GENESIS, MORPHOLOGICAL CHARACTERISTICS, AND MORPHOGENETIC FEATURES OF IRRIGATED MEADOW ALLUVIAL SOILS IN THE AMU DARYA DELTA

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ABSTRACT

The article analyzes the genesis, morphological characteristics, and morphogenetic features of irrigated meadow alluvial soils formed in the ancient Amu Darya delta. The study identified clearly differentiated genetic horizons including humus, transitional, illuvial, and parent material layers. The upper horizon is enriched with organic matter and plant roots, whereas the lower horizons are characterized by increased moisture, carbonate and iron accumulations, and groundwater influence. Furthermore, the results show that alluvial, hydromorphic, biological, and anthropogenic processes play a major role in soil formation and profile differentiation. The research confirms the high agricultural potential of these soils and emphasizes the importance of scientifically based irrigation and soil management practices for maintaining fertility and ecological stability.

The irrigated meadow alluvial soils of Amu Darya delta represent one of the most significant soil resources for agricultural production in arid regions of Central Asia. Their formation, morphological differentiation, and morphogenetic development are closely connected with long term hydrological processes, alluvial sedimentation, irrigation practices, and anthropogenic transformation. In recent decades, increasing pressure on irrigated lands, combined with the necessity of maintaining stable agricultural productivity, has intensified scientific interest in the genesis and functional properties of these soils. Consequently, the detailed study of soil morphology and morphogenetic characteristics has become an essential direction in modern soil science because the productivity, ecological stability, and reclamation potential of irrigated territories largely depend on the internal structure and developmental processes of the soil profile.

The investigated irrigated meadow alluvial soils were formed under the influence of layered alluvial deposits accumulated within the deltaic plains of the Amu Darya River. These deposits were transported and redistributed through repeated flooding events and fluvial sedimentation processes over long geological periods. As a result, the soil forming materials consist of alternated sandy, loamy, and light clayey sediments with different mechanical compositions. Moreover, the hydromorphic conditions of the territory significantly contributed to the development of characteristic genetic horizons and to the differentiation of the soil profile. At the same time, prolonged irrigated agriculture accelerated anthropogenic modifications within the upper soil layers, thereby creating a complex interaction between natural pedogenesis and human induced transformation [3].

The morphological analysis of the soil profile demonstrates a clearly differentiated genetic structure extending from the humus enriched upper horizon to the sandy parent material located in the deeper layers. The upper humus horizon, which occupies the depth of 0 to 28 cm, is characterized by a light gray to brownish coloration, moderate moisture conditions, loose structure, and light loamy mechanical composition. Furthermore, this horizon contains a considerable quantity of plant roots and partially decomposed organic residues, indicating intensive biological activity and active humification processes. The crumb and dusty structural aggregates observed in this layer contribute positively to aeration, moisture retention, and root penetration. In addition, the relatively soft consistency of the horizon reflects the influence of regular tillage operations and irrigation practices that continuously disturb and renew the upper soil structure.

The transitional horizon located between 28 and 43 cm reveals significant morphological changes compared with the upper layer. Its darker grayish brown color, increased density, and higher moisture content indicate the gradual weakening of biological activity and the intensification of downward migration processes. Simultaneously, the reduction in root abundance and the appearance of carbonate spots provide evidence of active eluviation and illuviation mechanisms within the soil profile. These processes are especially important in irrigated environments because continuous water movement promotes the redistribution of soluble compounds and fine particles along the profile depth [6, 26-39].

The illuvial horizons situated between 43 and 107 cm display even stronger morphogenetic differentiation. Their yellowish brown and reddish brown coloration, compact structural condition, and increased moisture content demonstrate the progressive accumulation of mineral compounds transported from the upper horizons. Moreover, the occurrence of iron and carbonate concretions confirms the existence of hydromorphic and geochemical transformations associated with fluctuating groundwater levels. The gradual decrease in plant roots within these layers further illustrates the reduction of biological influence with increasing depth. Consequently, these horizons function as zones of material accumulation where clay particles, carbonates, and iron compounds become concentrated due to vertical migration processes.

The lower transitional and parent material horizons extending below 107 cm are distinguished by weak structural development, sandy texture, and excessive moisture conditions. Particularly important is the strong influence of groundwater observed in the deepest parts of the profile. The parent material consists mainly of alluvial sandy deposits lacking stable aggregation and biological activity. Therefore, these horizons preserve the original characteristics of the fluvial sediments from which the soil developed. The close proximity of groundwater also indicates that hydromorphism continues to play a decisive role in the modern functioning of the soil system [1;2].

