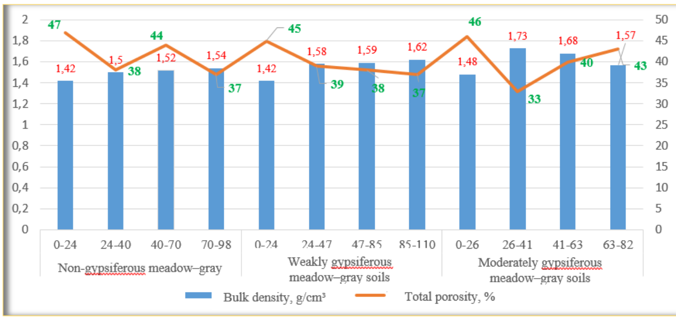

Figure 2. General physical properties of semi-hydromorphic soils

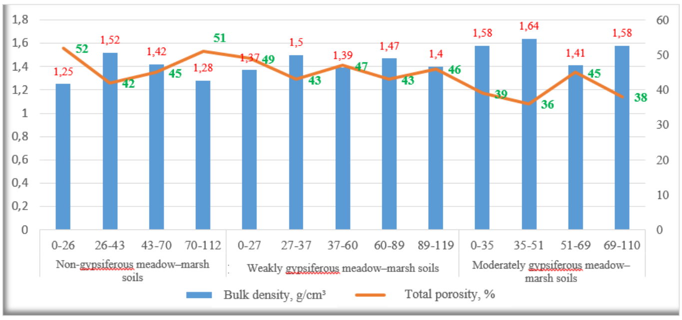

Figure 3. General physical properties of hydromorphic soils

increase in gypsum content in soils, as well as the depth of its occurrence, the thickness of the gypsum layer, and the heavier granulometric composition, lead to a reduction in total porosity. In non-gypsiferous typical gray soils, the total porosity of the plough layer reaches 53%, indicating a high level of soil aeration.

Based on experiments conducted by numerous scientific research institutions, optimal soil density indicators have been determined for the main soil types of the republic. According to the growth, development, and yield performance of cotton, the optimal bulk density for irrigated heavy loamy meadow–gray soils of the region ranges from 1.2 to 1.4 g/cm³, while the unfavorable (critical) density is 1.5–1.6 g/cm³.

According to the findings of R. Qurvantayev [5] and O'. T. Sobitov [8], the compacted layer beneath the plough horizon, commonly known as the plough pan, is formed as a result of irrigation water and, to some extent, the action of agricultural implements that break down soil aggregates and subsequently lead to soil compaction. For this reason, the sub-plough layers of irrigated gypsiferous soils generally exhibit relatively higher bulk density values, ranging from 1.51 to 1.73 g/cm³.

What agrotechnical measures can improve the physical condition of the compacted sub-plough layer? Several agronomic practices are aimed at improving the water–air, water–nutrient, and thermal regimes of the compacted soil horizon. Among them, the most important measures include periodically changing the ploughing depth and loosening the compacted soil layers.

However, this measure alone cannot fully solve the problem, because over several decades the ploughing depth may increase to 50 cm or even more. Such depths cannot be achieved by low-power, lightweight tillage machinery. Instead, powerful and heavy agricultural equipment is required. Even then, if the soil has a heavy mechanical composition, such machinery may still be unable to turn the soil at depths of 50–60 cm. In some cases, to prevent the development of the compacted layer, the ploughing depth should be varied annually or every two years. For example, if ploughing is carried out at a depth of 34 cm in one year, it may be reduced to 30 cm in the following year and to 26 cm after two years. This practice disrupts the formation of a consistently compacted sub-plough layer (plough pan) and slows its development.

One of the most effective methods for eliminating the compacted sub-plough layer is the biological approach, namely the cotton–alfalfa–wheat crop rotation system. This agrotechnical practice not only reduces soil compaction in the upper horizons but also enriches the soil with nutrients, including biologically fixed nitrogen.

4 Conclusion

In irrigated soils with different degrees of gypsification, soil compaction groups ranging from moderate to strong and very strong (1.40–1.73 g/cm³) are observed, regardless of the level of agricultural management practices. In non-gypsiferous irrigated soils, the total porosity of the plough layer ranges from 47% to 52%, with higher values typically found in the upper horizons and decreasing toward the lower layers.

In weakly gypsiferous irrigated soils, total porosity ranges between 37% and 49%, whereas in moderately gypsiferous soils this indicator decreases to about 33%. An increase in the gypsum content of soils, as well as greater depth and thickness of the gypsum horizon, leads to a gradual reduction in total soil porosity.

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