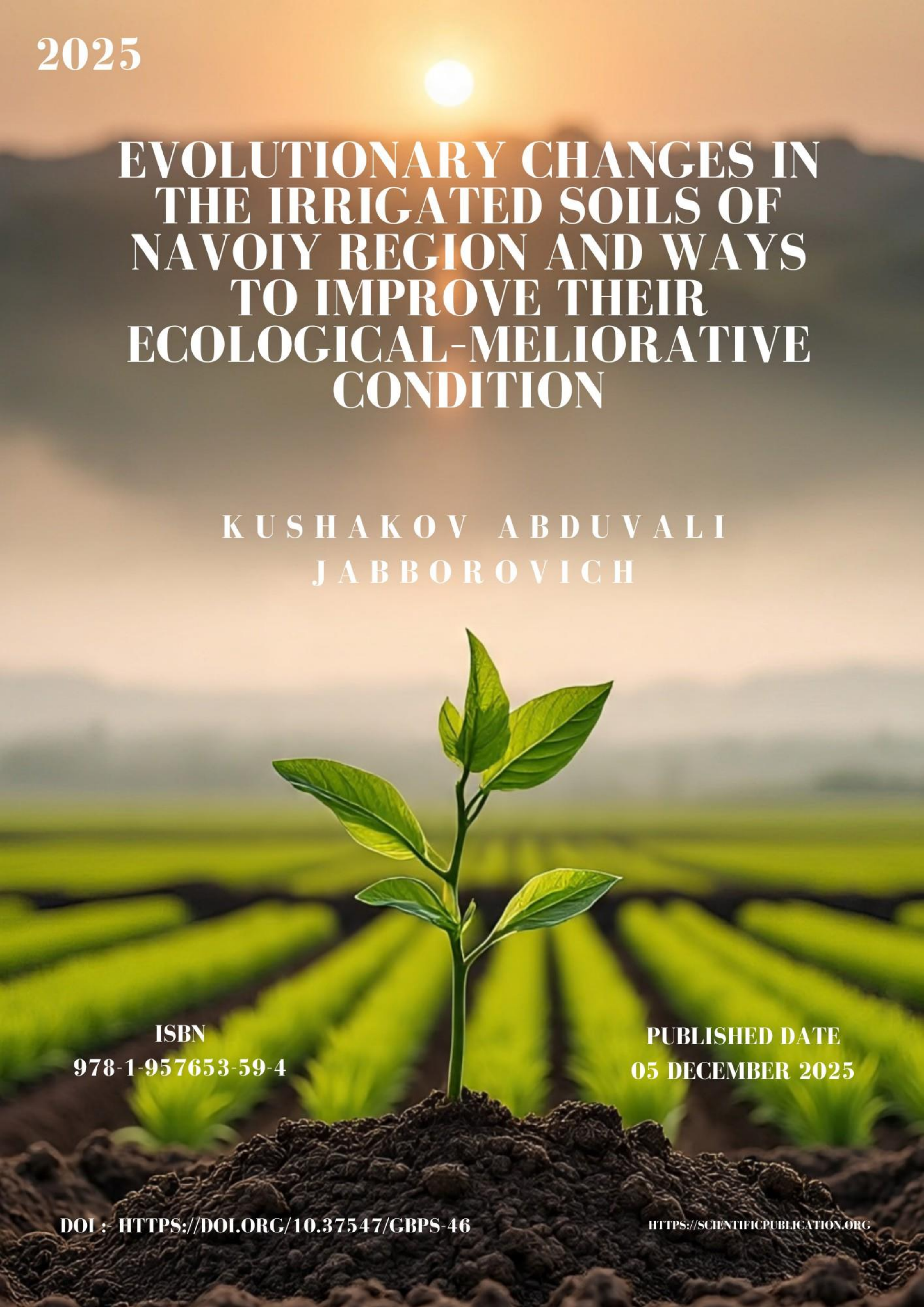

2025

EVOLUTIONARY CHANGES IN THE IRRIGATED SOILS OF NAVOIY REGION AND WAYS TO IMPROVE THEIR ECOLOGICAL-MELIORATIVE CONDITION

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ISBN
978-1-957653-59-4

PUBLISHED DATE
05 DECEMBER 2025

DOI :- HTTPS://DOI.ORG/10.37547/GBPS-46

HTTPS://SCIENTIFICPUBLICATION.ORG

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Kushakov Abduvali Jabborovich

Kushakov A.J. "Evolutionary Changes in the Irrigated Soils of Navoiy Region and Ways to Improve Their Ecological–Meliorative Condition"- **Monograph.**

This monograph presents information on the structure of the soil cover, the genesis, and morphogenetic characteristics of irrigated soils within the territory of Navoiy Region located in the Zarafshan Basin of the Republic of Uzbekistan, as well as on their ecologicaland meliorative status.

The results obtained are of great importance for maintaining the systems of "Land Cadastre" and "Land Monitoring", for improving the ecological and meliorative state of soils, and for enhancing knowledge in the fields of soil science, biology, and agriculture.
This work is intended for researchers, doctoral students, master's students, and a broad readership interested in the field of soil science.

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ISBN: - 978-1-957653-59-4 **DOI: - https://doi.org/10.37547/gbps-46**

PREFACE

At the present stage of our country's development, when agriculture is rapidly adopting advanced technologies, the issue of efficient use of soils is becoming increasingly urgent. Protecting irrigated soils and improving their ecological and meliorative condition through the application of agrotechnical, agromeliorative, and other measures, as well as increasing the efficiency of land resource utilization while preventing any adverse processes that may reduce soil fertility—particularly salinization and its consequences—has become one of the top priorities of today.

Maintaining, enhancing, and protecting the fertility of cultivated lands in the Republic requires comprehensive knowledge, accounting, and forecasting of their meliorative condition, which serve as the key to improving soil productivity. In order to improve the meliorative state of irrigated soils, it is, first and foremost, essential to have a thorough understanding of their genesis, geological, geomorphological, hydrogeological, and ecological characteristics. Studying the interrelation and mutual influence of various soil properties makes it possible to predict the ecological–meliorative transformations that soils may undergo under irrigation. This, in turn, enables determination of irrigation water quality, groundwater level, degree of mineralization, and the amplitude of their fluctuations.

It is also necessary to design and implement collector–drainage networks that are specific to each meliorative area. Furthermore, improving the meliorative condition of soils requires studying the causes of salt accumulation within soil layers, their levels, amounts, and types, as well as their solubility in water, in order to determine optimal rates and timing for leaching operations. It should be emphasized that in the process of removing readily soluble salts from soil layers, the agrophysical properties of soils must always be taken into account.

Despite the implementation of various measures in recent years aimed at improving the ecological and meliorative condition of soils in Navoiy Region, observations have shown an increase in the area of saline soils in certain massifs. The excessive accumulation of harmful salts has been thoroughly analyzed in terms of its impact on soil fertility and the reduction of agricultural crop yields.

This monograph presents comprehensive information on the structure of the region's soil cover, its morphogenetic features, the evolutionary transformations of soils under various anthropogenic influences, and the salinity conditions of irrigated soils across different districts. Moreover, it provides a system of measures and scientific recommendations aimed at studying and improving the ecological–meliorative state of irrigated soils.

INTRODUCTION

At present, in the Republic of Uzbekistan, systematic measures are being implemented across all sectors, including the rational use of land resources, their preservation, the enhancement of soil fertility, and the attainment of higher yields from agricultural crops. In this regard, the country's "Golden Land Fund" — its irrigated soils — requires the development and effective implementation of regionally and individually tailored meliorative measures aimed at improving their ecological and meliorative condition.

According to the results of scientific research and practical activities conducted in the Republic to date, out of a total of 2,418.1 thousand hectares of irrigated land, 1,743.6 thousand hectares (72.1%) are affected by salinization to varying degrees: 930 thousand hectares (38.4%) are slightly saline, 550.5 thousand hectares (22.8%) moderately saline, 149.5 thousand hectares (6.2%) strongly saline, and 113.6 thousand hectares (4.7%) very strongly saline.

Within the Zarafshan Basin, located in Navoiy Region, where irrigated agriculture is well developed (in six administrative districts), of the total 95.8 thousand hectares of irrigated land, 62.4 thousand hectares (63.2%) are affected by salinization of various degrees. Of these, 33.9 thousand hectares (35%) are slightly saline, 20.7 thousand hectares (21.3%) moderately saline, 7.4 thousand hectares (7.7%) strongly saline, and 418.1 hectares (0.5%) very strongly saline.

In the scientific research works of many scholars, the main causes of secondary salinization processes have been attributed to climatic warmth, evaporation of groundwater located in alluvial, agro-irrigational, loess, and loess-like deposits, and the accumulation of easily soluble salts in the upper soil horizons. However, in the foothill plains — in particular, in the Mirzachul, Malik, Orta, Karshi, and Jizzakh deserts, as well as in the Fergana Valley and other regions — secondary salinization processes develop under different geomorphological and lithological conditions, especially in newly reclaimed soils of deluvial, deluvial–proluvial, proluvial, and proluvial–alluvial plains.

Alongside these types of secondary salinization, disturbances in soil ecological conditions are also being observed in the foothill plains of the desert regions of our country, including the soils distributed across Navoiy Region within the Zarafshan Basin. The geomorphological and lithological conditions of this foothill area, where various soil-forming parent rocks such as granite, limestone, sandstone, shale, and others are distributed across the mountain ranges of Zarafshan, Ziyovuddin– Zirabuloq, and Qoratog‘, differ significantly from those of other desert regions of the Republic. Consequently, the genesis, geography, and geochemistry of saline soils and the ecological processes occurring within the oasis differ markedly from those in other areas.

At present, in the foothill plains of Navoiy Region within the Zarafshan Basin, newly formed anthropogenic landscapes are characterized by the accumulation of acidic, neutral, and alkaline salt compounds in the soil composition under the influence of various soil-forming factors. Over the centuries, easily soluble salts present in the irrigated light gray gypsum-bearing, pale gray, takir-meadow, and meadow soils of the oasis have been leached into surface and groundwater or have joined the effluent waters of the Zarafshan River as part of the general geochemical flow.

In the upper and middle horizons of the soil profile, slightly soluble salts such as $CaSO_4$ and $CaSO_4$ tend to accumulate. As a result of land reclamation activities in the oasis, the ecological and meliorative conditions of soils have been undergoing significant transformations under the influence of various anthropogenic factors - including irrigation, leaching, tillage, fertilization, and others. Due to these anthropogenic soil-forming processes, groundwater levels have risen closer to the surface (1–3 meters), and with an increase in groundwater mineralization above 3– 5 g/l, the activation of secondary salinization processes in soils has been observed. This has led to the seasonal accumulation of salts of varying amounts in soil layers, deterioration of physical and chemical properties, worsening of the ecological– meliorative condition, decline in soil fertility, and reduction of crop yields.

The evolutionary transformation, genesis, morphogenetic structure and features, physical and physico-chemical properties, and ecological–meliorative condition of irrigated soils developed under various hydrogeological, geomorphological, and lithological conditions in Navoiy Region remain insufficiently studied. Therefore, it is necessary to conduct research aimed at fundamentally improving the ecological meliorative condition of soils distributed in the foothill plains of the desert zone of our country — including those within the Zarafshan Basin of Navoiy Region to enhance soil fertility, develop rational methods for their use, and study the processes of soil salinization.At present, scientific studies are being carried out in priority areas such as improving soil fertility, maintaining it, and ensuring efficient utilization of soil resources in the oasis.

The Action Strategy for the Development of the Republic of Uzbekistan for 2017– 2021 sets out the following important tasks:

“.. to ensure the sustainable development of agricultural production, to further strengthen the country’s food security, to improve the meliorative condition of irrigated lands, to optimize crop areas by reducing fields under cotton and grain, and to allocate the freed lands for potatoes, vegetables, food and oil crops, as well as for establishing new intensive orchards and vineyards.”

In addition, the Decree of the President of the Republic of Uzbekistan No. PF-5742 of June 17, 2019, “On measures to ensure the efficient use of land and water resources in agriculture”, and the Resolution No. PQ-4575 of February 28, 2020, “On the implementation of tasks defined in the Strategy for the Development of Agriculture of the Republic of Uzbekistan for 2020–2030”, both serve as important policy foundations that this research supports and contributes to in a specific capacity.

CHAPTER I. CURRENT STATE OF RESEARCH ON THE SOILS OF NAVOIY REGION WITHIN THE ZARAFSHAN BASIN

In the course of the radical economic reforms currently being implemented in the agricultural sector of the Republic of Uzbekistan, special attention has been devoted to the principles of proper and efficient use of land resources, particularly irrigated lands. In this regard, alongside the cultivation of planned yields of major crops, it is considered essential to restore and continuously increase the fertility of the country's irrigated soils, to manage them scientifically, to protect them from various adverse processes, and to develop and implement comprehensive measures and new technological systems aimed at their prevention.

Soil performs numerous vital functions and plays a crucial role in human life. First and foremost, it serves as the natural living environment for humankind, and it is within soil that the primary portion of food necessary for human sustenance is produced. In other words, soil acts as the fundamental means of agricultural production. At present, the emergence of various evolutionary changes in the soils of our country, the deterioration of their ecological and meliorative condition, and the widespread occurrence of salinization represent major economic and ecological problems for Uzbekistan.

Based on the results of practical works and scientific research, it has been established that out of a total of 2,418.8 thousand hectares of irrigated land, 1,743.6 thousand hectares (72.1%) are affected by salinization of varying degrees: 930 thousand hectares (38.4%) slightly saline, 550.5 thousand hectares (22.8%) moderately saline,149.5 thousand hectares (6.2%) strongly saline, and 113.6 thousand hectares (4.7%) very strongly saline.

Improving the ecological and meliorative conditions of irrigated saline soils and protecting the environment in the oases and valleys of the country—including those of the Zarafshan Basin within Navoiy Region—constitute some of the most urgent issues in the field of soil science. Therefore, in order to elevate the culture of irrigated agriculture in these areas, one of the principal tasks of soil scientists is to study the transformation of soil properties under the influence of irrigation and to devise effective methods for reversing negative processes such as salinization, waterlogging, and crusting.

Navoiy Region is situated in the lower part of the Zarafshan Basin and occupies irrigated lands located on the deluvial, deluvial–proluvial, proluvial, and proluvial– alluvial plains of the Qoratog‘ mountain range. Due to the development of irrigation and farming activities under diverse soil–geomorphological conditions in these irrigated zones, the evolutionary processes of soil formation and their ecological–meliorative state also vary significantly.

In Uzbekistan and other regions, numerous scientific studies have been devoted to the genesis, evolutionary transformation, and characteristics of various irrigated soils, as well as to improving soil fertility and their ecological–meliorative state. Among the scholars who have contributed to this field are A.Z. Genusov, N.V. Kimberg, B.V. Gorbunov, F.I. Kozlovskiy, E.I. Pankova, G.M. Konobeeva, A.I. Tverdostup, L.B. Pachepskaya, Ya.A. Pachepskiy, A.V. Kim, B.V. Fedorov, S.P. Mikhaylov, I.N. Felitsiant, J.S. Sattarov, A. Maqsudov, L. Tursunov, R.Q. Qo‘ziev,M.M. Toshqo‘ziev, S. Abdullaev, X.H. Tursunov, U.T. Tadjiev, L.A. G‘ofurova, V. Isaqov, G‘. Yuldashev, R. Qurvontoev, Sh.M. Bobomurodov, A.U. Akhmedov, M. Colibas, A.N. Maianu, I. Colibas, M.E. Dregne, Claser Bruno, Guggenberger Georg, Gholam Reza Rahbar, Davar Khalili, S.V. Buol, F.D. Hole, and B.E. Butler.

However, in Navoiy Region, comprehensive studies devoted to the evolutionary transformation and ecological–meliorative improvement of irrigated light gray, dark gray-brown, takir-meadow, and meadow soils, as well as to the forecasting of soil fertility, have not yet been sufficiently conducted.As emphasized by the President of the Republic of Uzbekistan, Sh. M. Mirziyoyev (2019), in his work “A Great Nation’s Intentions Lead to Great Achievements, a Bright Life, and a Prosperous Future,” global climate change poses a growing threat:

“In most regions, soil degradation and the reduction of fertile lands are accelerating. Desertification, water scarcity, and drought have become serious problems affecting the provision of drinking water and quality food for the population. The ecological catastrophe of the Aral Sea region has intensified these threats in our part of the world. Therefore, it is essential to develop a concept of ‘personalized agriculture,’ which takes into account the specific reactions of agricultural crops to environmental factors such as soil, fertilizers, water, and biostimulants, focusing attention on their distinct genotypes.”

Between 1971 and 2022, scientific research conducted in the desert regions of the Republic of Uzbekistan primarily focused on the morphological and genetic structure, characteristics, and genesis of soils; the improvement of soil classification systems; soil bonitation and its practical application; development of agro-grouping and soil zoning; and quantitative evaluation of soil resource areas—all of which have contributed significantly to the advancement of soil science.Such scientific research and investigations have been conducted in all regions of our country. Researchers have analyzed the genesis, evolution, geography, salinization, and ecological–meliorative improvement of soils in different areas in a generalized orm. For instance, N.V. Kimberg [1974] thoroughly studied and classified irrigated light gray, dark brown, sandy desert, and other soils developed in the desert regions of our country including Navoiy, Bukhara, Khorezm, Kashkadarya, Surkhandarya regions, as well as in the Amudarya and Zarafshan river valleys — and supplemented their main diagnostic features and classifications with new genetic and geographical data.

Furthermore, in developing a complete classification of irrigated soils in the desert zone of our country, N.V. Kimberg [1974] considered the following factors:

- latitudinal variation and the structural formation of the Turan Plain in the desert zone;
- the impact of irrigation and groundwater on soil moisture;
- and the sequences of eluvial–hydromorphic, eluvial–automorphic, and eluvial–xeromorphic soils.

The classification of irrigated soils in desert regions developed by N.V. Kimberg [1974] formed the scientific foundation for the creation of the monograph "Soils of Uzbekistan" (1975).

S. Abdullaev [1975], in his research on the irrigated soils of Bukhara region adjacent to the Malikchul area, studied the agrophysical properties and salt regime of the soils and concluded that:

- these soils are poorly supplied with organic matter;
- the agrophysical properties of soils change under the influence of irrigation;
- mineralized groundwater and salts contained in Neogene deposits of the region have contributed to the salinization of the soils in Bukhara and Karakul regions.

As noted above, although the need to deeply study the periodic changes occurring in irrigated soils has long attracted the attention of scientists, research methodologies for their comprehensive study have not been sufficiently developed. Therefore, since 1975, many researchers have focused their work on developing methods for studying irrigated soils.

H.T. Artikova [2019] studied the morphogenetic characteristics and genesis of soil formation in the Bukhara region, identifying the formation and thickness of genetic horizons and the spatial–temporal changes in salinization processes within the soil profile. The interaction and interconnection between natural conditions and anthropogenic factors in the evolution of oasis soils were determined, and the formation conditions of cultural landscapes resulting from human activity were substantiated.