The morphogenetic features of the investigated soils clearly reflect the combined action of alluvial, hydromorphic, humus accumulative, and anthropogenic processes. First of all, alluvial processes determined the layered nature of the parent material and created substantial heterogeneity in mechanical composition throughout the profile. Secondly, hydromorphic conditions promoted the accumulation of moisture and the formation of iron mottles and carbonate concentrations within the subsoil horizons. Thirdly, humus formation processes transformed the upper horizons into biologically active and agriculturally productive layers enriched with organic matter. Finally, anthropogenic influences associated with irrigation, cultivation, fertilization, and land reclamation significantly altered the physical and chemical properties of the soil, especially within the plow layer.

The humus horizon deserves special scientific attention because it represents the most productive and biologically active part of the soil profile. The darkened coloration, stable aggregate structure, and abundance of roots indicate the accumulation of organic matter and the active participation of microorganisms in decomposition and mineralization processes. Moreover, humus substances improve the water holding capacity, buffering properties, and nutrient retention potential of the soil. As a result, the fertility of irrigated meadow alluvial soils largely depends on the preservation and enrichment of this upper layer. Nevertheless, excessive tillage, irrational irrigation, and unbalanced fertilizer application may gradually reduce humus content and deteriorate soil structure over time [5, 49-52].

Biological activity within the soil profile is concentrated mainly in the humus horizon where microorganisms, fungi, and soil fauna intensively participate in the decomposition of organic residues. In addition, root systems continuously interact with microbial communities, thereby stimulating nutrient cycling and enhancing the formation of mobile nutrient compounds available for plants. Such biological interactions accelerate the transformation of organic substances into stable humic compounds and contribute to the maintenance of soil fertility. However, biological activity decreases sharply in the deeper horizons due to limited aeration, higher density, and reduced organic matter content.

Anthropogenic transformation represents another essential factor affecting the morphogenesis of irrigated meadow alluvial soils. Continuous irrigation changes the natural water regime and intensifies the migration of dissolved salts and carbonates throughout the profile. Simultaneously, regular plowing operations disrupt natural aggregation and modify the structural organization of the upper horizons. Mineral and organic fertilizers also influence the chemical composition of the soil by increasing nutrient availability and altering reaction processes. Although these interventions enhance agricultural productivity, they may also create ecological risks when irrigation norms are violated or when drainage systems function inefficiently. Under such conditions, secondary salinization, waterlogging, and structural degradation may gradually develop [7;8].

The studied soils demonstrate a relatively stable morphogenetic profile despite prolonged agricultural use. This stability can be explained by the balanced interaction between natural alluvial processes and anthropogenic management practices. Nevertheless, the sustainability of these soils depends heavily on scientifically grounded agrotechnological systems. Rational irrigation scheduling, crop rotation, organic matter enrichment, and effective drainage management are necessary to preserve favorable physical and chemical properties. In particular, alternating cotton, cereals, and forage crops helps maintain nutrient balance and prevents the depletion of humus reserves. Likewise, the application of organic fertilizers improves aggregation and supports microbial activity, while properly regulated irrigation prevents excessive groundwater rise and salinization.

Furthermore, the reclamation condition of irrigated lands must be continuously monitored because the hydromorphic nature of these soils makes them highly sensitive to fluctuations in groundwater level and irrigation intensity. Timely agrotechnical measures aimed at reducing compaction and improving water permeability are therefore essential for maintaining long term productivity. Efficient drainage systems also play a critical role because they regulate excess moisture and minimize the accumulation of harmful salts within the root zone.

Overall, the investigated irrigated meadow alluvial soils possess a well differentiated genetic profile formed under the combined influence of alluvial sedimentation, hydromorphic conditions, biological activity, and long term irrigation agriculture. The upper horizons are enriched with humus and characterized by active biological processes, whereas the lower horizons exhibit clear evidence of illuvial accumulation and groundwater influence. The morphological and morphogenetic characteristics identified during the study confirm that these soils belong to a stable hydromorphic alluvial soil type with considerable agricultural potential. At the same time, their sustainable use requires scientifically based management strategies capable of preserving soil fertility, preventing degradation, and ensuring stable crop productivity under irrigated farming conditions.

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