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HUMUS STATUS AND AVAILABILITY OF MOBILE NUTRIENTS (NPK) IN THE SOILS OF SHAHRISABZ CITY

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Abstract: The article assesses the humus status and availability of mobile nitrogen, phosphorus, and potassium in irrigated typical sierozems, meadow-sierozems, meadow, and meadow-saz soils of Shahrissabz City, Kashkadarya Region of the Republic of Uzbekistan. The results revealed significant spatial and vertical differentiation in humus and nutrient contents. Humus content ranged from **0.485 to 3.962%**, N-NO₃ from **4 to 18 mg/kg**, P₂O₅ from **3.12 to 50.28 mg/kg**, and K₂O from **70 to 535 mg/kg**. The present condition of the soils has been shaped by the combined effects of natural pedogenesis, agropedogenesis, urbanopedogenesis, and biopedogenesis. The findings provide a scientific basis for assessing soil fertility and developing sustainable approaches to the management and conservation of urban soils.

Keywords: Kashkadarya Region, Shahrissabz City, MCA (Mahalla Citizens' Assembly), urban soils, humus, nutrients, nitrogen, phosphorus, potassium, soil fertility, agropedogenesis, urbanopedogenesis, biopedogenesis.

Introduction

Urban soils are an important component of modern ecological systems. They not only support plant growth and the sustainability of green spaces but also perform essential functions related to carbon and nutrient cycling, water retention, biodiversity conservation, and regulation of the urban microclimate. In the global approaches of the Food and Agriculture Organization of the United Nations (FAO) for 2025-2026, soil health under conditions of urbanization is considered an important priority. Since nearly two-thirds of the world's population is expected to live in urban areas by 2050, anthropogenic pressure on urban soils is expected to increase. In particular, soil sealing, compaction, contamination, and the loss of fertile peri-urban land as a result of urban expansion are identified as major threats.

FAO considers soil fertility a comprehensive property determined by the availability of essential nutrients to plants and by favorable physical, chemical, and biological soil properties. Nitrogen, phosphorus, and potassium are of particular



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importance as the major macronutrients required for plant growth. The Global Soil Organic Carbon Map (GSOCmap) initiative [3; 4] is aimed at assessing soil organic carbon stocks at the global scale and establishing a unified international database for monitoring soil organic carbon.

Scientific studies conducted during the last decade have shown that the content of organic matter in urban soils does not necessarily change in a uniform direction compared with natural soils. Vodyanitskii (2015) noted that organic matter accumulation in urban environments may be enhanced by vegetation cover, irrigation, maintenance of green spaces, and the input of anthropogenic materials [11].

Subsequent studies have examined in greater detail the effects of urbanization on soil carbon and nutrient cycling. O'Riordan et al. (2021) demonstrated that soil sealing can alter carbon and nutrient stocks in urban soils, while the mechanisms governing nitrogen and phosphorus cycling under such conditions remain insufficiently understood [8].

Salomon et al. (2020) found that nutrient balances in urban agricultural soils may differ substantially among sites, with excessive phosphorus accumulation occurring in some areas [9].

The global study by Guo, Du, et al. (2024) demonstrated that soil organic carbon stocks in urban green spaces vary considerably depending on climate, vegetation cover, and management conditions [5].

Yoon (2022) emphasized that the formation of organic carbon in urban soils is determined by the interaction of plant productivity, organic residue inputs, decomposition, mineralization, and humification processes [12].

A meta-analysis conducted by Malone, Berhe, and Ryals (2023) showed that organic matter amendments can improve organic matter content and soil quality in urban soils. Compost and biochar were found to be effective in increasing soil organic matter stocks, while biosolids contributed to an increase in nutrient availability [7].

Burghardt (2025) demonstrated that the contents of soil organic carbon and nitrogen in urban lawns and green spaces vary depending on land-use intensity, substrate origin, and the history of soil deposition [1].

Thus, recent studies indicate that the humus status and NPK availability of urban soils should be assessed not only in terms of their natural genetic properties but also in relation to irrigation, vegetation cover, management of green spaces, soil texture, and anthropogenic material inputs. From this perspective, investigating the humus status and nutrient availability of the soils of Shahrissabz City represents an important scientific and practical issue.

Research Object and Methods

The research objects were irrigated typical sierozems, meadow-sierozems, meadow, and meadow-saz soils distributed within the territory of Shahrissabz City. Their humus status and availability of mobile forms of N-NO₃, P₂O₅, and K₂O were assessed.