R.A. Turaev [2020] aimed his research at identifying the dynamics of quantitative changes in irrigated land resources of our republic and improving methodologies for land monitoring in agriculture through the application of modern digital technologies. Within this framework, a number of tasks were defined, and extensive analytical work was carried out.

Sh.M. Bobomurodov [2004] studied the development patterns and morphogenetic changes in desert-zone soils of the lower Zarafshan basin (Karakul region) under the influence of irrigation. Depending on the character of parent materials and agricultural land use, he determined regional features of soil formation and divided the oasis territory into 27 soil units. Moreover, he scientifically substantiated the positive effects of unconventional minerals and organo-mineral composts on the properties and fertility of light-textured irrigated desert soils, and developed a technology for producing organo-mineral composts based on a mixture of unconventional minerals, river sediments, and manure.

R.S. Asatov [2020] identified ongoing processes in the soils of the Bukhara region and determined the effects of groundwater depth and mineralization levels on the meliorative condition of irrigated lands. He demonstrated in detail the changes in salinization processes occurring under natural and anthropogenic influences and the mineralization degree of existing collector–drainage waters.

B.Q. Atoev [2018] developed a fertilizer application system for winter wheat varieties on irrigated dark brown meadow soils in the “S. Qulliev” farm of Kiziltepa district, Navoiy region, and on typical gray soils of the Tashkent region. The correlation between the agrochemical properties of soils, fertilizer application rates, and winter wheat yield was established. It was found that differentiated fertilizer application improved the growth and development of winter wheat and increased the accumulation of nutrients.

G.T. Parpiev [2021] revealed that in the northern–eastern (Tashkent region), central (Mirzachul region and Zarafshan valley), and southern (Surkhan–Sherobod valley) regions of the republic, the formation of fertility in gray-oasis, gray-meadow-oasis, and meadow-oasis soils correlates with properties such as humus content, absorbed bases, and bulk density. It was also established that the proportion of toxic salts relative to the total salt content decreases from the gray-oasis soils of the northeastern and central regions toward the gray-meadow-oasis and meadow-oasis soils, while conversely, it increases in the southern region — a phenomenon directly related to the prevalence of poorly soluble sulfate salts.

T.T. Tursunniyazov [2018] found that in newly developed irrigated desert soils of the Surkhan–Sherobod region — such as takyr, takyr–meadow, meadow–takyr, desert–sandy, and meadow soils — improving the content of fine-dispersed and organic matter positively affects the chemical, physicochemical, and hydrophysical properties of local soils.

F.D. Mamadiyorov [2022] studied the cultivation of winter wheat varieties on irrigated light gray soils of Qarshi district, Kashkadarya region. He demonstrated that intercropping alfalfa with winter wheat and incorporating its green mass as a siderate had a positive effect on the agrophysical properties of soils — reducing bulk density, increasing porosity, water permeability, moisture content, and nutrient supply.

I.K. Odilov [2022] scientifically substantiated that the germination rate of sugar beet seeds can reach 94% through the application of mineral fertilizers on irrigated light gray soils of Namangan region.

I.N. Bobobekov [2006] studied the distribution and contamination level of heavy metals in irrigated typical gray soils of the Samarkand region and the influence of the Samarkand Chemical Plant on these processes. Depending on the distance from the plant and the characteristics of the soil, the amount of heavy metals in soils and plants was determined. A contamination map of heavy metals in the soils surrounding the chemical plant was compiled. It was proven that applying organic and mineral fertilizers to heavy metal–contaminated soils improves the soil's nutrient regime and that the reduction in mobile heavy metals is related to their removal through the harvested crop yield.

F.I. Kozlovskiy and E.I. Pankova [1976] investigated the salt regime of light gray soils in the Jizzakh desert and developed a specific method based on mathematical calculations for their classification. They concluded that it is expedient to study soil salinization dynamics together with the salt regime.

S.N. Rijov and M.M. Toshqoʻziyev [1976] found that under conditions of a highly developed farming culture, the amounts of fertility elements in gray soils are significantly increased under irrigation. They also observed sharp changes (notably, a pronounced increase in humus and nutrient content) in takyr soils, concluding that takyr and gray soils differ significantly in this respect.

In the works of O.K. Komilov, M.D. Muratov, and G.G. Reshetov [1976], it was noted that under various hydrogeological conditions of the Mirzachul steppe, the process of automorphic soil formation tends to evolve toward a semi-hydromorphic direction as a result of irrigation under identical agricultural practices.Foreign researchers have also conducted numerous scientific and practical studies on the development of soils under the influence of natural and anthropogenic factors, changes in their properties, and the processes governing soil fertility formation.In particular, Russian scientists L.B. Pachepskaya, Ya.A. Pachepskiy, E.V. Mironenko, and E.G. Morgun [1976] developed a method transformation and development processes of irrigated soils under irrigation. They proposed using electronic computing machines (ECM) to determine direct correlations between indicators such as humus content, hygroscopic moisture, exchangeable Ca^{++}, Mg^{++}, Fe^{++}, available phosphorus, and pH in South Ukrainian chernozem soils, and the environmental factors (arguments) responsible for forming these parameters.

B.V. Gorbunov, G.M. Konobeeva, and A.I. Tverdostup [1976] studied the reclamation of areas covered with dark brown soils in the Kyzylkum region using artesian well water for irrigation. They determined that the implementation of irrigation and the construction of collector-drainage systems are necessary to develop fodder reserves for Karakul sheep breeding. However, they also observed that due to the low permeability of groundwater and its close proximity to the surface, salinization processes were developing in certain areas.

X.N. Qo‘ng‘irov [2009] analyzed the genetic and morphological characteristics of sandy desert, typical, dark gray, and mountain brown soils distributed across the Nurota Mountains and foothill plains. He demonstrated that the shortness of soil profiles, the underdevelopment of the sod horizon, low humus content, disintegrated and compacted aggregates, stoniness, the shallow occurrence of carbonate layers, and light mechanical composition are key distinguishing features formed under specific natural conditions.

I.U. Urazboev [2011] studied the genetic characteristics of soil cover structure (SCS) and the genetic and geochemical relationships of elementary soil areas (ESA) in the foothill and submountain plains of the Tashkent region and along the left bank of the middle Syrdarya. He provided morphometric classifications of elementary soil divisions and explained the morphogenetic and morphometric characteristics of soil structures. His research established that the diversity of soil cover structures is directly related to the complexity of the terrain.

V.V. Valiev and L.N. Tolstova [1978] determined that the nature of weathering in hydromorphic soils varies depending on the mechanical composition of certain horizons. In light-textured soils, silicon (Si) content is higher, whereas in heavy- textured soils, the content of Fe and Al oxides increases. As the soil texture becomes heavier, the $SiO_2 : R_2O_3$ ratio decreases, indicating that lighter soils are more susceptible to weathering processes.

A.U. Akhmedov [1976] analyzed the hydrogeological conditions of the eastern part of the Jizzakh desert and found that although the groundwater levels and degrees of mineralization differ, they vary according to a consistent pattern. The main groundwater flow is directed from south to north — from the foothill plains toward the lowlands. Along this direction, the degree of mineralization changes as well, with the salt content ranging from 0.6 to 70 g/L. The researcher also showed that the quantitative variations of certain ions in groundwater depend on the overall degree of mineralization. A.U. Akhmedov [1976] also determined the level of salinity in soils and groundwater distributed in the eastern part of the Jizzakh desert. He revealed that the formation of saline soils is associated with the depth of groundwater, its mineralization degree, and its type, and that these processes increase in intensity from south to north. Based on these findings, he provided recommendations for improving the meliorative condition of soils through various measures.

T.P. Gluxova and G.A. Koroleva [1976] observed the accumulation of salts such as NaCl, Na_2SO_4, $MgSO_4$, and $CaSO_4$ in the vegetative organs of cotton plants. The authors revealed that the accumulation of sulfur in the form of $Na_2 SO_4$ in cotton leaves decreases in moderately and strongly saline soils. Thus, they concluded that the amount of water-soluble salts in the vegetative organs of cotton increases, which inhibits seed germination.

R. Qo‘ziev [1996] studied the genetic structure of dark brown soils and identified the presence of clay accumulation and ferrugination processes in the dark-colored horizon of these soils, noting that these processes are among the main factors leading to the development of a distinct soil type.

A.E. Ergashev, U.K. Qosimov, and A.G. Jo‘raev [1976] introduced a system for applying organic and mineral fertilizers to newly irrigated dark brown soils of the Malikchul area. They studied the effects of different rates of N, $P_2 O_5$, and manure applications. The highest yield (39.6 centners/ha) was obtained in the treatment where 375 kg/ha of nitrogen, 175 kg/ha of phosphorus, and 20 tons/ha of manure were applied, resulting in an additional 7.0 centners/ha compared with the control.

T.R. Hamroev and M.U. Karimova [1978] established that irrigation processes in the dark brown soils of Malikchul lead to a heavier mechanical composition and leaching of carbonates and gypsum. They also noted that irrigation contributes to the enrichment of soils with humus, nitrogen, and phosphorus, while the reduction of potassium content is directly related to the limited water supply provided to cotton during the vegetation period.

A.Z. Genusov [1981] theoretically and practically demonstrated the genetic and geographical formation of Central Asian soils, particularly the dark brown, takyr, and takyr-like soils developed in the desert regions of the Turan province. He showed changes in the morphological structure of soils and declines in fertility resulting from processes such as humus accumulation, clay formation, and erosion. The research object, Malikchul, according to A.Z. Genusov’s classification, belongs to geomorphological units such as foothill alluvial–proluvial and Zarafshan valley alluvial plains. These geomorphological units occupy vast areas of the Turan province’s plain part and are directly connected with the Karshi desert. Structurally, these units are composed of ancient and modern river terraces of the foothill plains — the lower layers consisting of stones, gravel, sand, and sandy loam, while the upper layers comprise thin strata of loam and clayey soils. Considering these features, newly reclaimed irrigated dark brown soils spread across proluvial–alluvial foothill plains were identified as a separate soil type. According to the author, irrigation radically alters the water and thermal regimes of dark brown soils.

N.X. Mansurov, A.U. Akhmedov, and A.X. Umirzaqov [1989] compiled a salinization map of the soils of the “Paxtakor” farm in Mirzachul, which helps to analyze the processes of saline soil formation in this area. According to the authors, the abundance of strongly saline and gypsiferous soils and solonchaks, and the scarcity of slightly and moderately saline soils, are due to the high mineralization and chemical composition of groundwater inflowing from adjacent areas and to the extremely poor permeability of the farm’s groundwater. These factors must be taken into account when determining various agro–meliorative measures to combat salinization.

R.Q. Qo‘ziev [1994] comprehensively studied and analyzed the ecological condition and fertility of irrigated soils in Uzbekistan’s gray soil region. His research, conducted in the irrigated gray, meadow, bog-meadow, and multilayer soils of the Tashkent and Samarkand regions, analyzed the evolutionary transformations of these soils. According to the scientist, the evolution of irrigated gray soils consists of four stages:

1. migration of salts within the plow layer;
2. alteration of biological processes and accumulation of humus;
3. formation of a new structural plow horizon;
4. increase in the thickness of agro–irrigational deposits.

S.P. Mikhaylov [1994], in his work “Comparative Characteristics of Typical Dark Brown and Highly Gypsiferous Soils (on the Example of Malikchul)”, conducted an extensive study of upper-layer gypsiferous dark brown soils, or bozingen, which are widely used in irrigated agriculture but have been insufficiently investigated in diagnostic and taxonomic respects. Although these soils occur as separate soil varieties within the general background of typical dark brown soils, they do not appear as distinct geographic divisions over large territories. Therefore, bozingen soils differ sharply from typical dark brown soils in both genetic and diagnostic aspects.

This is because, in the main genetic horizon of bozingen soils, the clay-accumulation and ferrugination processes characteristic of typical dark brown soils are undeveloped in the “B” horizon. Hence, S.P. Mikhaylov proposed that soils should be recognized as a separate taxonomic unit — up to the level of a distinct soil type — in the classification of soils of the Republic of Uzbekistan.

A.Kh. Abdullaev [1995] expressed the opinion that, in order to maintain optimal indicators of the salt regime in irrigated soils, it is necessary to study it in direct connection with the water regime. He demonstrated that the development of secondary salinization processes in soils largely results from violations of irrigation technology. Further developing his argument, he stated that in order to prevent salinization processes, chloride ions in the soil and the soil pore solutions must be positioned at the lower boundary of the water layer applied for irrigation.

Research conducted by the State Scientific Research Institute of Soil Science and Agrochemistry on irrigated gray soils and meadow-gray soils of the Tashkent region, as well as on irrigated takyr soils of the Kashkadarya region, revealed that mulching the upper layer (surface) of the soil with white polyethylene film yields high effectiveness under various soil–climatic conditions. The temperature difference between mulched and control variants at a 20 cm depth within a 24-hour period was 6–7°C. The experimental results showed that the development rate of cotton plants on mulched fields was on average 15–20 days earlier, and the yield increased by 8– 10 centners per hectare.

A. Maqsudov, M. Mamajonov, and I. Ibragimov [1995] considered human activity to be one of the main factors influencing the transformation of the properties of irrigated soils in the Fergana Valley. The irrigated desert dark brown and gray soils of the Fergana Valley have developed on different parent materials, and their transformation due to human activity can mainly be distinguished according to the thickness of the agro-irrigational horizon. The authors conducted observations on fields that had been irrigated for more than 20 years, and for 10, 5, and 3 years. According to their studies, by the end of the vegetation period, the concentration of chloride ions in the upper 120 cm layer of irrigated meadow-alluvial soils planted with cotton increased from 0.001 to 0.002 mol/L. Similar changes were also observed at depths of 140–170 cm in irrigated typical gray and meadow-bog soils. The researchers concluded that although the amount of salts entering with irrigation water is small, studying the movement of these salts through soil horizons could help prevent the formation of saline soils.

According to O.U. Akhmedov and Kh.K. Nomozov [1995], at present, 65–70% of the irrigated lands of the Republic are affected by salinization. Their calculations indicate that cotton yields decrease by 20–25% on slightly saline fields, by 40–50% on moderately saline fields, and by up to 80% on strongly saline fields. The “spot- like” salinization occurring on irrigated lands also causes significant damage. In some cases, saline spots on slightly or moderately saline croplands account for 20– 40% of the total area. As a result, cotton yield in these “spotted” areas reaches only7–10 centners per hectare (whereas in non-saline lands, cotton yields range between 25–32 centners). Based on their scientifically grounded data, the authors estimated that due to salinization of soils, the Republic annually produces 500–600 thousand tons less cotton and other food products.In the studies of O.K. Komilov, J.S. Sattorov, and R.Q. Qoʻziev [1996] on soil reclamation and bonitation (evaluation), it was concluded that the specific advantages of various irrigated soil types had not been adequately taken into account.

Therefore, the authors emphasized that if research is conducted while considering the genetic characteristics and properties of soil types, and by employing modern scientific and technical advancements (such as mathematics, electronic computing machines, computer information systems, etc.), then the reforms introduced by the Government of the Republic of Uzbekistan in the fields of taxation and land evaluation could be implemented at the required theoretical and practical level. Sh.M. Akhmedov, T. Abdurakhmonov, and L.T. Tursunov [1996] studied the effective use of dark brown soils for agricultural crop cultivation and the relationship between soil fertility and the irrigation regime. Their experimental research proved that prolonged irrigation leads to an increase in humus and nitrogen content while causing a reduction in gypsum content. The use of organic and mineral fertilizers promotes the accumulation of fine soil particles, phosphorus, and potassium, thereby contributing to the improvement of soil fertility.

In the study conducted by Sh. M. Akhmedov [1999], information is presented on the amount of lead in the gray-brown soils distributed around the city of Navoi, as well as on its effects on the chemical, physico-chemical properties, and biological activity of the soils. According to the map-chart developed based on the research results, the contamination of gray-brown soils with lead, as well as the spatial distribution of lead, were found to be dependent on the geomorphological features of the area, wind speed, and wind direction. It was shown with precise data that within the investigated area, 640 hectares contained a total lead content up to 10 sanitary norms, while in 34.3 hectares it reached up to 20 sanitary norms. Furthermore, it was established that the downward migration of lead along the soil profile depends on the humus and carbonate contents, mechanical composition, and adsorption capacity of the soil. Lead was found to accumulate mainly in the upper soil layer (0–10 cm), with a migration depth of 20–50 cm.

In the gray-brown soils that have long been irrigated, the relatively high content of humus and the heavier mechanical composition were observed to result in a decrease in the influence of lead on the biological activity of the soil.

In the study by R. Qurvantaev [2000], titled “Optimization of the Agrophysical State of Irrigated Soils in the Desert Zone of Uzbekistan,” the issues of determining the optimal limits of plow-layer density and agrophysical properties, as well as increasing the fertility of major irrigated soil types such as meadow-alluvial, takyr-like, and gray-meadow soils, were investigated. According to the author, when the soil density in light loamy and heavy sandy loam soils is 1.2–1.3 g/cm³, and in medium and light sandy soils is 1.3–1.4 g/cm³, the chemical composition of the soil deteriorates and salt accumulation occurs regardless of the mechanical composition, based on the laws governing moisture movement.

X. Ch. Bo‘riev and L. A. G‘ofurova [2000] emphasized the necessity of organizing agrolandscape monitoring to improve the agroecological conditions of irrigated soils in the Republic. For this purpose, the authors noted the importance of continuously monitoring processes such as water balance in soils, groundwater regimes, desertification, drainage of lands, salinization, as well as water and wind erosion.In recent years, studies published by Bukhara State University have provided recommendations for the use of various measures to improve soil fertility in the Zarafshan Delta, including the Malikchul and other regions of the Bukhara province, where meadow-alluvial, gray-brown, sandy-desert, and various degrees of cultivated and saline soils are distributed. These works analyzed the physical and chemical properties and characteristics of the soils, as well as methods to increase their productivity.

In the research conducted by S. A. Abdullaev, C. Zikryaeva, T. Abdurakhmanov, S. Sidiqov, and Z. Abdushukurova [2001], it was noted that the groundwater level beneath the soils surrounding the Aydar-Arnasay water reservoir had risen above the critical depth (~3 m) during the past five years, and that the degree of mineralization had reached 3–5 g/L. As a result, soils that were previously non-saline or weakly saline have transformed into moderately and strongly saline soils, and in some areas have developed into solonchaks.

In the study by R. K. Qo‘ziev and V. E. Sektimenko [2001], it is emphasized that one of the main responsibilities of soil scientists in our country is the organization of land monitoring, which involves observing desertification, erosion, and pollution processes in soils, identifying changes occurring within them, assessing these changes, and determining their future trends.