The study was based on field observations, morphological description of soil profiles, laboratory analyses, and comparative-statistical interpretation. Soil sampling and

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profile description were conducted in accordance with standard approaches to soil survey and laboratory analysis [10]. This methodological guide establishes standardized procedures for describing soil profiles in the field, collecting soil samples, and preparing them for laboratory analysis.

The determination of organic carbon and organic matter was based on methodological principles involving the oxidation of soil organic matter, together with modern dry-combustion approaches [2].

The availability of mobile phosphorus was assessed using soil-extraction principles. Olsen, Bray, and Mehlich extraction procedures are widely used methods for determining plant-available phosphorus in soils [6].

The obtained data were used to assess the distribution of humus, N-NO₃, P₂O₅, and K₂O by soil depth, their levels of availability, and the agroecological condition of the soils. The interpretation of pedogenetic processes considered the interaction of natural pedogenesis, agropedogenesis, urbanopedogenesis, and biopedogenesis.

Research Results and Discussion

The results of the investigation of the humus status and availability of mobile nutrients in the soils of Shahrizabz City, Kashkadarya Region of the Republic of Uzbekistan demonstrated considerable differentiation depending on soil genetic type, moisture conditions, texture, duration of irrigation, vegetation cover, and the nature of anthropogenic land use. The obtained data indicate that the vertical distribution of humus, N-NO₃, P₂O₅, and K₂O is closely associated with the combined effects of natural pedogenesis, agropedogenesis, urbanopedogenesis, and biopedogenesis.

1. Irrigated Typical Sierozems

In the irrigated typical sierozems studied within Shahrizabz City, Kashkadarya Region of the Republic of Uzbekistan humus content was **1.061% in the 0–5 cm layer, 0.765% in the 5–25 cm layer, and 0.735% in the 25–100 cm layer**. Thus, a clear decrease in humus content with increasing soil depth was observed. This distribution is associated with the regular input of plant residues, root biomass, and products of microbial activity into the upper soil layer.

The humus content of **0.735–1.061%** indicates low to low-moderate organic matter availability in these soils. At the same time, the N-NO₃ content of **5–8 mg/kg** indicates a very low level of available mineral nitrogen. This result demonstrates that there is no direct proportional relationship between humus content and mineral nitrogen. Although the soil contains a certain reserve of organic nitrogen, its conversion into mineral forms and subsequent retention in the soil are limited.

The P₂O₅ content ranged from **4.25 to 16.17 mg/kg**, while K₂O ranged from **136 to 261 mg/kg**, indicating very low to low availability of phosphorus and low to moderate availability of potassium. Therefore, the major agroecological limiting factors in these soils are the low availability of mineral nitrogen and mobile phosphorus.

This condition can be explained by the predominance of **agropedogenesis**. Long-term irrigation and intensive land use result in continuous removal of nutrients by crops,



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while part of the organic residues undergoes rapid mineralization. Consequently, although the humus content is maintained at a certain level, substantial accumulation of mineral nutrient forms does not occur.

2. Irrigated Meadow-Sierozems

In the irrigated meadow-sierozems, humus content ranged from **0.767 to 2.263%**, indicating stronger organic matter accumulation than in typical sierozems. In the Oq Saroy area, humus content in the 0–5 cm layer reached **2.263%**; in the Buyuk Ipak Yoli area it reached **1.927%** in the 0–9 cm layer; in the Boston area it reached **1.738%** in the 0–30 cm layer; and in the Yangi Hayot area it reached **1.502%**.

The relatively high humus content is associated with meadow-forming processes, development of vegetation cover, and accumulation of root residues in the upper soil layer. At the same time, the decrease in humus content to **0.767–0.899%** in the Kunchiqar area indicates that even within the same genetic soil type, conditions governing the organic matter balance may differ substantially.

The N-NO₃ content ranged from **5 to 14 mg/kg**, corresponding to a very low level of availability in all studied profiles. This indicates that although organic matter accumulation has increased in meadow-sierozems, mineral nitrogen is actively involved in biological cycling. Part of the mineral nitrogen formed is rapidly absorbed by plants, while another part is converted back into organic forms through microbial processes.

The P₂O₅ content ranged from **3.97 to 39.44 mg/kg**, whereas K₂O varied from **85 to 535 mg/kg**, demonstrating strong spatial differentiation in nutrient availability. The P₂O₅ concentration of **39.44 mg/kg** in the Buyuk Ipak Yoli area and the K₂O concentration of **535 mg/kg** in the Kunchiqar area indicate a significant influence of biological and anthropogenic factors on nutrient balances in these locations.