A. U. Akhmedov [2001, 2003] thoroughly analyzed the urgent problems related to the reclamation of saline soils in our country. According to his findings, by 2001, the area of slightly saline lands in the Republic had increased to 229.3 thousand hectares (6.9%), moderately saline lands to 117.9 thousand hectares (3.6%), and strongly saline lands to 261.0 thousand hectares (7.2%). In total, by 2001, the area of saline lands in Uzbekistan had reached 2,446 thousand hectares (65.9%), of which moderately and strongly saline soils accounted for 1,187 thousand hectares (32.0%).

The author pointed out that the emergence of such an unfavorable situation is associated with the following factors:

1. The insufficiency and poor quality of collector–drainage systems constructed during the 1950–1970s and later, with more than 50% of them having become inoperative;
2. The lack of technical improvement in irrigation and drainage systems, and the long-term uncontrolled use of mineralized drainage waters for irrigation due to water scarcity;
3. The expansion over the past 10–12 years of areas where the mineralization level of groundwater ranges between 3–5 and 5–10 g/L, among other factors.

The author provided a number of recommendations related to the reclamation of saline soils, emphasizing the need to further develop and improve scientific research aimed at creating new methods for maintaining a stable meliorative condition of irrigated lands.

When comparing data from 1989 with recent figures, the fertility of irrigated soils in our Republic has significantly decreased over the past 20 years, during which the area of medium- and low-quality lands increased by 14.0%. One of the main causes of this negative situation is the deterioration of the meliorative condition of irrigated soils. Over the past two decades, the area of saline lands has increased by 850 thousand hectares, reaching a total of 2,446 thousand hectares — which accounts for more than half of the irrigated land area. The accumulation of salts and the intensification of soil salinization are particularly evident in the zones of irrigated light gray, irrigated gray-brown, irrigated takyr-meadow, and irrigated meadow soils. Moreover, the development of gypsiferous soils has led to land subsidence, causing these areas to be rapidly excluded from agricultural use.

As mentioned earlier, currently, in the desert regions of our Republic, lands suitable for irrigation have been developed for the cultivation of cotton, wheat, and other agricultural crops. The reclamation of the Qarshi and Malikchul areas has been carried out using water from newly constructed reservoirs (Talimarjan, To‘dako‘l, and Quyimozor), which requires the efficient use of water resources. The commissioning of the Amu-Bukhara Machine Canal has doubled the capacity for land resource utilization in the Bukhara and Navoi regions, clearly demonstrating this point.

The soils distributed across the deserts of our Republic contain low amounts of humus, ranging only between 0.4–0.8%. Gray-brown and light gray soils occupy a large portion of the desert regions of the country. In the process of reclaiming these soils for irrigation, it is essential to study their composition in detail. When irrigating gray-brown soils, the dissolution of carbonates and l gypsum in their composition eads to subsidence of the upper layer, which disrupts the microrelief and complicates adherence to agrotechnical requirements during crop cultivation. Therefore, it is recommended that the gypsum and saline components in newly reclaimed desert soils be thoroughly leached.

At present, considerable attention is being paid to developing measures for improving the meliorative condition of soils within the territory of the Republic of Uzbekistan, particularly through detailed studies and comprehensive analyses of the properties and characteristics of saline soils that have developed in different regions. Numerous scientists have developed recommendations in this area. According to a review of the literature, the following anthropogenic-evolutionary changes are taking place in the irrigated soil cover of Uzbekistan's provinces (Syrdarya, Jizzakh, Navoi, Bukhara, Kashkadarya, Khorezm, and others) under the influence of irrigation:

- Currently, the ecological and meliorative condition of irrigated soils is experiencing more adverse irrigation impacts compared to 10–20 years ago;
- The increase in the mineralization level of irrigation waters, along with the application of chemical substances (fertilizers, pesticides, herbicides), is intensifying the processes of soil salinization and pollution;
- During the 1960–1980s, large-scale land reclamation projects (Qarshi Desert, Surkhan-Sherabad Desert, Mirzachul, and others) and the monoculture of cotton led to excessive water consumption;
- The overuse of irrigation water, coupled with the rise of groundwater tables (1–3 m) beneath medium, heavy, and clay-textured soils and the reduced permeability of these waters, has resulted in an increase in soil salinization processes in newly developed regions of the country (Mirzachul, Qarshi Desert, Malikchul, and other desert areas);
- In irrigated areas, salinization initially appears in patches and later develops into widespread salinity. In contrast, in areas located near canals and main drainage ditches with adequate groundwater flow, salinization processes are almost absent. In these regions, the humus content increases, the meliorative condition improves, and biochemical activity intensifies;
- At present, one of the most urgent and complex issues in newly developed regions is the study of soil water-salt regimes, the forms of salinization processes, and the periodic changes in their spatial extent, necessitating the strengthening of scientific research in this area;
- In newly reclaimed gray-brown soils, secondary salinization and subsidence processes have been observed. This requires the analysis of the differentiated soil cover (meadow, saline, solonchak, non-gypsiferous, non-saline, etc.) and

their evolutionary changes within the meso- and microrelief forms of newly developed territories;

- According to researchers, the results of such studies, taking into account the properties, characteristics, and specific transformations of various soils developed under different soil-climatic conditions within the country, will assist in developing scientifically based measures grounded in modern scientific and technological advances. These measures will contribute to improving soil fertility and enhancing productivity in farmers' and peasant households.

There are a number of difficulties associated with the reclamation and agricultural use of soils in the Zarafshan Basin. The main challenges include the excessive consumption of irrigation water, the development of secondary salinization processes in the soils, the initial formation of meadow-like processes in microrelief forms, and the consequent decline in crop productivity.

Observations indicate that the assessment of the meliorative condition of soils in the Zarafshan Basin is insufficiently conducted. In the long-irrigated areas, agro- technical and agro-meliorative measures based on traditional irrigation and leaching systems have not yielded the expected results. In particular, the agro-meliorative and agro-technical methods recommended for irrigated light gray, meadow, and takyr- meadow soils developed on multilayered agro-irrigational deposits have shown low effectiveness for the foothill gray-brown soils, which necessitates revising these measures in some cases. To achieve the aforementioned goals, the following tasks should be carried out:

1. To conduct a comprehensive study of the soil formation conditions of various soil types distributed in the Navoiy oasis;
2. To study the morphological and genetic structure, properties, and characteristics of irrigated light gray soils, irrigated gray-brown soils, irrigated meadow soils, and irrigated takyr-meadow soils used in irrigated agriculture within the Zarafshan Basin of Navoiy region, and to identify solutions for improving their ecological and meliorative conditions;
3. To investigate salinization processes in irrigated light gray, gray-brown, meadow, and takyr-meadow soils used in irrigated agriculture within the Zarafshan Basin of Navoiy region, focusing on the influence of meso- and microrelief, parent materials, groundwater depth, and their degree of mineralization on the formation of salinity. On the basis of this research, it is necessary to develop appropriate measures and modern technologies to improve the ecological and meliorative condition of these lands.

1.2. Soil Genesis, Evolution, and Morphogenetic Characteristics

All soil types distributed throughout the territory of our country differ significantly from each other in their genetic formation processes. The genesis, evolution, and morphogenetic characteristics of soils are closely linked to natural conditions. These soils have developed on ancient alluvial-proluvial terraces composed of loess deposits, on foothill proluvial plains, and on gently sloping deluvial-proluvial and loess formations along mountain slopes.

The genesis of the gray-brown soils in the studied area is directly related to the second and third terraces of the Zarafshan River. Over many centuries, human activity—including irrigation, fertilization, and tillage—has modified the natural hydro-physical, chemical, and biological regimes of these soils. As a result of these anthropogenic factors, the gray-brown soils, which originally underwent periodic moistening, have transformed into irrigation-moistened types characterized by horizons subject to constant leaching.

Through irrigation, carbonates, soluble salts (0.5–1.0 g/L), and fine suspended particles accumulate in the fields. Consequently, irrigated soils differ markedly from non-irrigated soils in terms of their biocenotic activity, that is, the activity of their cultivated plant microflora and soil fauna. The combination of moisture, heat, tillage, and fertilization enhances the biological activity of the soils. Therefore, the features, properties, and characteristics of irrigated gray-brown soils differ substantially from those of non-irrigated soils.

These newly developed soil features have evolved primarily under the influence of the agro-irrigational soil formation process, replacing the original humus and subsoil horizons with a thick humus layer referred to as the agro-irrigational horizon. This has profoundly altered soil-forming processes, leading to the emergence of an anthropogenic soil formation process.

In the initial years of irrigation, the humus content tends to decrease. However, over time, it gradually increases, while the composition of humic and fulvic acids changes. As a result, clay migration processes begin within the soil profile, leading to soil compaction, especially in the plow layer, and an increase in total and mobile phosphorus content.

The morphological structure of irrigated gray-brown soils reveals a relatively uniform and weakly differentiated soil profile. Typically, this profile includes a plow (humus) horizon, underlain by a compacted sub-plow layer, and an agro-irrigational horizon of grayish or ashy color. The humus horizon can range in thickness from 25 cm to as much as 1.5 meters or more. The plow layer is generally 25–30 cm thick, while the sub-plow horizon ranges from 10–20 cm, characterized by a darker gray- brown color and higher compaction, distinguishing it from other agro-irrigational horizons.

Due to centuries of irrigation, the agro-irrigational deposits contain numerous anthropogenic inclusions—clay fragments, pottery shards, brick pieces, bone remnants, charred wood fragments, and other materials.Thus, the morphological structure, hydro-physical, chemical, and biological properties of irrigated gray-brown soils differ sharply from those of natural gray soils. With prolonged irrigation and tillage, their fertility, microaggregate composition, porosity, groundwater drainage capacity, and gypsum horizon depth undergo continuous evolutionary transformation.

The meadow soils of the region are considered among the youngest, having developed mainly on alluvial deposits. Their evolutionary development can be represented by the following sequence: newly formed river alluvium → meadow-floodplain alluvial soils → meadow-alluvial soils → takyr-meadow soils. If groundwater flow is reduced, these soils may evolve into solonchaks.In these soils, groundwater typically occurs at depths of 1–3 meters, providing moderate moisture to the soil horizons and supporting a meadow-type vegetation cover on the surface. The decomposition of plant residues under aerobic conditions leads to the formation of a turf horizon in which humus accumulates. Consequently, the humus content in meadow soils is significantly higher than in other automorphic soils. The middle and lower horizons often show the development of gleyed, calcareous, and gypsiferous layers. Salt migration through soil capillaries is intensified, which can lead to the formation of solonchaks.

On floodplain terraces along riverbanks, where fine sediments are abundant and consist of coarse fractions, the mechanical composition of these soils varies considerably. Depending on the content of humus, nitrogen, phosphorus, potassium, and other elements, the developmental sequence of these soils follows: meadow-floodplain alluvial soils → meadow-alluvial soils → takyr-meadow soils.The morphogenetic characteristics of takyr-meadow soils are quite complex and are distinguished by their heavy mechanical composition. These soils are found in the Zarafshan River delta and in lowland areas such as Karmana and Qiziltepa districts. Their main diagnostic features include:

1. the development of crusting processes;
2. extremely large clod formation in cultivated layers;
3. reduced hydro-physical properties;
4. intensification of takyr (surface hardening) processes in the absence of irrigation.

During the formation of takyr-meadow soils, new agro-irrigational horizons of varying thickness develop within the irrigated soils. The formation of these horizons fundamentally alters the morphological structure, physical, chemical, biological, and mineralogical properties of the genetic horizons. For this reason, takyr-meadow soils are classified as a distinct soil type.The thickness of the agro-irrigational layer in takyr-meadow soils ranges from 30 cm to as much as 300 cm. The formation of these horizons depends on human activities and the characteristics of the suspended sediments in irrigation water— such as their color and turbidity—which actively participate in modifying and shaping the structure, features, and key properties of the genetic horizons.

The dominant color of the horizons in these soils is bluish-gray, characteristic of the silty deposits of the Zarafshan River. Due to the uniform deposition of fine particles under irrigation, the use of local fertilizers, tillage practices, uniform agro- meliorative measures, and the long-term stability of the hydrothermal regime, the color, mechanical composition, density, hardness, inclusions, and other chemical properties of the agro-irrigational horizons have become relatively homogeneous. Consequently, these factors have led to the development of a uniform morphogenetic structure typical of takyr-meadow soils.

CHAPTER II. NATURAL CLIMATIC CONDITIONS OF THE ZARAFSHAN BASIN

2.1. Geographical Location of Navoi Region

The Navoi Region is located in the central and northern parts of the Republic of Uzbekistan, occupying a significant portion of the Kyzylkum Desert. It shares a 643 km border with the Republic of Kazakhstan to the north and northeast. The region is bordered by Jizzakh and Samarkand regions to the east and southeast, Kashkadarya Region to the south (along a short stretch), Bukhara Region to the southwest, and the Republic of Karakalpakstan to the west.

On the map, Navoi Region displays a distinctive territorial shape. Its territory predominantly consists of true desert landscapes, characterized by pasture-based livestock farming and mining industries. The total area of the region is 110.9 thousand km², which constitutes approximately one-quarter of the total territory of the Republic of Uzbekistan, making it the largest administrative region in the country. The area of Navoi Region accounts for 24.7% of the territory of Uzbekistan and two-thirds of the Zarafshan economic zone.Because much of the region lies within the desert zone and lacks sufficient local sources of irrigation water, its natural conditions are considered somewhat unfavorable. The Zarafshan River, the region’s primary water source, flows through its southern part, further limiting water availability for agriculture.

Nevertheless, the region’s geographical position also provides favorable conditions for its socio-economic and cultural development. Historically, the Great Silk Road passed through this territory, demonstrating its strategic geographical importance. The large territorial scale of the region and its location at the crossroads of international routes and communications enhance its social, economic, political, and cultural growth potential. The establishment of the Navoi Free Industrial Economic Zone serves as further evidence of these advantages.

As of the most recent data, the total population of the region is 935.3 thousand people. The administrative structure of the region is relatively simple, comprising eight rural districts (Karmana, Konimekh, Navbahor, Nurota, Tomdi, Uchquduq, Xatirchi, and Qiziltepa), six cities (Navoi, Zarafshan, Uchquduq, Qiziltepa, Nurota, and Yangirabod), 47 urban-type settlements, 55 rural citizens’ assemblies, 282 neighborhood citizens’ assemblies, and 575 rural settlements.

2.2. Climate

The irrigated lands of Navoi Region are situated within the foothill plains and desert zones, occupying the eastern part of the Kyzylkum Desert. Due to its great distance—thousands of kilometers—from oceans and open seas, this region is among the driest areas of Uzbekistan.

Climatically, it belongs to the temperate zone, located in a transitional area between desert and subtropical climates. The region's climatic variability is strongly influenced by its geographical position, particularly its location in the foothill zones. Generally, the climate of the Zarafshan Basin is characterized by dry subtropical air masses in summer and cold air intrusions from temperate latitudes in winter, placing it within the Turan soil-climatic province [25].

The average annual air temperature is +14.9°C, while the hottest month, July, has an average monthly temperature of +28.3°C (see Table 2.1.1). In the sandy and gravelly plains surrounding the Zarafshan Basin, summer temperatures can reach 60–70°C on certain days. The coldest month is January, with average temperatures ranging from –0.4°C to –3.2°C.

The annual precipitation ranges from 177.0 mm to 236 mm, with the majority falling during the winter and spring seasons. The summer months are characterized by dry air, high temperatures, and intense evaporation. The annual evaporation rate reaches 2338 mm, which significantly exceeds the amount of precipitation. Consequently, moisture conservation in irrigated lands becomes one of the key practical challenges of irrigated agriculture, particularly since the sum of effective temperatures during the growing season reaches 2000–2530°C.

When comparing the temperature of the upper soil layer to air temperature across the Zarafshan Basin, it is observed that for 10 months of the year, the soil surface temperature exceeds that of the air, with negative values recorded only in November and December. It is during this period that soil freezing processes begin, which usually end by March.

Table 2.1.1. Climatic Indicators of the Zarafshan Basin (According to Data from the Karmana Meteorological Station)

Indicators	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**Annual Average / Total**
Air temperature, °C	0.4	3.2	8.2	15.0	21.7	25.8	28.3	25.9	20.1	13.0	7.1	2.3	**14.9**
Precipitation, mm	28	25	35	30	13	0	0	0	0	4	14	25	**177**
Evaporation, mm	40	54	94	167	278	355	384	346	277	177	114	52	**2338**

Indicators	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual Average / Total
Moisture coefficient	0.7	0.5	0.4	0.2	0.05	0.001	0	0	0	0.02	0.12	0.5	**0.08**
Effective temperatures, °C	–	–	33	191	555	1028	1596	2090	2399	2509	529	–	**2529**

Source: Compiled based on data from the *Karmana Meteorological Station*.

2.2. Temperature and Air–Soil Thermal Fluctuations

The smallest difference between soil surface temperature and air temperature is observed in December (0.2°C), while the largest difference occurs in July (0.7°C). During autumn and winter seasons, the difference between soil surface temperature and air temperature remains relatively small. The diurnal temperature variation of the soil surface reaches up to 20–25°C [130].

According to long-term observation data, the climate of the Zarafshan basin creates favorable conditions for agricultural crop cultivation in the regional soils. However, the negative aspect of the climate is associated with the low annual precipitation and prolonged periods of high temperature, which lead to soil salinization on the surface layer and, in some cases, to the occurrence of waterlogging processes.

2.3. Geological, Geomorphological, and Lithological Structure

The geology, relief, and lithological structure of the described region are quite complex; therefore, the influence of numerous factors on the soil cover is diverse. The current landscape of the Zarafshan basin has been formed as a result of the interaction between internal and external geological forces over long geological periods. Although the oasis area mainly consists of plains, it possesses a complex geological history. This territory lies on the epigersinic (post-Hercynian) platform.

Initially, before the Paleozoic era, this area, like much of Central Asia, was part of an active geosynclinal marine basin. As thick marine sediments accumulated, tectonic activity intensified. During the second half of the Paleozoic era, the powerful Hercynian orogeny drastically altered the previously stable tectonic environment. High mountain ranges belonging to the Tien Shan system rose in the areas adjacent to this region. Through tectonic faults, magma intrusions occurred, accompanied by processes of uplift and subsidence. The accumulation of both marine and continental sediments continued, and volcanic activity became prominent in the mountains (particularly in the Tomditau range). By the end of the Paleozoic and the beginning of the Mesozoic era, these mountains were completely eroded, the entire area was leveled, and a stable platform surface was formed.

The Quaternary period in the Zarafshan basin is of particular significance because nearly 90% of its territory is covered by alluvial, proluvial, and sandy deposits belonging to this period. The thickness of the Quaternary deposits in the upper part of the Zarafshan formations reaches 60–80 meters, gradually decreasing westward.According to the local stratigraphic scheme proposed by G. F. Tetyukhin, the Quaternary deposits and the terraces formed by them are divided into four complexes. During the Lower Quaternary, the conditions of the late Neogene period continued, with the basin predominantly characterized by alluvial plains.

In the Middle Quaternary, the second and third terraces of the Zarafshan (the Qarnab complex) were formed. During the Upper Quaternary, primarily the third terrace of the Zarafshan was developed, including areas adjoining the northern part of the Bukhara region. Sand and loam predominate among the sediments of this period. The final stage of the Quaternary—the Holocene period (the Zarafshan complex)— is represented by deposits that are widely distributed, corresponding to the first and second terraces of the Zarafshan River, as well as ancient dry riverbeds and floodplains.

The territory of the Navoiy region lies in the central part of the Turan lowland and, according to its natural conditions, is divided into three parts. The northwestern part is occupied by the Kyzylkum Desert, which contains closed depressions (Qaraqota, Mo’llali, Mingbuloq), flat sandy plains, and residual mountains (Ovminzatov, Etimtov, Bo’kantov, Tomditov, Qozoqtov, etc.). The southeastern part is occupied by the western sections of the Nurota mountain range, consisting of low and medium-altitude mountains (Qoratov, Oqtov, and others) and intermountain depressions (such as the Nurota depression). The central part of the region, where the Zarafshan River flows, is the irrigated agricultural zone of the province.

Topographically, the Navoiy region slopes from the southeast to the northwest, with elevations decreasing from 300–200 meters to about 100 meters above sea level in that direction. This configuration creates a specific geophysical and environmental situation: the upper (southeastern) part of the region differs markedly from the lower (northwestern) part in terms of climate, soil composition, water resources, and other characteristics. As the elevation decreases relative to sea level, atmospheric circulation, as well as the properties of surface and groundwater, also change accordingly, which in turn influences the properties of the soil.In the Navoiy region, elevations generally range between 250 and 300 meters above sea level, while the highest mountain peaks (in the Oqtov range) reach up to approximately 2065 meters.

The Nurota, Oqtov, and Qoratov ranges connect in the outh and southeast with the Turkistan and Zarafshan mountain systems. These mountains are rich in various mineral resources.The mountains within the oasis are composed mainly of rocks from the Silurian, Devonian, Carboniferous, Cretaceous, Paleogene, and Neogene periods. The region as a whole is rich in different types of mineral deposits. The Nurota, Oqtov, and Qoratov ranges merge southward with the Turkistan and Zarafshan ranges, all of which are known for their abundance of mineral resources. In particular, the smaller residual mountains hold significant economic importance. The region is especially notable for its substantial gold reserves.

Geologically, the oasis is composed of structures formed within the Ziyovuddin– Zirabuloq mountain system, consisting of various anticlinal folds and Quaternary deposits characteristic of the Zarafshan valley. In the lower parts of these folded mountainous structures, gypsum accumulation processes are typically observed in the soil layers.In the northern part of the Ziyovuddin–Zirabuloq mountain range, the Qiziltepa Plateau is located, where a portion of the irrigated soils is found. These soils occupy relatively small areas situated on the present alluvial and alluvial-proluvial terraces of the Zarafshan River (Figure 2.2.1).

Thus, the geomorphological and lithological conditions of the oasis have led to the development of the following relief forms and soil-forming parent materials:

1. In the southern part of the Zarafshan River, various types and subtypes of gray soils (bo‘z soils) are distributed. The areas adjacent to the river and its northern side are characterized by the formation of light gray soils.
2. In the proluvial–alluvial deposits of the Nurota mountain range, particularly in the northwestern part of the river, meadow soils are widespread.
3. In the undulating and gently sloping areas of the Qiziltepa Plateau, developed on deluvial–proluvial, proluvial, and proluvial–alluvial deposits, gypsiferous brown soils and meadow–takir soils are prevalent.
4. The modern Quaternary deposits, consisting of alluvial and alluvial–proluvial sediments, encompass the first, second, third, and fourth terraces of the Zarafshan River floodplain and above-floodplain levels. These deposits play a significant role in the formation of hydromorphic and automorphic soils.

Figure 2.2.1. Schematic Representation of the Geomorphological and Lithological Structure of Navoi Region

1. Steeply sloping deluvial deposits.
2. Foothill inclined areas with deluvial–proluvial deposits.
3. Undulating foothill plains with proluvial deposits.
4. Foothill plains with proluvial–alluvial deposits.
5. River terraces composed of alluvial deposits.

Hydrogeology At present, in the Zarafshan Basin, as the productivity of crops cultivated on newly reclaimed gray-brown soils (sur tusli qo‘ng‘ir tuproqlar) continues to increase annually through the activities of farms and peasant households, the hydrogeological and reclamation conditions of these lands are deteriorating, leading to the emergence of various problems. Among the most significant adverse phenomena observed in newly reclaimed areas are the rise of groundwater levels close to the soil surface (1–3m) and the consequent development of secondary salinization processes due to evaporation. The main causes of such negative processes in the reclaimed lands of Navoi Region are as follows:

1. The unsystematic implementation of irrigation practices on reliefs of various

forms (meso- and microrelief) and on sloping plains;

2. The heterogeneity of soil-forming parent materials (deluvial–proluvial, proluvial, etc.) and the variability of the mechanical composition of the soils developed on them;
3. The susceptibility of irrigated gray-brown, irrigated meadow, and irrigated meadow-takir soils, as well as gypsiferous gray-brown soils, to salinization processes;
4. The insufficient capacity of drainage and collector networks to ensure adequate groundwater flow;
5. The improper implementation of prescribed agrotechnical measures, among other factors.

According to the results of our research, in the studied area, the groundwater table beneath newly reclaimed gray-brown soils lies at a depth of 1.8–2.0 m in January, while in July, it rises significantly, reaching 1.40–1.70 m below the surface. This phenomenon directly contributes to the transformation of soils from automorphic types to semi-hydromorphic and hydromorphic types, while also promoting salinization processes. Therefore, examining the development patterns and laws governing these processes—including groundwater depth, degree of mineralization, spatial variability, and impact on soils—forms a central component of this research. The hydrogeological conditions of the Zarafshan Basin and their influence on soil formation processes will be analyzed in depth in the following sections of this dissertation.

It should be emphasized that the irrigated soils of the Zarafshan Basin and the soil substrata of the region can be divided into the following areas based on their lithological structure and groundwater conditions:

1. The northwestern foothill undulating uplands of Qoratog‘. In these areas, the eluvial, deluvial, and deluvial–proluvial deposits contain groundwater at depths of 10–20 m or more, which do not affect modern soil formation processes.
2. The broad, undulating, and leveled foothill slopes. Here, the groundwater table in deluvial–proluvial and proluvial deposits occurs at depths of 5–10 m, while in reclaimed lands and foothill plains, it is

found at 2–4 m, and in low-lying areas, at 1–2 m. Due to poor groundwater drainage, irrigated light gray soils, irrigated gray-brown soils, irrigated meadow soils, and irrigated meadow-takir soils exhibit a progressive development of salinization.

3. The second, third, and fourth terraces of the Zarafshan River. These terraces are mainly composed of proluvial–alluvial, alluvial, and agro-irrigational deposits consisting of gravel, sand, sandy loam, and clay layers. Groundwater levels in these areas are at depths of 1–3 m, and under their influence, semi-hydromorphic and hydromorphic soils with varying degrees of salinization are forming.

In summary, the sources of groundwater recharge beneath the irrigated light gray soils, irrigated gray-brown soils, irrigated meadow soils, and irrigated meadow-takir soils of Navoi Region are primarily derived from subsurface flows from mountain slopes, atmospheric precipitation, as well as infiltration from the Zarafshan River and irrigation waters. Among these, irrigation water plays the dominant role, as it directly contributes to the rise of the groundwater table, soil formation processes, and the intensification of salinization.

2.4. Soils

The Navoi Region is located within the bio-climatic desert and semi-desert zones, where, under diverse geomorphological and climatic conditions, a wide genetic series of soils has developed. Within the system of elevated regions, brown, dark gray, typical, and light gray soils and their semi-hydromorphic varieties are distinguished. In the desert region, sandy-desert, gray-brown, and takir soils and their semi-hydromorphic types have formed. Meadow soils have developed both in the gray-soil region and in the desert zones.

In irrigated agriculture, the main cultivated areas are characterized by typical and light gray soils, gray-brown soils, takir-meadow soils, and meadow soils. Crops are grown under rainfed conditions mainly on dark gray, typical, and light gray soils.

The irrigated light gray soils are distributed on foothill sloping plains adjoining the cone-shaped alluvial fans of small streams. The parent materials of these soils consist of loess-like sandy loams. These soils belong predominantly to the category of anciently irrigated soils. The humus horizon reaches a depth of 0.5–0.7 meters, corresponding to the depth of the agro-irrigation layer. The ecological and meliorative condition of these soils is relatively poor, and they are slightly affected by salinization processes.The irrigated gray-brown soils have developed on proluvial–deluvial deposits along the sloping foothills. These soils are classified as low-humus soils. Among them, both non-saline and slightly saline variants are common.

The irrigated takir–meadow soils occur on ancient alluvial–proluvial plains and on elevated relief forms of the second above-floodplain terrace of the Zarafshan River, where the groundwater table does not rise above 2–2.5 meters. The plow layer contains 0.6–1.3% humus and 0.04–0.08% nitrogen, gradually decreasing with depth. These soils exhibit low to moderate degrees of salinization.

The irrigated meadow soils are distributed within the light gray soil region and the desert zone. In the lower terraces of rivers, meadow soils have formed under natural alluvial hydrological regimes, where groundwater lies close to the surface. Due to this, irrigated meadow soils are often saline, while the anciently irrigated soils are non-saline (leached), with some areas showing slight salinity.

2.5. Vegetation

The vegetation of the Zarafshan Basin changes systematically from the Qiziltepa Plateau in the south toward the northwestern foothills of the Turkestan mountain range, across deluvial, proluvial–alluvial, and proluvial plains, and the floodplain and above-floodplain terraces of the Zarafshan River. This zonation follows clear natural regularities. The sequential alternation of vegetation types is largely influenced by geomorphological, lithological, and soil-forming parent material factors, as well as by human activities.

In the foothill slopes of the studied area, where ecological conditions are particularly harsh, plant species belonging to gypsophytic and halophytic groups are predominant. These plants develop on weakly developed gray-brown, meadow, desert-meadow, and gypsiferous meadow soils.

In the gently sloping and undulating plains and newly reclaimed lands of the Zarafshan Basin, widespread weeds include Bermuda grass (Cynodon dactylon), Chenopodium album, Amaranthus retroflexus, Setaria viridis, Medicago minima, Solanum nigrum, Convolvulus arvensis, Tribulus terrestris, Xanthium strumarium, Cirsium spp., Erigeron spp., and others. In strongly saline soils (solonchaks), vegetation is almost absent, whereas in slightly to moderately saline soils surrounding them, halophytic plants occur.

In these areas, one can observe annual saltworts (Salsola spp.), red saltbush (Atriplex tatarica), semi-shrubs such as Halocnemum strobilaceum, Halostachys belangeriana, and other species belonging to the Chenopodiaceae family. Dense turf formations develop in meadow areas.

Between the reclaimed lands of the Zarafshan Basin and the higher terraces of the Zarafshan River, sandy and loamy dunes are covered with plants such as Haloxylon ammodendron (black saxaul), Calligonum spp. (sandy shrubs), Salsola arbuscula, Ephedra spp., and Artemisia spp. (wormwood).

Of particular ecological significance are the riparian (tugai) forests found on the first and second terraces of the Zarafshan River. These forests are composed of trees, shrubs, and grasses, including Tamarix spp., Populus spp. (willow), and Elaeagnus spp. (oleaster), with perennial climbing plants such as Clematis orientalis often entwining their trunks and branches.

In the shrub layer of the tugai forests, Tamarix hispida, Lycium ruthenicum (black thorn), and Halostachys belangeriana are common. In saline depressions, the large saltbush (Atriplex cana) is found. The grass vegetation on the lower terraces of the Zarafshan River varies depending on distance from the river, soil texture, and other environmental factors. In the lower parts of floodplains, where groundwater lies close to the surface, reeds (Phragmites australis) are widespread. On riverbanks periodically flooded by snowmelt and rainfall, species such as Typha spp. (bulrush), Glycyrrhiza glabra (licorice), and Cannabis ruderalis (wild hemp) grow.

At present, a part of the tugai forests has been converted into agricultural land, where cotton, wheat, maize, and other crops are cultivated. However, due to improper irrigation management and inadequate soil cultivation practices, salinization processes in the soils of the irrigated areas of the Zarafshan Basin are intensifying, leading to decreased crop productivity.

Along collector and drainage channels, plant species such as Alhagi maurorum (camelthorn), Salsola spp. (saltwort), and Phragmites australis (reed) are also found. Among trees, mulberry (Morus alba), turan oleaster (Elaeagnus angustifolia), and willow (Salix spp.) occur. Along irrigation ditches and canals, Cynodon dactylon, Phragmites, Alhagi, Convolvulus arvensis, and Chenopodium album are widespread. Many of these weeds are also common in cotton fields, wheat fields, vineyards, and orchards.

In the newly reclaimed agricultural lands of the Zarafshan Basin, cultivated plants include cotton, wheat, alfalfa, maize, and others.

Thus, all soil-forming factors in the studied area—including the diversity of vegetation types—directly influence the development of various soil varieties across the region.

2.6. Human Activity

The soil-forming factors described above — climate, geomorphology, lithology, hydrogeology, vegetation, and others — were first systematically studied by V.V. Dokuchaev, who explained the interrelationships among soil horizons and their dependence on natural environmental conditions, thereby providing a scientific basis for understanding the development and transformation of various soil types.

Extensive research has demonstrated that irrigated soils used in agricultural production differ markedly from soils formed under natural conditions. According to many researchers, soil formation under human influence, especially in irrigated and reclaimed lands, is characterized by several distinct features:

- Changes in the morphological structure of the humus and transitional horizons;
- Formation of multi-layered agro-irrigation horizons;
- Variations in bulk density and specific mass, along with an increase in the mechanical density of the soil;
- Enrichment of the soil with humus, nitrogen, and cation exchange complexes;
- Upward migration of Al_2O_3 and Fe_2O_3 from the lower to the middle and upper horizons;
- Accumulation of layered silicate structures such as mica, hydromica, and hydromica–montmorillonite in the illuvial (B) horizon;
- Rising groundwater tables beneath irrigated soils, leading to the development of secondary salinization and gleying processes.

In the Zarafshan Basin, particularly within the Navoi Region, human activity is also one of the dominant soil-forming factors influencing the evolution of the soil cover. In the studied areas, irrigation waters supplied from the Zarafshan River and the Kuyimozor Reservoir through the Navoi Canal carry suspended sediments, mineral and organic substances, and plant residues, which, upon mixing with soil aggregates, contribute to the formation of cultivated agro-irrigation horizons within the soil profile.

Due to the unique geomorphological and lithological structure of the Navoi Region, the thickness of the agro-irrigation layers varies depending on the slope of irrigated lands and the degree of anthropogenic impact. Consequently, the processes and regularities of anthropogenic soil formation differ across the landscape.

In the upper parts of the study area, i.e., on deluvial–proluvial sloping plains, the agro-irrigation horizon reaches a thickness of 20–30 cm; on proluvial slopes, it ranges between 25–40 cm; and on proluvial–alluvial plains, it attains 40–50 cm.

However, improper adherence to agrotechnical practices during irrigation not only affects the formation of agro-irrigation horizons but also leads to the rise of groundwater levels close to the soil surface. The intensive evaporation of this groundwater accelerates the salinization processes in irrigated soils.

Thus, under the influence of human activity, the soils of the Navoi Region exhibit both positive and negative transformations. On the one hand, beneficial changes such as the formation of agro-irrigation horizons and the enrichment of soils with nutrients are observed. On the other hand, adverse processes including salinization, gleying, migration of elements, and soil compaction are developing simultaneously.The specific thermal regime of the Navoi Region, combined with the establishment of artificial irrigation, creates favorable conditions for cultivating subtropical crops such as cotton, grapes, pomegranates, and others.

Chapter III. Structure of the Main Soil Cover, Morphology, and Morphogenetic Characteristics of the Soils of Navoi Region

3.1. Soil Cover and Its Structure

The Navoi Region is bordered by the Republic of Kazakhstan and partially by the Jizzakh Region to the north and northeast, by the Samarkand Region to the southeast, by the Republic of Karakalpakstan and the Bukhara Region to the west, and by the Kashkadarya Region to the south. The region is characterized by limited irrigation water resources, vast sandy massifs, and extensive saline and waterlogged lands. Despite these challenges, the Navoi Region occupies an important position within the Republic, possessing vast tracts of land, expansive dry areas, and favorable climatic conditions. With sufficient irrigation water supply, these lands have the potential to significantly enhance cotton and grain production.

The lands currently being reclaimed for cotton cultivation are located within the reserve land fund of the region and are presently used mainly as low-productive pastures. The introduction of irrigation to these pasture areas not only expands the area of irrigated lands but also increases the productivity and comparative potential of livestock farming, particularly Karakul sheep breeding.

The earliest data on the soil cover of this region were provided by L.L. Nozhin between 1912 and 1915, who gave an initial description of the Zarafshan Valley soils and their properties. Around the same period (1913–1914), under the supervision of N.A. Dimo (1915), the Land Reclamation Department carried out route-based soil surveys in the valley, providing insights into the composition, distribution, and agricultural use of the soils.

A more comprehensive understanding of the soil cover of the lower Zarafshan Valley was achieved through the research conducted by M.A. Orlov in 1925, who compiled detailed soil maps and numerous analyses characterizing the chemical and physical properties of the soils. To provide a unified interpretation of soil genesis, he conducted an extensive description of the structure of the regional soil cover. Although Orlov's soil essays were never published, the materials were later incorporated into various publications (Orlov, 1933, 1934, 1937).

After these works, no major investigations were conducted in the irrigated part of Navoi Region until 1952. In 1952–1953, the Soil-Meliorative Research Sector of UzGIPROVODKHOZ undertook a new study of the entire territory, preparing an updated soil map and an explanatory note.Since these studies were conducted long ago, the current state of the soil cover differs considerably, making it essential to study the transformations of soils under irrigation as one of today's most important scientific tasks.

In 1954 and 1963, N.V. Kimberg prepared and published, through the Institute of Soil Science, the U-41 and K-41 state soil maps along with explanatory notes that included a general geographical description of the soils and an analysis of the laws governing the development of irrigated soil covers in the region.Further studies by I.N. Felitsiant (1983–1984) provided a comprehensive characterization of the physical-chemical properties, formation processes, hydrogeology, morphogenetic features, and fertility improvement measures for the soils of Navoi Region.

In 1983, T. Abdurakhmanov devoted his research to examining the influence of human activity on soil formation. He studied the genesis, morphology, formation, and evolution of gray-brown soils, and conducted comparative analyses with light gray and meadow-alluvial desert soils of adjacent regions.The climate of Navoi Region is characterized by high annual and diurnal temperature amplitudes, hot and arid summers, cold winters, low cloudiness and humidity during summer, low annual precipitation, and specific wind regimes. These factors -particularly the low relative humidity and frequent winds - intensify evaporation from soil and groundwater, thereby contributing to soil salinization.