3. Irrigated Meadow Soils

The greatest genetic and spatial variability was observed in the irrigated meadow soils. Humus content in these soils ranged from **0.485 to 3.453%**. The highest values were recorded in the 0–5 cm layer of soils in the Marifat area (**3.453%**) and in the 0–6 cm layer of soils in the Ziyokor area (**3.366%**). These values indicate active accumulation of organic matter in the upper soil layers.

In contrast, humus content decreased to **0.485%** in the 50–100 cm layer of soils in the Tiklanish area and to **0.595%** in the 70–105 cm layer of soils in the Oymovut area. This is associated with reduced input of fresh organic matter and lower biological activity with increasing depth.

In some profiles, deviations from the conventional pattern of decreasing humus content with depth were also observed. For example, in the Namaton area, humus content was **1.125%** at 0–30 cm, **0.923%** at 30–50 cm, and increased to **2.414%** at 50–100 cm. In the Kamolot area, humus content was **1.675%** at 0–27 cm, **1.770%** at 27–65 cm, **1.588%** at 65–96 cm, **0.839%** at 96–145 cm, and **1.581%** at 145–205 cm.

Such irregular distribution may indicate the presence of different genetic horizons, redistribution of organic matter within the soil profile, preservation of traces of former



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vegetation cover, and the influence of irrigation and anthropogenic disturbance. Therefore, the vertical distribution of humus in urban soils should not be evaluated solely according to the classical pattern of decreasing content with depth; urbanopedogenetic conditions should also be taken into account.

The N-NO₃ content in irrigated meadow soils ranged from **4 to 18 mg/kg** and generally corresponded to a very low level of availability. The highest values, **17–18 mg/kg**, were recorded in the upper layers of soils in the Ziyokor and Marifat areas. Thus, even soils with high humus content remain limited in terms of mineral nitrogen accumulation.

P₂O₅ ranged from **3.12 to 38.33 mg/kg**, while K₂O varied from **70 to 520 mg/kg**. In particular, K₂O reached **520 mg/kg** in the Ziyokor area and **511 mg/kg** in the Marifat area, indicating high potassium availability. In Sariosiyo, however, K₂O decreased to **70–86 mg/kg**, corresponding to very low availability.

Therefore, nutrient distribution in meadow soils is determined not only by their genetic type but also by **irrigation, vegetation cover, organic matter inputs, and urban economic activities**.

4. Irrigated Meadow-Saz Soils

The highest values of organic matter and available nutrients were recorded in the irrigated meadow-saz soils. In the soils located along the Shahrizabz City Cadastral Agency Street, humus content in the 0–8 cm layer was **3.962%**, P₂O₅ was **50.28 mg/kg**, and K₂O was **508 mg/kg**. These values indicate high availability of humus, phosphorus, and potassium.

Such high values cannot be explained solely by the natural fertility of the soil. Under urban conditions, plant residues, organic fertilizers, irrigation, landscaping, and other anthropogenic inputs can directly affect the balance of organic matter and nutrients in the soil. Long-term incorporation of organic materials may increase soil organic carbon and available nutrient contents.

In the soils of the Yashil Diyor area, humus content was **2.405%**, P₂O₅ was **6.81 mg/kg**, and K₂O was **165 mg/kg**, which were considerably lower than the values recorded along Cadastral Agency Street. This confirms that even within the same genetic soil type, the effects of urban environmental conditions and land-use regimes may differ considerably.

Relationship Between Humus and NPK

One of the most important findings of the study is that **no complete parallel relationship was observed between humus content and mineral nutrient concentrations**. For example, although humus content exceeded **3.3%** in the soils of the Marifat and Ziyokor areas, N-NO₃ remained only at **17–18 mg/kg**. This can be explained by the fact that a major proportion of soil nitrogen occurs in organic compounds and that mineralization and immobilization processes remain in dynamic equilibrium.

The formation and stabilization of humus can increase the capacity of soils to retain nutrients. Interactions between humic substances and mineral components affect cation



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exchange capacity and the retention of nutrients. However, under conditions of active plant uptake, mineral nitrogen may not accumulate in the soil for long periods and can rapidly enter biological cycling.

The variation in P_2O_5 from **3.12 to 50.28 mg/kg** demonstrates its sensitivity to soil mobility and anthropogenic inputs. The even greater variation in K_2O , from **70 to 535 mg/kg**, indicates that potassium reserves are closely related to soil mineralogical and textural composition, moisture regime, and land-use practices.

Soil Evolution and Urbanopedogenesis

From the perspective of soil evolution, the obtained results demonstrate the interaction of **natural pedogenesis** → **agropedogenesis** → **urbanopedogenesis** → **biopedogenesis** within the soils of Shahrizabz City.