During winter, low temperatures cause freezing of the upper soil layer, which worsens its water-physical properties and complicates tillage and leaching operations. In the lower Zarafshan Valley, the average annual air temperature ranges between 14.2–15.1°C, the hottest month (July) reaches 28.3–29.6°C, and the coldest month (January) ranges between –0.4°C and –1.5°C. During the vegetation period, the average monthly temperature is 22.8–24.4°C.

The average annual precipitation in the Navoi Oasis is 177–236 mm, indicating a transition from desert to semi-desert climatic conditions. In the Navoi–Konimekh Oasis, the average relative humidity constitutes 55–56%, fluctuating seasonally between 31–78%. The high air temperature and low humidity contribute to intense evaporation, with annual evaporation from open water surfaces amounting to 1752– 2077 mm, of which 1462–1658 mm occur during the vegetation period. Thus, moisture conservation in soils during this period becomes essential.

The frost-free period lasts 212–214 days on average. The first frost usually occurs between March 26–31, occasionally in early April, and the last frost between October 22–25. Heavy spring rains can temporarily lower the air temperature and cause soil crusting, requiring re-sowing of crops. The snow cover is unstable, with an average thickness of 3–10 cm, sometimes reaching 25–30 cm. The average annual relative humidity is 50–55%, rising to 75–80% in winter and dropping to 25–30% in summer. During this period, irrigation compensates for the lack of natural moisture.

The studied areas are located at 400–500 meters above sea level and above river terraces, while foothill regions reach 500–850 meters in elevation. The combination of a long frost-free period and high temperatures allows for the cultivation of medium- and late-maturing cotton varieties, but only under artificial irrigation. Rainfall in the Navoi–Konimekh Oasis is sufficient only to partially support rain- fed crops.

High evaporation rates of mineralized groundwater near the soil surface contribute to the formation of a negative salt balance, leading to soil salinization. The irrigated soils of Navoi Region are located in the middle and lower reaches of the Zarafshan River and are divided into three geomorphological units, which historically shared a common water source — the Zarafshan River. These include the Navoi– Konimekh, Bukhara, and Karakul oases, forming a unified lithological–geomorphological system.

The Navoi–Konimekh Oasis is bounded by the Zarafshan River to the south and by the branches of the Turkestan mountain ranges to the north, occupying the southwestern margin of the Zarafshan Basin. It is bordered by proluvial–deluvial foothill plains to the north and by the Avtobachi and Kyzyltepa plateaus with undulating proluvial–deluvial ridges to the south.Within the oasis, the surface formed by proluvial–deluvial deposits and Tertiary plateaus represents the erosional base of at least two ancient Zarafshan River terraces in addition to the modern floodplain. The first terrace lies 1–1.5 m above the current river level and consists of a flat relief dissected by ancient river channels. The second terrace, extending along both riverbanks, is elevated by 4–4.5 m in the east and 2–2.5 m in the west. Its surface is mainly flat, with minor depressions and interfluves.Another terrace, the Qushchi Terrace, occurs within the Navoi–Konimekh Oasis but covers a limited area and is therefore of minor significance. It is formed by smooth surfaces shaped by ancient proluvial–deluvial water flows.

The deposits of the Navoi–Konimekh Oasis can be divided into three genetic types: marine sediments of the Tertiary period, ancient alluvial fan deposits, and modern river sediments. From a geological–lithological perspective, the oasis includes sands, gravels, conglomerates, gypsum-bearing Neogene deposits (Malikchul Formation), and loess-like sandy loams. The right and left banks of the Zarafshan River are covered by Quaternary agro-irrigation deposits of varying salinity levels.

The Navoi–Konimekh Oasis is separated from the Bukhara Oasis by the Hazora Depression, filled with Tertiary deposits of the Avtobachi and Kyzyltepa plateaus. The oasis extends 80 km in length and up to 50 km in width, bounded by the Hazora Depression (east), the Jangara Gorge (southwest), the Kyzylkum and Avtobachi plateaus (north), and the Quyimozor, Kyziltepa, and Devkhona plateaus (south and southwest).

In addition to the modern floodplains intersected by the current Zarafshan flow, two ancient river terraces can also be distinguished. According to Yu.P. Lebedev (1954), the formation of mesorelief structures in the region is linked to continuous sediment accumulation by fluvial processes. The formation of agro-irrigation layers is directly influenced by the mechanical composition of sediments, which vary from sandy to clayey, though the majority of the region is characterized by medium to heavy soils.

Based on the lithological and geomorphological characteristics of the irrigated zone, the Navoi Region can be divided into two sections:

1. Section I: Soils formed on proluvial–deluvial slopes of the Navoi Oasis, consisting of loess-like deposits with gravelly layers that are sometimes superimposed upon one another.
2. Section II: The Navoi Oasis area located in the middle reaches of the Zarafshan River, including:
   a) First-order terraces of internal alluvial fans covered with thin layers of sand and sandy loam, composed of coarse sand and gravel;
   b) Second-order terraces consisting of sandy loams up to 5 meters thick, alluvial sands, and alluvial–agro-irrigation layers of varying thickness.

The complex morphogenetic conditions, hydrogeological features, and economic activities of the Navoi Region have determined the development of numerous soil formations. Based on the physical–geographical characteristics of the territory, these formations can be grouped into three soil-geographical zones, each containing several subdivisions.

1. The Region of Virgin and Irrigated Light Gray Soils Developed on the Proluvial–Deluvial Fine Deposits of the Foothill Slopes of the Turkestan Mountain Ranges

2. The Region of Virgin and Irrigated Dark Brown Soils Formed on the Proluvial–Deluvial Fine and Gravel–Sandy Deposits of the Mountain Slopes of the Turkestan and Zarafshan Ranges

3. The Region of Virgin and Irrigated Takyr–Meadow, Meadow, Meadow–Marsh, and Marsh Soils Formed in the Lowlands of the Western Part of the Zarafshan Mountain System

This region, in turn, is divided into two sections (A and B):

A) Alluvial soils of the second and third floodplain terraces of the Zarafshan River, covered with gravel and sand at a depth of 0.5–5 meters.
B) Alluvial soils of the first floodplain terraces of the Zarafshan River, underlain by sand, clay, gravel, and sandy deposits at depths of 1–0.5 meters.

Description of the Main Soils in the Irrigated Areas

Navoi region is located within the bio–climatic desert and semi–desert zones. It also has a complex geomorphological structure that includes fan deposits, Tertiary plateaus and residual uplands, middle–altitude and low mountains adjoining terraces of various ages, as well as foothill plains and gently sloping piedmont areas. Due to this geomorphological and climatic diversity, a wide genetic sequence of soils has developed across the region.

In the mountainous areas, brown, dark gray, typical gray, and light gray soils, together with their semi–hydromorphic variants, have been identified. In the desert zone, sandy–desert, gray–brown, and takyr soils, as well as their semi– hydromorphic varieties, have developed. In both the gray–soil and desert zones, meadow soils are also present.

Under irrigated agriculture, typical and light gray soils, gray–meadow, dark brown, dark brown–meadow, desert–meadow, takyr–meadow, and meadow soils are used. Rainfed crops, on the other hand, are mainly cultivated on dark gray, typical gray, and light gray soils.

Irrigated Typical Gray Soils

Irrigated typical gray soils are developed on proluvial, deluvial, and partly loessal deposits located in the leveled lower sections of undulating foothill areas. In terms of mechanical composition, these soils are medium loamy, occasionally weakly skeletal, and in some locations contain gravel deposits at depths of 0.5–1 meter.

The humus layer is not thick; humus ranges from 0.9 to 1.5%, and nitrogen from 0.04 to 0.12%. The amount of organic matter sharply decreases down the profile. Total phosphorus content is 0.12–0.18%, and potassium1.5–2.0%.

The soils are evenly carbonated — 7–8% CO_2, with sulfates (gypsum) appe aring only in the lower horizons, ranging from 8to 22%. Slight quantities of water–soluble salts (0.5–1.0%) may occur. The soils are non- saline but slightly affected by irrigation erosion. Their cation exchange capacity is low — 6–10 meq per 100 g of soil, with calcium dominating, and magnesium appearing in small amounts.

Irrigated Light Gray Soils

These soils are found on piedmont sloping plains connected to the alluvial–proluvial fans ofsmall streams.The parent material consists of loess–like loams, and most of these soils have long been under irrigation. The humus horizon is 0.5–0.7 m thick, coinciding with the agro–irrigation layer. The plow layer contains 0.7–1.0% humus and 0.04–0.06% nitrogen, which gradually decrease downward.

Total phosphorus is 0.18–0.20%, and potassium 1.7–2.2%, reflecting the chemical composition of the parent rock. Carbonate contentis very high 8–10% CO_2 throughout the profile. The cation exchange capacity is 6–8 meq per 100 g soil. The upper profile is saturated mostly with calcium (90%), while magnesium is less abundant. In the lower horizons, magnesium may dominate, causing weak magnesium salinization.

Irrigated Gray–Meadow Soils

These soils develop under conditions where the groundwater table lies at 2–3 meters, mainly within the third terrace of the Zarafshan River, in areas of typical and light graysoils. The parent material consists of loess–like loams or, less often, pure loess. The anciently irrigated layer thickness ranges from 0.3–0.5 m (typical gray soil region)to 0.6–0.8m(light graysoilregion). The soils are medium to heavy loamy; in some places, gravels occur at 0.5–1.0 m. The humus content of the plow layer is 0.8–1.7%, nitrogen 0.05–0.12%, total phosphorus0.09–0.16%,andpotassium 0.7–1.3%.

These soils are highly carbonated (7–11% CO_2) and saline to varying degrees - slightly saline in the typical gray zone and moderately to strongly saline in the light grayzone,with local gypsum content. The cation exchange capacity ranges from 5–12 meq per 100 g soil, depending on texture and organic matter. Calcium accounts for 75–80%, and magnesium for 4– 15% of exchangeable bases.

Irrigated Dark Brown Soils

These soils occur on piedmont slopes formed on proluvial–deluvial skeletal fine deposits.They are medium to light loamy and skeletal, often with gravel or crushed stone at 0.3m depth. A dense, dark brown horizon typical of this soil type is observed in the middle profile.They are low in humus: in newly irrigated soils, humus is 0.6–0.8%, nitrogen 0.02– 0.04%; in long–irrigated soils, these rise to 1.5% and 0.06–0.09%, respectively.Down theprofile, humuscontent decreases sharply.Total phosphorus is 0.05–0.16%, and potassium 1.2–2.0% (lower in newly cultivatedsoils).Carbonates range from 5–7% CO_2, with deeper layers rich in gypsum (up to 30% SO_2) and some salinity. Cation exchange capacity: 4–8 meq/100 g soil, dominated by calcium and magnesium.

Where drainage is impeded, irrigation raises groundwater to 2.5–3 m, converting automorphic dark brown soils into semi–hydromorphic dark brown–meadow soils. These are medium to light loamy and skeletal, with gravel at 0.5–1 m, containing 0.8–1.2%humus.Other nutrient characteristics resemble those of the irrigated gray–brown soils. Noticeable changes include intensified salinization processes.

Irrigated Desert–Meadow Soils

Formed as a result of irrigation on sandy massifs with compacted substrata. The rapid rise of groundwater to 2–3 meters induces hydromorphic soil–forming conditions. These soils are sandy to sandy–loamy and poor in humus 0.3–0.5% humus, 0.02– 0.03% nitrogen, and 0.06–0.10%phosphorus. They are slightly carbonated and affected by mild to moderate salinity and erosion.

Irrigated Takyr–Meadow Soils

These occur on ancient alluvial–proluvial plains and the second terrace of the Zarafshan River, where groundwater remains 2–2.5 m below the surface. The lower profile contains rusty and bluish spots, indicating meadow gleying. The upper profile consists of a uniform agro–irrigation layer (0.6–1.0 m thick). The soils are light to medium loamy, weakly skeletal, and may have gravel at 0.5–1 mdepth.The plow layer contains 0.6–1.3% humus, 0.04–0.08% nitrogen, total phosphorus 0.10–0.12%,andhigh carbonates(7–9% CO_2). Gypsum isabsent. Salinity varies -from non–saline to slightly and moderately saline conditions.

Irrigated Meadow Soils

These are found in the light gray soil region and desert zone. In the lower terraces of rivers, they form naturally under the influence of alluvial groundwater regimes close to the surface. In the piedmont slopes and upper terraces, hydromorphic conditions are anthropogenically induced through irrigation, as groundwater rises to 1–2 m, causing the transition from automorphic and semi–hydromorphic to fully hydromorphic meadow soils. In some places, gravel layers occur at 0.3–1.2 m depths. The majority of these soils contain a well–developed agro–irrigation horizon.

Table: Land Use Structure of Navoi Region by Districts and Cities

№	Districts / Cities	Total Area (ha)	Total Cropland (ha)	Including:	Irrigated Area (ha)	of which:	Degraded Lands (ha)	Rainfed Lands (ha)	Perennial Plantations Total (ha)	of which:	Orchards (ha)	Vineyards (ha)	Mulberry Plantations (ha)	Total Hayfields (ha)	Pastures (ha)	Total Agricultural Lands (ha)	Total Household (Private) Plots (ha)	of which:	Farmland (ha)	Lands of Gardening Associations (ha)	Ameliorated Lands (ha)	Total Forested Areas (ha)	Non-agricultural Lands (ha)
1	Karmana	94,157	14,948	14,948	585		753	590	12	151	724	52,695	69,120	5,089	14	298	714	1,135	17,801				
2	Konimekh	1,595,576	4,729	4,729	1,107		145	80	39	26	448	1,239,963	1,245,285	660	174	98	255,434	94,099					
3	Kyzyltepa	218,520	22,584	22,584	1,427		2,130	910	679	541	4,441	131,795	160,950	3,366	56	418	2,462	51,324					
4	Navbahor	157,079	19,254	19,058	1,152	196	1,471	774	216	481	338	110,022	131,085	3,732	248	26	911	4,378	16,947				
5	Nurata	593,628	26,891	3,292		23,599	1,381	1,265	78	38		416,597	444,868	5,736	439		3,517	139,507					
6	Tomdi	3,577,611	244	244								3,113,533	3,113,777	169		297		425,055	38,313				
7	Uchquduq	4,501,226	120	120								3,699,077	3,699,197	74				578,303	223,652				
8	Khatirchi	141,797	29,619	25,774	1,130	3,845	4,377	984	2,789	604	894	77,936	112,826	6,442	202	668	543	21,318					
9	Navoi City	6,251	950	950			11	10	1			961	351		106		4,833						
10	Zarafshan City	2,618	3	3								487	490		25		2,103						
11	Uchquduq City	210																		210			
12	Gazgan City	59,413	3,560	265		3,295	31	31				51,878	55,469	15	11		3,929						

Regional Total (Navoi Region)

Indicator	Area (ha)
Total Area in Use	**10,948,086**

Indicator	Area (ha)
Total Cropland	**122,902**
of which: Irrigated	**91,967**
of which: Rainfed	**5,401**
Perennial Plantations (Total)	**30,935**
of which: Orchards – 10,299; Vineyards – 4,644; Mulberry Plantations – 3,814	
Hayfields	**1,841**
Pastures	**8,893,983**
Total Agricultural Lands	**9,034,028**
Total Household (Private) Plots	**25,634**
of which: Farmland – 1,144; Gardening Associations – 752	
Ameliorated Lands	**2,809**
Total Forested Areas	**1,270,827**
Non-agricultural Lands	**614,036**

3.2. Morphology and Morphogenetic Characteristics of Irrigated Light Brown Soils Developed at Different Periods

The soils that have been irrigated since ancient times are characterized by a humus content in the plow layer ranging from 1.0–1.5%, and total nitrogen between 0.07– 0.12%. In newly developed soils, the amount of humus depends on the genetic characteristics of the previously existing soils and varies within the range of 0.4– 0.8%. The total nitrogen content in these soils is relatively low, averaging 0.02– 0.06%. The soils are highly calcareous, with carbonates uniformly distributed throughout the profile (9–11% CO_2). The amount of gypsum is low (0.10–1.18% SO_2).Due to the shallow groundwater table, the irrigated meadow soils are generally saline, whereas the anciently irrigated soils are non-saline (leached), and in someareas, slightly saline. In the cation-exchange complex, calcium dominates (78–86%), though magnesium also constitutes a significant portion in some cases.

When comparing the analytical results obtained from our studies on virgin and irrigated soils with earlier research data (Felitsiant, 1983, and others), it is evident that, although a time gap of 30–40 years exists between the investigations, the overall findings are largely similar. However, during this period, the scale of evolutionary changes in the soils has considerably expanded. With the development of irrigated agriculture in the region, the thickening of agro-irrigation horizons has altered the structure of soil genetic horizons and contributed to an increase in soil fertility.

At the same time, the rise of groundwater levels due to irrigation has led to an expansion of saline soil areas, a process further influenced by climatic changes. Consequently, in recent decades, compared to earlier periods, the genesis, evolution, and morphology of the soil cover in the region have developed in accordance with changing environmental conditions.

3.3. Irrigated Light Brown Soils Developed at Different Times: Their Morphology and Morphogenetic Features

During the Quaternary geological Alpine orogeny, various regions—including the Zarafshan mountain system and the Ziyovuddin–Zirabuloq uplands on its western side—underwent intense weathering of limestones, sandstones, slates, granites, and other rocks, resulting in the formation of eluvial, deluvial, and proluvial deposits in the foothill areas.The evolution, genesis, composition, and structure of these deposits, as well as the soil-forming processes, distinguish the soils of the Zarafshan basin from those of other regions. The soil formation processes in these foothill plains occur under conditions typical of the desert foothill zones.

In the foothill plains of the Zarafshan basin, characterized by sparse vegetation, limited precipitation, and high temperatures, light brown soils have formed under these specific climatic and geomorphological conditions (Fig. 3.1.1). The cover of light brown soils is complex and heterogeneous, including stony, gravelly, sandy, loamy, gypsiferous and non-gypsiferous soils with varying layer thicknesses and degrees of development.

During the second half of the 20th century, the expansion of agriculture in areas dominated by light brown soils caused a rise in the groundwater table, leading to a deterioration of the ecological and reclamation (meliorative) status of the cultivated lands. As a result, in many areas, evolutionary changes have shifted soil-forming processes from automorphic (well-drained) to hydromorphic (poorly drained) conditions.

Although light brown soils have been investigated by many researchers in earlier periods, the rapid ongoing evolutionary changes in soil environments today necessitate a comprehensive analysis of the genesis, evolution, and ecological-meliorative state of these soils.

Thus, although takyr-meadow, meadow, sandy desert, and light brown soils in the Zarafshan basin develop under similar environmental conditions, they differ significantly in many properties. Light brown soils possess a shallow genetic profile: the upper horizon is light-colored and slightly porous, the middle horizons are light brown, calcareous, and gypsiferous. These features distinguish them from the previously described soil types.

According to R. Qo‘ziev (1994), the genetic structure of light brown soils exhibits processes of clay accumulation and iron enrichment within the brown horizon. He identified these processes as key factors in the development of light brown soils as an independent soil type. The genesis of light brown soils, however, is linked not to modern pedogenesis but rather to ancient soil-forming processes.

S.P. Mikhaylov (1994) conducted extensive studies on gypsiferous light brown soils—commonly referred to as bozingen—which are widely used in irrigated agriculture but have been insufficiently studied from diagnostic and classification perspectives. Although these soils occur locally as a distinct subtype within the general background of typical light brown soils, they are not widespread as a separate geographic unit. Therefore, bozingen soils differ sharply from typical light brown soils in both genetic and diagnostic aspects, primarily because clay accumulation and iron enrichment processes typical of the “B” horizon in standard light brown soils are absent in their corresponding layers.

Leading researchers in the field note that in the genetic horizons of light brown soils, the formation of gypsum layers and brownish coloration occurs due to the upward movement of sulfate salts with groundwater, accompanied by the accumulation of iron oxides in the upper layers. In the studied region, gypsiferous and calcareous brown horizons occur at varying depths, quantities, and forms, depending on the geological and geomorphological conditions of the deluvial-proluvial plains formed during different geological periods.

The results of the scientific research conducted in the studied area serve as a fundamental basis for understanding the morphological structure, diagnostic features, and physicochemical properties of light brown soils distributed within the region.According to the Soil Classification of the Republic of Uzbekistan and the guidelines used by the State Scientific Research Institute of Soil Science and Agrochemistry (“O‘zdaverloyiha”), the following types of light brown soils have been identified in the study area:

1. Virgin (non-irrigated) light brown soils
2. Newly developed (reclaimed) light brown soils
3. Irrigated light brown soils
4. Anciently irrigated light brown soils

When dividing the light brown soils into these groups—newly developed, newly irrigated, and anciently irrigated—the classification was based on the officially accepted Soil Classification of Uzbekistan, taking into account the distinguishing features of soil-forming processes and the residual characteristics inherited from non-irrigated soils (such as gypsum accumulation, mechanical composition, and humus content).To differentiate the effects of irrigation on soil formation over 10–20 years, 20–50 years, and 50–100 years, the light brown soils of the Navoi oasis were analyzed accordingly, categorizing them into newly developed, newly irrigated, and anciently irrigated light brown soils (see Table 3.2.1).

Morphological and Morphogenetic Characteristics of Newly Reclaimed Gray-Brown Soils

In the Navoiy oasis, these soils occupy newly reclaimed areas with a total area of approximately 5,628 hectares. Within the studied territory, the newly reclaimed gray-brown soils are distributed across several key zones: the Navoiy massif of Karmana district, the Qiziltepa Plateau and its southern parts, the northwestern segment of the III terrace of the Zarafshan River within Konimex district, and the south-eastern agricultural lands of the Oʻrtachoʻl massifs in Qiziltepa district (see Fig. 3.1).

The main sources of irrigation for these soils are the Zarafshan River and the Navoiy Canal, which extends approximately 45 kilometers. The canal originates from the Tudakoʻl Reservoirs and supplies water to the newly reclaimed lands of Karmana and Qiziltepa districts. Additionally, the newly reclaimed lands belonging to Konimex district are irrigated using the waters of the Zarafshan River.

The parent materials of the newly reclaimed gray-brown soils consist primarily of deluvial and proluvial deposits. These soils are found across slightly inclined, inclined–undulating, and undulating plains, which are characteristic of the piedmont zones (see Figs. 2.4.1 and 3.4.2).

Figure 3.4.1. General View of Newly Reclaimed Gray-Brown Soils Developed on Deluvial–Proluvial Parent Materials

The newly reclaimed gray-brown soils constitute the principal cultivated lands in the above-mentioned districts of Navoiy Region (Karmana, Qiziltepa, and Konimex). These reclaimed areas are used for the cultivation of cotton, wheat, alfalfa, maize, and other crops; vineyards and apple orchards have also been established.Under the influence of irrigation, the morphological structure of these soils— particularly the AV humus horizon, B transitional horizon, and gypsum horizon— has undergone significant modification. The following example of a soil profile illustrates these morphological features in detail.

Profile 1 – AK Section

Date: 28 October 2020
Described by: A. J. Kushakov
Location: Karmana District, Navoiy Massif
The section is located 500 m east of the Bukhara–Tashkent railway and 300 m west of the Navoiy Canal. It lies on the upper part of an undulating proluvial plain with a general slope directed from east to west. The site represents a cotton field, where cotton plants cover approximately 60–75% of the surface, while the remaining portion is occupied by weeds such as Phragmites australis (reed), Elytrigia repens (couch grass), Cynodon dactylon (Bermuda grass), Alhagi pseudalhagi (camelthorn), and others.
In certain parts of the field, irrigation erosion processes have developed, with eroded areas reaching depths of 35–40 cm.

A (x) 0–30 cm – Plow Layer.Grayish-reddish in color, dry, dense and compacted, medium loamy, with large clods and moderate porosity. Fine plant roots are few in number.A (xo) 30–60 cm – Subplow Layer (Plow Pan).Gray, reddish, and grayish-brown in color; dry, strongly compacted, medium loamy, finely porous, and cloddy. Very few fine plant roots are present. Remains of decomposed and semi-decomposed roots occur sporadically. In the lower part of the horizon, gray-white gypsum patches are observed.

B(cs) 60–90 cm – Gray-Brown Gypsiferous Horizon.Grayish-brown in color, gypsum-enriched, and uniform in structure. The lower portion contains small stones (3–8%), often coated or cemented with gypsum. The stones measure 3–8 cm in diameter.

C(cs,p) 90–120 cm – Gypsiferous, Gravelly, Moist Layer.Whitish-yellow in color, gypsiferous, gravelly, structureless, light sandy loam, and porous. Groundwater is located at a depth of 3.0–5.0 meters

As a result of irrigation, tillage, and fertilization—the main agrotechnical practices applied in newly reclaimed areas—distinct plow and subplow horizons have developed within the soil profile, indicating active anthropogenic transformation of the soil-forming processes.

Figure 3.4.2. Newly Reclaimed Strongly Salinized Gray-Brown Soils and Saline Patches

Under the influence of irrigation, the groundwater table in these soils has risen to a depth of 2.0–3.0 meters below the surface. This is considered one of the most significant anthropogenic factors affecting soil formation. The proximity of groundwater to the soil surface, along with evaporation during spring, summer, and autumn, has led to the salinization of highly gypsiferous gray-brown soils.

Although the development of agro-irrigational horizons in these soils is not yet strongly pronounced, distinct plow (A_x) and subplow (A_{xo}) horizons have already formed. As previously noted, the salinization process observed in newly reclaimed gray-brown soils is mainly the result of groundwater evaporation, where capillary rise brings soluble salts to the upper horizons.

The contents of mobile phosphorus and potassium vary, but these soils are generally poorly supplied with these nutrients. The carbonate content ranges from 7.00% to 9.47%, and is distributed uniformly across the soil profile. In some profiles, however, the accumulation of carbonates in the plow and subplow layers is associated with the precipitation of calcium carbonates from irrigation water.

Thus, during the use of newly reclaimed gray-brown soils for irrigated agriculture, noticeable morphological and morphogenetic changes have occurred, including:

1. The formation of distinct plow (A_x) and subplow (A_{xo}) horizons, with a combined thickness of up to 50–60 cm.
2. The development of agro-irrigational horizons, characteristic of both newly and long-term irrigated soils, though at an early stage of anthropogenic soil formation compared to naturally developed gray-brown soils.
3. The rise of groundwater toward the upper layers and its evaporation, leading to the onset of salinization processes and the accumulation of salts—mainly in the upper horizons.

Morphology and Morphogenetic Characteristics of Newly Irrigated Gray-Brown Soils

In the Navoiy Oasis, these soils represent the main soil group developed on deluvial– proluvial and proluvial undulating and gently sloping plains. They occupy areas in the Karmana District bordering the Qiziltepa District. Newly irrigated gray-brown soils have formed on deluvial–proluvial and proluvial deposits, where the lower parts of the profiles are densely compacted with gravel, pebbles, and sand, overlain by a gypsiferous horizon. Typically, the gypsiferous layer begins at a depth of 50– 80 cm and extends to 150–240 cm.

Profile 2 – AK Section

Date: 20 October 2020
Described by: A. J. Kushakov
Location: Karmana District, Uzbekistan Massif, west of the Tinchlik settlement,

bounded by the Dormon Massif. The profile is situated 250 m northeast of the Bukhara–Tashkent highway, on a proluvial undulating plain. The site is a cotton field, where plant cover occupies 25–50% of the surface. Approximately 60–70% of the field consists of moderately to strongly salinized areas. The profile was excavated within a salinized zone.Salinization processes are most evident along the upper parts of irrigation furrows.

Weeds such as Phragmites australis (reed), Elytrigia repens (couch grass), Atriplex cana ("salomalaykum"), Alhagi pseudalhagi (camelthorn), and Cynodon dactylon (Bermuda grass) are common. The groundwater table lies below 250 cm, occasionally rising to 200 cm for short periods.A_x 0–30 cm – Plow Layer.Gray in color, dry, slightly compacted, medium loamy, with fine cloddy-dusty structure, and porous. Small plant roots and decomposed organic residues occur sporadically.A_{xo} 30–60 cm – Subplow Layer.Light gray to grayish-brown, dry, dense, heavy loamy, large-cloddy, finely porous. Few fine roots of plants are present.

Bcs 60–90 cm – Upper Gypsiferous Horizon.Contains a thin gypsum-enriched layer in the upper portion. Whitish-yellow to grayish in color, structureless, porous, and composed of uniform medium loam.BCcs 90–120 cm – Transitional Gypsiferous Horizon.Lower parts are gray-brown, occasionally yellowish-reddish, medium loamy, cloddy-dusty, porous. Contains granular particles and aggregates; gypsum crystals and patches are present throughout. BC120–160 cm – Layered Proluvial Deposits.Sandy to sandy loam, grayish-red to grayish-yellow in color, moist, structureless. Occasional stones (1–3%) occur. Small reddish-yellow iron oxide spots are observed. The groundwater is located at a depth of 250 cm, sometimes rising to 200 cm.

The mechanical composition of these soils varies from light to heavy loam, with sandy and clayey layers occasionally appearing in the lower parts of the profile. In terms of morphology and morphogenetic characteristics, these soils differ slightly from non-irrigated and newly reclaimed gray-brown soils (see Table 3.4.1). They are characterized as variously salinized and gypsiferous gray-brown soils, where gypsum accumulation is most pronounced in the lower horizons. Consequently, under prolonged irrigation, gray-brown soils exhibit several distinct morphological and morphogenetic differences compared to non-irrigated and newly reclaimed variants:

1. In the A_x and A_{xo} horizons, the natural gray-brown coloration shifts toward gray and grayish tones, with denser, cloddy-dusty, and porous structures, and a slightly heavier mechanical texture.

2. In the upper part of the A_x horizon, the evaporation of shallow groundwater (2–3 m) leads to the formation of weak to moderate saline patches, accompanied by increased concentrations of residual salts, chloride, and sulfate ions, while the thickness of the gypsiferous layer decreases.
3. As the duration of irrigation increases, the cation exchange complex shows a rise in Ca^{2+} dominance and a corresponding reduction in Mg^{2+} content, reflecting changes in the soil's chemical equilibrium under long-term irrigation.

Morphology and Morphogenetic Characteristics of Long-Term Irrigated Gray-Brown Soils

In the Navoiy Oasis, long-term irrigated gray-brown soils are distributed in the western parts of the Karmana, Tinchlik, and Dormon settlements, as well as in the northeastern part of the "Bo'ston" collective farm in Qiziltepa District, and within the Konimex District. These soils have developed on proluvial–alluvial deposits, covering a total area of 652 hectares.The mechanical composition of long-term irrigated gray-brown soils consists mainly of medium and heavy loams and clays, with the lower parts composed of stony, gravelly, and sandy materials. Because these soils are located in the lowest parts of the undulating plains of the Navoiy Oasis, they have been used for irrigated agriculture for many centuries. In ancient times, these lands were irrigated by the waters of the Zarafshan River, with Duldul and Yangiaryk serving as the main irrigation channels. At present, part of these soils is irrigated with water from the Navoiy Canal, although Duldul and Yangiaryk still function as secondary irrigation branches.

The described soils differ significantly from newly reclaimed and newly irrigated gray-brown soils in their morphological structure, physical, chemical, and agrochemical properties, and in the pattern of salt accumulation (see Table 3.4.1). These differences are determined, on the one hand, by the long duration of irrigation, and on the other, by the shallow position of the groundwater table and the intensification of salinization processes. These evolutionary changes in soil formation conditions are clearly reflected in the structure of the soil profile.

Profile 3 – AK Section

Date: 22 October 2020
Described by: A. J. Kushakov
Location: Karmana District, Hazora Massif; 1000 m southwest of the Bukhara–Navoiy highway and 160 m east of the Hazora-1 settlement.

These soils have developed on the III terrace of the Zarafshan Valley, on proluvial–alluvial deposits. The site is a cotton field, where the weed cover (mainly

Phragmites australis (reed), Elytrigia repens (couch grass), and Atriplex cana ("salomalaykum")) occupies 4–6% of the surface. The area is slightly saline (1–3%), and the groundwater table lies at a depth of 160 cm.

A_x 0–30 cm – Plow Layer.Gray, dry, sandy-clay loam, slightly compacted, cloddy-dusty, moderately porous. In the middle and lower parts of the horizon, plant roots and partially decomposed residues are present. Grayish-yellow stains from irrigation sediment are also observed.

A_{xo} 30–60 cm – Subplow Layer.Grayish-yellow, dry, compact, clayey, cloddy, finely porous, homogeneous in structure. Contains fine roots and decomposed organic remains. Red patches of clayey deposits occur sporadically.AVag 60–90 cm – First Agroirrigational Horizon.Light gray, slightly moist, compact, clayey, large-cloddy, finely porous. In the middle part of the horizon, numerous reddish brick fragments and yellowish-red clay spots are observed. Small gypsum spots and crystals also occur.

AVag 90–120 cm – Second Agroirrigational Horizon.Grayish-brown to yellowish, moist, medium to light loamy, finely cloddy, porous. Contains gypsum spots and crystals, and in the lower part of the horizon, reddish iron oxide stains are present.

In these soils, the physical clay content within the soil profile ranges from 35% to 68%, which indicates a heavier mechanical composition compared to newly reclaimed and newly irrigated gray-brown soils. The increase in texture heaviness is mainly due to the long-term accumulation of fine particles carried by irrigation water.In poorly leached, saline gray-brown soils, under dry and hot climatic conditions, the evaporation of mineralized groundwater through soil capillaries causes seasonal accumulation of salts in the surface and middle horizons.Thus, the long-term irrigated gray-brown soils of the Navoiy Oasis differ from other soil groups of the region by the following morphogenetic features, evolutionary transformations, and specific physical-chemical properties:

1. The development of agroirrigational horizons in the lower parts of the A_x and A_{xo} layers.
2. A mechanical composition dominated by heavy loamy and clayey fractions.
3. Weak salinization processes, with the presence of easily soluble salts such as NaCl, Na_2SO_4, and $MgSO_4$, and occasionally $CaSO_4$ in the deeper horizons.
4. Compared to newly reclaimed and newly irrigated soils, long-term irrigated gray-brown soils are richer in humus and nitrogen, with their contents in the A_x and A_{xo} horizons reaching 0.944% and 0.843% humus, and 0.056% and 0.053% nitrogen, respectively.

3.4. Transformation and Morphogenetic Characteristics of Irrigated Light Gray Soils

In Uzbekistan, irrigated gray soils (bo‘z soils) occupy extensive areas in the foothill and low-plain zones, particularly within the Fergana, Chirchiq–Angren, Mirzacho‘l, Kitob–Shahrisabz, Zarafshan, and Surkhan–Sherabad oases, among others. From the standpoint of their genesis and evolution, these soils have developed from natural gray soils under the influence of long-term irrigation and anthropogenic activity. Gray soils generally occupy foothill plains and the upper and lower terraces of river valleys, and their altitudinal position varies according to location.

In the Zarafshan basin, gray soils occur at elevations of 350–400 meters above sea level, distributed irregularly from south to north. These soils exhibit substantial variation depending on local climatic conditions, surface relief, parent material composition, and the character of irrigation agriculture practiced in different areas. Within the Navoiy oasis, the distribution of light gray soils extends southeastward to the border with Samarkand region.

The northeastern part of the Navoiy oasis is enclosed by branches of the Turkestan mountain system—notably the Nurota Range (up to 2,169 m) and Oqtov (up to 2,003 m)—while the southern boundary is framed by the Zarafshan Range (western branch reaching 2,204 m). The southwestern part is bordered by the Ziyovuddin–Zirabuloq hills, and the northern margin merges into the Kyzylkum Desert.

The study area possesses a long history of irrigated agriculture, which has significantly altered its hydrogeological conditions. For example, in the foothill zone of the Qoratog‘ Range within Khatirchi District and the southwestern part of Karmana District adjoining the Ziyovuddin–Zirabuloq heights, irrigated gray soils are prevalent. In these areas, the groundwater table historically lay at a depth of 6–10 meters, thus having no direct influence on soil formation processes.Over time, due to the reclamation of new lands and expansion of irrigation, the groundwater table has risen to 3–5 meters, thereby affecting pedogenesis. As a result, evolutionary transformations have occurred within automorphic typical gray soils, leading to the development of several subtypes of gray soils.

Because light gray soils generally occupy foothill plains and areas adjacent to rivers, the natural drainage of groundwater was initially satisfactory. However, the widespread practice of irrigation and heavy water use have caused the groundwater level to rise sharply, particularly in the lower parts of the region where light gray soils are distributed. This rise, accompanied by an increase in groundwater mineralization, has led to the development of secondary salinization processes. Consequently, the formerly automorphic and semi-automorphic soils have undergone evolutionary transformation toward semi-hydromorphic and hydromorphic conditions (see Table 3.4.1).

Profile 7 – AK Section

Date: 22 October 2020
Described by: A. J. Kushakov

Location: Zarafshan Massif, Khatirchi District, Navoiy Region. Geomorphologically developed on alluvial–proluvial deposits. Represents light gray soils formed in the middle reaches of the Zarafshan River, at an elevation of 400 m a.s.l. Situated 350 m north of the Navbahor–Khatirchi local road and 300 m south of the Zarafshan River, within a cotton field.Ahq (0–30 cm) – Uniform dark gray, slightly moist, medium loamy, finely granular- cloddy, non-compacted, abundant plant roots, including partially decomposed cotton roots from the previous year; numerous insect traces and burrows; carbonate mottles present.Ahoq (30–60 cm) – Darker gray, moist, medium loamy, fine nutty structure, moderately compacted, with many fine roots; abundant insect burrows, earthworm casts, and fragments of ancient pottery.