Natural pedogenesis established the genetic foundation of the soils. Subsequently, irrigation and agricultural use intensified **agropedogenesis**, resulting in changes in soil moisture and nutrient regimes. Urban development, regular irrigation, landscaping, incorporation of organic materials, and mechanical disturbance have contributed to the development of **urbanopedogenesis**. At the same time, the activity of plant roots and microorganisms under tree, shrub, and grass cover has intensified, and **biopedogenesis** continues to promote the transformation of organic matter and biological cycling of nutrients.

These processes explain the mosaic character of urban soils compared with natural soils. Urbanization can cause soil compaction, sealing, and changes in organic matter and nutrient stocks, while the incorporation of organic materials may, under certain conditions, increase carbon and nitrogen stocks.

From an overall agroecological perspective, the **main nutritional limitation in the soils of Shahrizabz City is the very low availability of mineral nitrogen**. In contrast, P_2O_5 and K_2O show pronounced spatial differences, with deficiencies occurring in some areas and high accumulation in others.

Therefore, it is scientifically insufficient to classify urban soils as having simply “high” or “low” fertility. Their agro-production and ecological condition should be evaluated comprehensively using **humus + $N-NO_3$ + P_2O_5 + K_2O + soil texture + moisture regime + land-use type**.

Overall, the variation in humus content from **0.485 to 3.962%**, $N-NO_3$ from **4 to 18 mg/kg**, P_2O_5 from **3.12 to 50.28 mg/kg**, and K_2O from **70 to 535 mg/kg** demonstrates the high heterogeneity of the soil cover of Shahrizabz City. These differences result from the combined effects of genetic soil properties, irrigation, vegetation cover, organic matter inputs, and urbanization.

From this perspective, the present condition of the soils of Shahrizabz City can be regarded as a **dynamic soil system shaped jointly by natural-genetic and anthropogenic-biological processes**. In particular, the accumulation of organic matter and the activity of biopedogenetic processes in green spaces are important for maintaining the ecological functions of urban soils. The multifunctionality of urban soils-including carbon



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storage, nutrient cycling, plant support, and regulation of the water regime-should therefore be considered comprehensively in urban soil management.

Conclusions and Recommendations

1. **The humus status of the soils of Shahrissabz City**, Kashkadarya Region of the Republic of Uzbekistan **is considerably differentiated**. Humus content in the studied soils ranged from **0.485 to 3.962%**. The lowest value, **0.485%**, was recorded in the 50–100 cm layer of the Tiklanish area, while the highest value, **3.962%**, was found in the 0–8 cm layer of the soil along Cadastral Agency Street. This variation reflects differences in soil genetic type, moisture regime, vegetation cover, and anthropogenic influence.

2. **Mineral nitrogen reserves represent the principal limiting factor**. N-NO₃ content ranged from **4 to 18 mg/kg**, and very low availability was observed in almost all studied soils. Even in the soils of the Ziyokor and Marifat areas, where humus content reached **3.366–3.453%**, mineral nitrogen did not accumulate at a high level. This is associated with the predominance of organic nitrogen in humus and the rapid uptake of mineral nitrogen by plants.

3. **Strong spatial differentiation was established in the availability of mobile phosphorus and potassium**. P₂O₅ ranged from **3.12 to 50.28 mg/kg**, while K₂O varied from **70 to 535 mg/kg**. The highest P₂O₅ concentration (**50.28 mg/kg**) and a high K₂O concentration (**508 mg/kg**) were recorded in the soils along Cadastral Agency Street, indicating high nutrient availability. In contrast, K₂O decreased to **70–86 mg/kg** in some soils of the Sariosiyo area, indicating very low availability.

4. **The variability of humus and NPK contents demonstrates the combined influence of natural and anthropogenic pedogenetic processes in the soils of Shahrissabz City**. In addition to natural pedogenesis, irrigation-induced agropedogenesis, urbanization-related urbanopedogenesis, and plant–microorganism-mediated biopedogenesis play important roles in the present condition of these soils. In particular, the variation in humus from **0.485 to 3.962%** and K₂O from **70 to 535 mg/kg** scientifically confirms the mosaic character of matter and nutrient cycling in urban soils.

5. In areas with **very low N-NO₃ availability (4–18 mg/kg)**, soil-test-based nitrogen fertilization systems should be introduced, together with the application of organic fertilizers and compost.

6. In soil layers where **humus content is below 1%**, the incorporation of organic materials, use of green manure crops, prevention of excessive soil compaction, and optimization of irrigation rates are recommended. These measures will contribute to restoring humus reserves, improving nitrogen cycling, and increasing the ecological sustainability of urban green-space soils.

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