B (60–90 cm) – Gray, moderately moist, medium loamy, fine granular structure, slightly compacted, many fine roots, numerous worm casts and insect burrows, occasional rust stains along root channels; fragments of archaeological ceramics encountered. Transition to the next horizon is distinct by color and moisture.B(90–120 cm) – Gray-brown, strongly moist, medium loamy, fine granular structure, slightly compacted; contains decomposed and partially decomposed plant roots, indicating biological activity; fragments of red pottery also found.

Transition to the next horizon is evident by moisture, structure, and density differences.

Groundwater table:1.5–3.0 m,moderately mineralized. Parent materials: primarily loess and loess-like loams, occasionally stony-loamy and fine gravelly-proluvial deposits.The vegetation cover is diverse but short-lived, yet it contributes to the formation of a thin sod horizon in the upper layer. The thickness of this sod horizon increases progressively from light gray to dark gray soils. The soil profile exhibits well- differentiated humus, carbonate, and subsoil genetic horizons.

The humus content ranges from 0.39% to 1.0%, total nitrogen averages 0.064%, and available phosphorus reaches 0.175%. The humus horizon of light gray soils is well- structured, with a distinctly visible carbonate horizon, where carbonates appear as white specks, fine crystals, or mycelial accumulations along root channels and animal burrows. The highest concentration of carbonates occurs in this horizon, Formation and Evolution of Light Gray Soils

R.Q. Qo‘ziev (1994) comprehensively examined the evolutionary development and fertility dynamics of gray-oasis soils formed on the upper terraces of the Zarafshan River. According to his findings, once natural soils are brought under irrigation and cultivation, their morphological structure begins to reflect the specific soil–climatic zone in which they occur. This process culminates in the formation of oasis gray soils, which are a product of long-term anthropogenic and hydrological influences.

A defining morphological feature of these soils is the thickness of the humus layer, which—apart from the agro-irrigation layer—is directly related to the depth of anthropogenic sediment accumulation. In irrigated light gray soils, the agro- irrigation layer reaches 40–50 cm in thickness (Table 3.3.1). Qo‘ziev noted that this horizon can be regarded as a relic of meadow soil formation, typical of hydromorphic soils in the middle reaches of the Zarafshan River, associated with groundwater rich in bicarbonate ions. The persistent soil moisture and mechanical pressure from cultivation also contribute to the increased density of the sub-plow layer.

A.J. Ismanov (2012), studying light gray soils on proluvial deposits in the Fergana Valley, found that long-term irrigation and intensive agricultural use led to the formation of oasis soils and a thickening of the agro-irrigation horizon.

L.A. Gafurova and O.B. Sharipov (2000), using M.U. Umarov’s (1975) classification, divided oasis meadow-alluvial soils according to the thickness of their agro-irrigation layers:

- Thick – Oasis meadow-alluvial soils,
- Medium-Irrigatedmeadow-alluvialsoils.Furthermore, they observed a biological activity gradient—measured by catalase, peroxidase, and polyphenol oxidase activity—in the order: Oasis meadow-alluvial soils > Irrigated meadow-alluvial soils > Irrigated desert-sandy soils.

Sh.M. Bobomurodov (2002) explored the morphogenetic transformation of desert soils under irrigation in the Qorako‘l oasis, identifying regional patterns of soil formation related to parent material and agricultural use. He classified the oasis territory into 27 soil variants and demonstrated that nontraditional mineral amendments and organo-mineral composts (derived from river sediments, manure, and minerals) improved soil fertility and physicochemical properties.

X.T. Artiqova (2005), researching the Bukhara oasis, particularly around the Shohrux canal, examined the transformations of soil cover under irrigation. She analyzed the quantity and quality of suspended particles in canal waters, as well as the mechanical and microaggregate composition of irrigated soils. Her findings indicated significant changes in humus, nitrogen, phosphorus, and potassium contents in the main soil types and subtypes of the oasis and elucidated the role of irrigation in the formation of saline soils.

Historical and Regional Context

According to the State Land Fund of Uzbekistan, gray soil regions occupy 16.7% (7,472.8 thousand ha) of the country's total land area. Over several centuries of continuous agriculture, the morphology, agrophysical, hydrophysical, physicochemical, and biological properties of irrigated soils have undergone marked transformation.

L.T. Tursunov demonstrated these processes in the gray-meadow soils of the Qarshi desert, where cultivation initiated significant morphogenetic changes. Plowing produced a distinct arable layer (Ah horizon) in which the natural sod and sub-sod layers merged, forming new morphological features. Irrigation accelerated humus formation, altered the soil color, and reshaped its structure.

Within just 1–2 years of land reclamation, changes appeared in soil morphology— the natural sod horizon was replaced by a plow layer, marking a major genetic shift. This new layer exhibited better porosity and improved air–water, nutrient, and thermal regimes. Over time, the soil color evolved from the grayish-brown typical of virgin light gray soils to a pale gray under prolonged irrigation.After 30–40 years of irrigation, the groundwater table rose to 2–4 meters, actively participating in pedogenesis. Consequently, automorphic soils gradually evolved into semi-hydromorphic gray-meadow soils.

Although gray soils form the core of Uzbekistan's agricultural land, their fertility potential is relatively limited, and the processes of soil formation and productivity development differ across regions.

Morphogenesis in the Navoiy Oasis

In the Navoiy oasis, light gray soils are distributed around specific river basins, where the color, texture, mineral, and chemical composition of the agro-irrigation deposits depend on the irrigation water source. Consequently, gray-oasis soils in each region exhibit distinct morphological features.

The evolutionary development of soils under natural and anthropogenic influences is thus governed by biogeochemical processes. Soils formed on different parent materials within a single region display unique properties, each contributing to soil fertility formation.

Land reclamation and irrigation induce pronounced changes in the morphogenetic properties of the soil profile—color, mechanical composition, chemical and mineralogical content, structure, and porosity.

Reinvestigations of the light gray soils in the Navoiy oasis after 35 years (I.N. Felitsiant, 1984; A.J. Kushakov, 2020–2023) confirmed distinct morphogenetic transformations. Numerous archaeological ceramic fragments were found within a 2-meter-thick agro-irrigation horizon. The lower horizons (52–125 cm) were gray, containing fine root residues, with soil color transitioning from dark gray to brownish gray downward. Salinization was absent, but new carbonate mottles, moisture variation, and incipient salinity were observed—linked to fluctuating groundwater levels and unstable water regimes.

The sub-plow layer was moderately compacted (up to 1.44 g/cm³) but did not form a hard "plow pan." The soils are irrigated with turbid waters from the Zarafshan River, and their morphogenetic structure varies according to irrigation frequency and sediment load. In light gray-brown soils, agro-irrigation horizons up to 1.5–2.0 m, and sometimes 2.5–3.0 m, were recorded.

Overall, these soils are characterized by a well-developed arable horizon (Ah, 0–30 cm) and a clearly defined humus layer extending to 100 cm depth. The upper 0–60 cm exhibits a granular structure typical of fertile, cultivated soils.

The groundwater table, fluctuating around 2.0 meters, actively influences soil formation. The water regime is irrigational in type, and the stable capillary moisture zone (1.0–2.0 m depth) fosters internal weathering processes, further modifying the soil's morphogenetic profile.

Morphology and Morphogenetic Characteristics of Irrigated Takir-Meadow Soils

Within the Zarafshan basin, another group of soils widely distributed across the Navoiy region are the irrigated takir-meadow soils, whose morphology and morphogenetic characteristics are described below (Table 3.4.1). These soils have developed in large plains under conditions where the percolation of groundwater is well ensured. As a result of groundwater being located deeper than in meadow and other soils, they are less prone to salinization, and consequently, the relative proportion of saline soils among them is comparatively lower. Furthermore, due to the favorable meliorative conditions, these soils have been more extensively used for irrigated agriculture than meadow soils and continue to display morphological and genetic similarities.

Their mechanical composition does not differ significantly from other soil groups and mainly consists of heavy and medium loams. In the genetic horizons of the soil cover, at various depths, clayey and loamy layers occur beneath sandy and sandy- gravel deposits. The vegetation cover is typical of oasis ecosystems and consists of both annual and perennial species.

Profile description of soil pit 4-AK (22.10.2020, A.J. Kushakov): Location – G‘ardiyon massif, Qiziltepa district, Navoiy region. The site is geomorphologically composed of alluvial-proluvial deposits. Wheat field with 90–95% plant cover and 2–5% weed presence. These soils are formed west of the Zarafshan River and are classified as irrigated takir-meadow soils. Altitude: 250–300 m above sea level; located 350 m north of the Karmana–Qiziltepa internal road, within a cotton field.

- Ax (0–30 cm): Dark grayish-black, non-compacted, granular-lumpy, medium loam, porous, homogeneous. Contains roots of wheat and other plants, as well as decomposed and partially decomposed residues.
- Axo (30–60 cm): Gray, dry, moderately compacted, large-lumpy, heavy loam, with small pores and uniform texture.
- AV_1 ag_1 (60–90 cm): First agro-irrigation horizon; grayish-brown, slightly moist, heavy loam, weakly compacted, fine-lumpy and dusty; lower part moist gray.
- AV_2 AG_2 (90–120 cm): Second agro-irrigation horizon; gray, soft, wet, light loam, lower part slightly sandy.

The mechanical composition of these soils, as well as other takir-meadow soils, is characterized by a high content of fine sand particles and relatively lower contents of coarse and fine clay. The low clay fraction is notable and is a typical feature of all agro-irrigation horizons in the region. The salinization processes in these soils are also characteristic—predominantly sulfatic and occasionally chloride-sulfatic in nature.

In terms of nutrient content, these soils do not differ significantly from meadow soils. Compared with irrigated grayish-brown soils, they contain more humus and nitrogen, and the carbon-to-nitrogen ratio is higher, with most nutrients concentrated in the upper horizon. The soils are enriched with mobile forms of phosphorus, particularly in the upper (arable) horizon, while their content decreases sharply downward. The distribution of carbonates within the soil profile shows a slight increase with depth, indicating the continuation of illuviation processes.

Hence, irrigated takir-meadow soils differ from irrigated meadow soils primarily by exhibiting slower and less intensive salinization processes, which makes them more favorable for agricultural use and allows their classification as fertile soils.

Morphology and Morphogenetic Characteristics of Irrigated Meadow Soils

This group of soils has developed under hydromorphic soil-forming processes influenced by human activities. Therefore, the irrigated meadow soils, throughout their evolutionary stages, have formed under the influence of complex pedogenetic processes and possess unique morphogenetic features (Table 3.4.1).The studied soils are mainly distributed on the floodplain and low terraces of the Zarafshan River, occurring in relatively small areas adjacent to the river. Presently, these soils have undergone evolutionary transformations due to centuries of human intervention—drainage, tillage, irrigation, and other agricultural practices—with groundwater playing a decisive role in their development. The groundwater table, located at depths of 1.0–2.0 m, contributes to gleying, oxidation-reduction, and salinization processes, which in turn intensify the meadow-forming (hydromorphic) pedogenesis.

In the Navoiy oasis, irrigated meadow soils are primarily found between Yangiravot (Navbahor district) and Toshrabot (Qiziltepa district) massifs, covering an area of approximately 2,452 hectares. Due to their proximity to the Zarafshan River, these soils have been used for irrigated agriculture for centuries.

Profile description of soil pit 5-AK (22.10.2020, A.J. Kushakov): Location – near the village of Armijon, Navbahor district, on the second terrace of the Zarafshan River; arable land (cotton field) with 90–95% crop cover and 2–5% weed cover. Minor seasonal saline patches (1–3 m wide) occupy about 2–3% of the area. The groundwater table is at a depth of 190 cm.

- Ax (0–30 cm): Dark grayish-black, dry, compacted, granular-lumpy, medium loam, porous, homogeneous, containing abundant plant roots and decomposed organic residues.
- Axo (30–60 cm): Gray, dry, strongly compacted, large-lumpy, heavy loam, small pores, uniform texture.
- AVag (60–90 cm): First agro-irrigation horizon; grayish-brown, slightly moist, heavy loam, weakly compacted, fine-lumpy and dusty; contains brick fragments; small reddish-yellow iron oxide spots in the lower part.
- AVAG (90–120 cm): Second agro-irrigation layer; grayish-yellow, soft, moist, light loam; lower part sandy and gleyed, with numerous small reddish Fe_2O_4 oxide spots concentrated toward the bottom of the horizon.

The groundwater lies just below this horizon.Summarizing the morphological and genetic structure of ancient irrigated meadow- alluvial soils, their main features are as follows:

1. The Ax and Axo horizons are distinctly dark gray to gray in color.
2. The transitional horizon (AV) comprises two agro-irrigation layers, with the lower one affected by gleying processes.
3. The groundwater table, located close to the upper layers (190 cm), plays a major role in shifting the soil-forming process toward meadow development.

According to the obtained data, the mechanical composition of irrigated meadow soils consists of medium and heavy loams and light clays, displaying a vertical distribution pattern. The fine clay particles (<0.01 mm) constitute 46.5–51.6% in the arable and sub-arable layers, while in the lower horizons their proportion decreases to 21.5–23.9%. During soil evolution, a gradual increase in mechanical density is observed in the sub-arable horizon, linked to the accumulation of suspended particles from irrigation waters during seasonal replenishment.

An increase in humus content is directly accompanied by a rise in nitrogen content. Thus, in the Ax and Axo horizons, nitrogen accumulation reaches 0.073–0.096%. The total phosphorus content varies but is highest in the arable horizon. Carbonates account for 9–11%, and the pH ranges between 7.3–7.5. The soils are predominantly saturated with Ca^{2+} and Mg^{2+} cations, while K^{+} and Na^{+} cations play a lesser role in the soil-forming processes.

Table. Comparative Morphological and Chemical Characteristics of Soils in the Navoiy Oasis
(*Based on N.I. Felitsiant et al., 1983; A.J. Kushakov, 2022*)

No.	Indicators	Navoiy – Light Gray Soils(N.I. Felitsiant et al., 1983)	Navoiy – Dark Gray-Brown Soils(N.I. Felitsiant et al., 1983)	Takir-Meadow Soils(N.I. Felitsiant et al., 1983)	Meadow Soils(N.I. Felitsiant et al., 1983)	Light Gray Soils(A.J. Kushakov, 2022)	Dark Gray-Brown Soils(A.J. Kushakov, 2022)	Takir-Meadow Soils(A.J. Kushakov, 2022)	Meadow Soils(A.J. Kushakov, 2022)
1	Thickness of humus horizon, cm	16–20	10–12	9–11	11–15	18–26	17–19	17–21	16–20
2	Depth of humus coloration, cm	120–130	80–90	65–75	80–90	50–70	85–90	70–80	85–95
3	Humus content in the humus horizon, %	0.26–2.08	0.10–0.99	0.39–0.86	1.27–2.07	0.7–1.0	0.6–0.8	0.6–1.3	1.0–1.5
4	Gypsum content (%) at the upper and lower boundaries of the soil layer	0.077–0.095	0.92–22.141	0.140–0.239 *(low)*	0.103–0.181 *(low)*	2–3 *(very low)*	30–35	–	0.10–1.18 *(low)*
5	Carbonate content (%) at the upper and lower boundaries of the soil layer	7.67–10.01	7.82–11.01	7.52–8.42	9.23–8.45	8–10	5–7	7–9	9–11
6	Degree of salinity	Non-saline	Saline	Slightly saline	Moderately saline	Weakly to moderately saline	Moderately saline	Slightly saline	Weakly saline

As a result of many years of irrigation, cultivation, and fertilization, the quantity of exchangeable cations in the soil composition undergoes continuous change. The relatively heavier mechanical composition and the higher humus content of these soils—compared to newly or long-term irrigated gray-brown soils—contribute to an increase in the amount of absorbed cations, particularly calcium (Ca^{2+}) and magnesium (Mg^{2+}).

CHAPTER IV. Physical and Certain Agrophysical Properties of Soils in Navoiy Region Affected by Natural and Anthropogenic Factors (Under Various Irrigation Periods) and Their Transformations

4.1. Mechanical Composition of Soils

Studies devoted to the investigation of the mechanical composition of soil cover within the Zarafshan Basin, particularly within the boundaries of the Navoiy Region, have been reflected in the works of I.N. Filetsiant (1984), S.P. Mikhailov (1994), Kh.N. Qo‘ng‘irov (2009), A.U. Akhmedov et al. (2003). However, the mechanical composition of soils under the influence of irrigation and various agrotechnical measures has been comprehensively analyzed by a number of other researchers.

This issue has been addressed in the works of R.Q. Qo‘ziyev, Sh.M. Bobomurodov, L. Tursunov, R. Bobonorov et al. (2000), R. Qurvantaev (2000), and A.U. Akhmedov (2001).According to the scientific literature, the following viewpoints have been expressed regarding this process. In studies conducted by L. Tursunov et al. (2004), it was demonstrated that irrigation improves the moisture regime within the soil profile, which consequently leads to the internal disintegration of coarse soil particles.

In the research of Sh.M. Akhmedov (1999), data are presented on the amount of lead (Pb) in gray-brown soils around Navoiy City and its effects on the chemical, physico-chemical, and biological properties of these soils. The mapping results showed that the contamination of gray-brown soils with lead and its distribution are largely dependent on the geomorphological features of the area, as well as on the wind speed and direction. Based on accurate data, it was established that within an area of 640 hectares, the total amount of lead reaches up to 10 sanitary norms, while in 34.3 hectares it reaches up to 20 sanitary norms.

It was also determined that the downward migration of lead within the soil profile (from top to bottom) depends on the content of humus, carbonates, mechanical composition, and the soil’s adsorption capacity. Lead tends to accumulate mainly in the upper soil layer (0–10 cm), with its downward migration depth ranging between 20–50 cm.In long-term irrigated gray-brown soils, the relatively higher humus content and heavier mechanical composition reduce the adverse effects of lead on soil biological activity.

In his monograph “Mineralogical Composition and Physico-Chemical Properties of Southern Uzbekistan Soils” (1989), J.R. Ismatov analyzed the mineralogical composition, chemical and physico-chemical properties of sandy desert, gray- brown, gray, brown, and high-mountain soils typical of the Turan province. Thestudy also investigated the accumulation of silt and colloidal fractions along the soil profile and their role in soil formation processes. The author’s findings enriched the understanding of the genetic, diagnostic, and geographical characteristics of desert, foothill, mid-mountain, and high-mountain soils of Uzbekistan.

T.R. Khamroyev and M.U. Karimova (1978), in their studies on Malikchul gray- brown soils, found that irrigation processes lead to the compaction of the soil's mechanical composition and the leaching of carbonates and gypsum. They noted that irrigation increases the soil's content of humus, nitrogen, and phosphorus, while the reduction of potassium is directly associated with limited water supply during the cotton vegetation period.

V.V. Valiyev and L.N. Tolstova (1978) determined that the nature of weathering in hydromorphic soils varies depending on the mechanical composition of individual horizons. They showed that light-textured soils contain higher amounts of silicon (Si), whereas heavy-textured soils exhibit increased concentrations of iron (Fe) and aluminum (Al) oxides. As a result, the SiO_2 ratio decreases as the soil texture becomes heavier, and such soils are more prone to weathering compared to light- textured ones.

According to M. Umarov (1968), light gray soils are predominantly sandy and light loamy in texture, with coarse silt particles (0.05–0.01 mm) comprising 60–75% of their composition. It follows that in the extremely arid conditions of the Qarshi Desert, mechanical particles undergo only physical weathering.

N.G. Minashina (1960), using the soils of the Murgab Oasis as an example, demonstrated that the internal weathering of soil mineral components leads to silting. By comparing the content of fine silt particles (0.005–0.001 mm) in alluvial and agro-irrigation layers, she established that the clay fraction (<0.001 mm) tends to accumulate in the middle part of the soil profile.

According to V.A. Molodtsov (1963), even in ancient irrigated soils, salinization does not occur uniformly across areas. This process varies depending on the granulometric composition of the irrigated soils, which in turn depends on the quantity and quality of suspended sediments carried by irrigation waters into the fields. The author concluded that changes in the mechanical composition of irrigated soils occur in two interrelated ways: first, through comparison with loess deposits to trace their genesis, and second, due to periodic irrigation introducing agro- irrigational sediments.

However, these regularities manifest differently within the studied area's soil cover. As noted above, the mechanical composition of soils is associated with both the texture of agro-irrigational sediments and the relief structure. Within each irrigation network and field section, soils may exhibit different mechanical compositions depending on their position in relation to the irrigation canals.

Our research also confirmed this phenomenon. In various relief conditions and irrigation networks, the distribution of suspended sediments and their texture varies according to the duration and method of irrigation. When irrigation is carried out through canals, coarser sediment fractions tend to accumulate in the fields. Depending on the proportion of physical clay fractions in the medium, soils may exhibit moderately sandy-silty or light loamy-silty textures. In sediment distributors, the texture is usually heavy loamy-silty or medium loamy-sandy-silty, while in drainage ditches it is often clayey or heavy loamy-silty.

In all cases, a notable increase in the fine clay fraction (<0.001 mm) and a corresponding reduction of coarse sand and coarse silt fractions (0.25–0.01 mm) are characteristic.In the studied region, light gray, gray-brown, takyr-meadow, and meadow soil types exhibit suspended sediments of light, medium, or heavy loamy textures in the upper and middle parts of irrigation networks, similar to their parent materials.

These data indicate that the lightening or compacting of irrigated soil textures is primarily caused by silty suspended sediments. Consequently, the variation in the mechanical composition of irrigated soils depends on the long-term redistribution of sediment fractions.For example, under the influence of irrigation with Zarafshan River water, various soil types in the area contain predominantly medium suspended deposits and sediments.

In the Navoiy Region, irrigated soils are mainly watered by the Zarafshan River and partially by the Navoiy Canal, which receives water from the Amu Darya. The suspended load of the Navoiy Canal plays a relatively minor role in this region. However, in the soils irrigated by the Zarafshan River, suspended sediments are clearly distinguished by texture—light, medium, or heavy loamy, and coarse silty fractions predominate.

Thus, each regional soil type under irrigation demonstrates distinctive characteristics in terms of mechanical composition. Even within a single contour (field), soils may differ significantly depending on their proximity to irrigation channels. Typically, in the lower parts of fields, the texture becomes heavier due to surface slope effects. Such redistribution of mechanical fractions results in textural heterogeneity across fields, which directly influences plant growth and, consequently, crop productivity.

In irrigated soils of the Zarafshan Basin, heavy-fraction minerals and feldspars are two to four times more abundant than in light fractions. Therefore, the suspended sediments of the Zarafshan irrigation system are not only more quartz-rich but also contain considerable amounts of hornblende and micas (biotite and muscovite). These minerals play an important role in maintaining soil fertility.

According to A.N. Rozanov (1958), a comparative analysis of irrigation from the Zarafshan River in the Samarkand, Navoiy, and Bukhara regions showed that suspended sediments of highly quartzized composition are characteristic for all areas. The researcher emphasized that the mineralogical composition of suspended sediments in each oasis's irrigation system exhibits substantial stability.

In conclusion, irrigation-derived sediments exert a significant influence on the mineralogical composition of irrigated soils. Due to the periodic deposition of suspended sediments on field surfaces during irrigation, various mineral assemblages form and accumulate within the soil, often leading to an overall increase in their content.

Irrigation-Derived Waters and the Mechanical Composition of Soils

Irrigation-induced waters are naturally non-saline and therefore classified among the weakly fresh waters, with a mineralization level of approximately 0.5 g/L. Typically, due to the periodic deposition of sandy to light loamy irrigation sediments between irrigation network rows, the more these sediments accumulate and improve the soil structure, the higher the fertility becomes. Hence, specialists in the field have identified irrigation-induced sediments as one of the key factors contributing to soil fertility enhancement.

It should also be particularly noted that irrigation sediments sometimes exert their influence very slowly, and in many cases, unexpected effects may also occur. As mentioned above, irregular deposition of such sediments in the upper parts of irrigated fields often leads to lightening of the mechanical composition in higher sections and heavier textures in lower parts, resulting in the formation of partial mesorelief. Under modern, highly mechanized irrigation agriculture, effective use of these sediments must be aligned with soil-specific characteristics and management practices.

The main soil types studied in the region differ significantly in mechanical composition—ranging from light, medium, and heavy loams to sandy and clayey textures in certain locations. Each soil's unique texture determines its specific physical properties, which, in turn, reflect their genesis and evolutionary development.

Within the Navoiy Region of the Zarafshan Basin, the primary soil types investigated include:

- Newly reclaimed gray-brown soils,
- Newly irrigated gray-brown soils,
- Old irrigated gray-brown soils,
- Irrigated light gray soils,
- Irrigated takyr-meadow soils, and

- Irrigated meadow soils.

Comparative data on their mechanical composition are presented in Table 4.1.1. As shown in the table, both the total proportion of mechanical particles of different sizes and their distribution throughout the soil profile exhibit distinctive characteristics for each soil type.

Irrigated Light Gray Soils

In terms of mechanical composition, irrigated light gray soils are primarily characterized by light sandy-loamy textures and, in some cases, mixed medium loamy and fine sandy layers.

In these soils, physical sand (>0.01 mm) fractions are dominated by fine sand (0.1– 0.05 mm) and coarse silt (0.05–0.01 mm) particles. The content of fine sand ranges between 9.0–11.1%, while coarse silt fluctuates between 37.1–41.0%. The proportion of physical clay (<0.01 mm) varies within 33.2–47.7%, of which medium silt (0.01–0.005 mm) accounts for 10.4–12.9%, and fine silt (0.005–0.001 mm) comprises about 16.5–20.5% (see Table 4.1.1).

Newly Reclaimed Gray-Brown Soils

These soils occupy the main parts of newly reclaimed areas in Karmana, Qiziltepa, and Konimex districts, totaling approximately 5,628 hectares. Geographically, they are distributed between the Qiziltepa Plateau and the southern foothills of the Qoratog‘ Range, extending northward to the third terrace of the Zarafshan River, eastward through the “Navoiy” and “Uzbekistan” agricultural massifs in Karmana District, and westward to the “Bo‘ston” massif in Qiziltepa District.

Their main source of irrigation is the Navoiy Canal, approximately 45 km long, which originates from the Tudako‘l Reservoirs and supplies water to newly reclaimed areas of Karmana and Qiziltepa districts.

The parent materials of these soils consist of deluvial and proluvial deposits, distributed across slightly inclined, inclined-wavy, and wavy plains. These soils form the principal cropland areas of the aforementioned districts, where cotton, wheat, alfalfa, maize, and other crops are cultivated, alongside vineyards and orchards.

In terms of texture, these soils are light to medium loamy, containing 34.15–38.32% physical clay, while fine clay particles (<0.001 mm) account for 15.75–18.82% of the soil profile (Table 4.1.1). Although the development of agro-irrigation layers remains moderate, the plow and subplow horizons are distinctly formed.

This group represents the main soil type developed on deluvial-proluvial, proluvial wavy, and sloping plains. Their area is bounded by the Navoiy Canal to the south, the Bukhara–Tashkent highway to the north, the Tinchlik railway station to the east, and the Qiziltepa District boundary to the west.

These soils formed on deluvial-proluvial and proluvial deposits. In their lower horizons, gravelly and sandy layers are densely compacted and intermixed, above which a gypsiferous layer has developed. The thickness of this gypsum horizon typically ranges from 50–80 cm, extending to 150–240 cm.

Their mechanical composition varies from light, medium, to heavy loams, with some profiles exhibiting sandy or clayey heavy loam layers in the lower sections (Table 4.1.1). The main fractions are 0.25–0.1 mm and 0.1–0.05 mm, while physical clay (<0.01 mm) constitutes 30.2–43.5%, medium silt (0.01–0.005 mm) — 12.1–15.6%, and fine silt (0.005–0.001 mm) — 6.1–10.6%.Compared to the light gray and newly reclaimed gray-brown soils, these soils show a more balanced and slightly heavier mechanical composition.

Old Irrigated Gray-Brown Soils

Within the study area, old irrigated gray-brown soils are distributed across Hazora and Do‘rman massifs of Karmana District and the northeastern part of Toshrabot massif in Qiziltepa District, formed on proluvial-alluvial deposits. Their total area covers approximately 652 hectares.These soils exhibit medium to heavy loamy and clayey textures, with lower horizons composed of stony, gravelly, and sandy materials. Located in low-lying wavy plains, they have been under continuous irrigation agriculture for centuries, using waters from the Zarafshan River.

Morphologically and physically, these soils differ sharply from the light gray, newly reclaimed, and newly irrigated gray-brown soils. This difference is attributed to both their long irrigation history and the proximity of groundwater to the soil surface, which enhances salinization processes.

Their fine sand (0.1–0.05 mm) content ranges 4.3–14.5%, while coarse silt (0.05– 0.01 mm) constitutes 26.0–47.2%. The physical clay (<0.01 mm) fraction fluctuates between 35.3–68.4%, including medium silt (0.01–0.005 mm) — 8.8–18.2%, and fine silt (0.005–0.001 mm) — 13.1–29.3% (Table 4.1.1).

These soils are noticeably heavier in texture compared to others, largely due to the accumulation of fine suspended particles from irrigation water over many years. Thus, the (A_x) and (A_{xo}) horizons exhibit agro-irrigation development and textural evolution toward heavier loamy and clayey states.

Irrigated Takyr-Meadow Soils

In the Navoiy section of the Zarafshan Basin, irrigated takyr-meadow soils have developed on low alluvial and proluvial plains, covering parts of Karmana and Qiziltepa districts. Their evolution is directly associated with the Zarafshan River's activity, involving the accumulation and sedimentation of alluvial mud under arid climatic conditions.

The texture is typically heavy loamy, light loamy, or silty-clayey, consisting of layered sediments and sands. The distribution of mechanical particles of different sizes varies significantly across the profile. In heavier loamy sections, fine silt (0.005–0.001 mm) and clay (<0.001 mm) dominate, while in lighter textures, sand (1–0.05 mm) and coarse silt (0.05–0.01 mm) prevail (Table 4.1.1).

Due to their naturally heavy texture, these soils possess distinct moisture, nutrient, temperature, and aeration regimes. Therefore, improving their aggregate structure is considered a crucial agronomic task.

Irrigated Meadow Soils

This soil group formed under hydromorphic conditions and anthropogenic influence, thus reflecting complex pedogenic evolution. Found mainly on floodplains and upper terraces of the Zarafshan River, they occupy small areas adjacent to the river and have been subjected to human activity (drainage, cultivation, irrigation) for centuries.Groundwater levels occur at 1.0–2.0 m depth, promoting gleying, oxidation- reduction, and salinization processes, as well as the development of elementary soil- forming mechanisms.

These soils are widespread in the areas between Armijan, Yangiravot, Qumariq, Toshrabot, and Duldul villages, covering a total area of 2,452 hectares. Having been used for irrigated agriculture for centuries, they now exhibit distinct genetic and morphological traits.Their mechanical composition is medium to heavy loamy and light clayey, with physical clay (<0.01 mm) content ranging 37.1–58.3% in the plow and subplow layers, and 21.0–41.7% in lower horizons (Table 4.1.1). A gradual increase in texture heaviness is observed in deeper layers, resulting from the seasonal accumulation of suspended particles from irrigation water and natural redistribution of alluvial deposits.

Compared to newly and old irrigated gray-brown and takyr-meadow soils, irrigated meadow soils exhibit a higher proportion of medium and heavy loam textures.Excellent — here is your full dataset **professionally translated into English** and formatted as a clear, academic table suitable for inclusion in a dissertation or scientific article.
All headings, locations, and values are preserved precisely; only the language and formatting have been converted into scholarly English.

Table 4.1.1. Mechanical Composition of Irrigated Soils in the Navoiy Region

Depth, cm	Fraction content (%) by particle size (mm)							Physical clay (<0.01 mm)
	Coarse sand (>0.25)	Medium sand (0.25–0.1)	Fine sand (0.1–0.05)	Coarse silt (0.05–0.01)	Medium silt (0.01–0.005)	Fine silt (0.005–0.001)	Clay (<0.001)	(%)

7-AK Profile. Irrigated Light Gray Soils. Khatirchi District, Zarafshan Massif

Depth (cm)	>0.25	0.25–0.1	0.1–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	Physical Clay (<0.01 mm)
0–30	2.0	7.8	9.0	38.4	10.4	20.0	12.2	42.8
45–55	1.8	5.2	11.0	41.0	11.3	16.5	13.3	33.2
55–85	2.1	2.4	10.1	38.2	12.9	18.8	15.3	47.1
85–120	0.9	3.2	11.1	37.1	12.6	20.1	15.0	47.7

1-AK Profile. Newly Reclaimed Gray-Brown Soils. Karmana District, Navoiy Massif

Depth (cm)	>0.25	0.25–0.1	0.1–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	Physical Clay (<0.01 mm)
0–32	3.10	4.12	22.04	32.42	8.80	13.77	15.75	38.32
32–50	5.83	6.06	26.18	24.32	8.92	11.37	18.02	37.61
50–90	7.45	8.18	27.50	22.72	5.85	11.00	17.30	34.15
90–135	9.13	8.63	20.67	27.25	5.75	9.75	18.82	34.32

2-AK Profile. Newly Irrigated Gray-Brown Soils. Karmana District, "Uzbekistan" Massif

Depth (cm)	>0.25	0.25–0.1	0.1–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	Physical Clay (<0.01 mm)
0–30	1.5	6.0	31.1	9.2	12.1	10.0	8.1	30.2
30–60	1.2	4.7	24.2	5.5	13.5	6.1	14.8	34.4
60–90	1.3	3.1	25.0	7.10	15.6	8.5	19.4	43.5
100–130	7.0	9.5	23.4	8.2	15.4	8.1	15.4	38.9

4-AK Profile. Old Irrigated Gray-Brown Soils. Karmana District, Hazora Massif

Depth (cm)	>0.25	0.25–0.1	0.1–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	Physical Clay (<0.01 mm)
0–32	0.50	0.84	4.30	34.57	14.89	24.70	19.76	59.79
32–50	0.38	0.70	5.35	32.31	19.20	22.30	20.20	61.26
50–90	0.43	0.74	4.30	26.05	17.28	29.35	21.85	68.42
90–135	0.30	3.02	14.16	47.20	8.80	13.16	13.36	35.32

5-AK Profile. Irrigated Takyr-Meadow Soils. Qiziltepa District, G'ardiyon Massif

Depth (cm)	>0.25	0.25–0.1	0.1–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	Physical Clay (<0.01 mm)
0–35	0.9	1.7	10.5	34.5	15.4	17.8	19.2	52.5
35–46	0.3	1.2	6.3	42.7	15.5	16.0	19.3	46.8
46–90	0.9	9.6	25.1	41.1	10.0	6.1	19.5	23.3
90–135	1.9	2.5	14.0	34.5	18.7	14.2	33.2	77.1

6-AK Profile. Irrigated Meadow Soils. Navbahor District, Armijan Massif

Depth (cm)	>0.25	0.25–0.1	0.1–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	Physical Clay (<0.01 mm)
0–25	1.4	0.3	20.7	38.4	11.2	16.6	9.3	37.1

Depth (cm)	>0.25	0.25–0.1	0.1–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	Physical Clay (<0.01 mm)
35–50	0.7	0.1	13.6	38.2	16.3	20.0	14.0	58.3
60–85	0.8	0.1	0.1	32.2	22.2	28.3	33.3	41.7
95–130	3.2	0.2	5.1	44.6	15.3	19.4	7.0	21.0

Notes for academic presentation:

- "AK" refers to *analytical soil profile (cut).*
- "Physical clay (<0.01 mm)" includes medium silt, fine silt, and clay fractions.
- The data reveal textural differentiation both vertically and horizontally among the studied irrigated soil types.

The Soils Studied and Their Development under the Influence of Constantly Flowing Waters

The soils under study have developed under the influence of constantly flowing irrigation waters. Due to the variability in the size and composition of suspended sediment particles contained in the irrigation water, the mechanical composition of these soils also varies. The fact that the upper and middle horizons of these soils have sandy or sandy-loam textures is mainly due to the periodic renewal of fine, light-textured alluvial deposits carried by river water. The observed increase in the mechanical composition of the lower soil layers in some areas can be explained by the washing down and deposition of finer particles from the upper layers, as well as by internal weathering processes occurring within the soil profile.

From the analyses presented above, it becomes clear that a general characteristic feature is evident for all soils in the studied area. According to the distribution patterns of mechanical fractions obtained from the analyses, a certain regularity is observed. For instance, based on the maximum values of particular fractions, the quantities of medium silt (0.01–0.005 mm) and clay (<0.001 mm) particles in the plow layer and sub-plow layer tend to increase consistently from the southwest toward the northeast — that is, from higher elevations downward in accordance with the direction of the river flow.Following this regularity, the sequence of increasing quantities of medium silt (0.01– 0.005 mm) and clay (<0.001 mm) fractions across soil types can be expressed as follows:

Irrigated light gray soils > Newly developed dark brown soils > Newly irrigated dark brown soils > Old irrigated dark brown soils > Irrigated meadow soils > Irrigated takir-meadow soils.

In our opinion, the main reason for this pattern is the vertical zonation law governing the development of irrigated soils, resulting directly and indirectly from the influence of irrigation waters and their suspended sediments of varying particle sizes.In the upper and middle horizons of these soils, the proportion of clay particles (<0.001 mm) increases, which in turn leads to a gradual increase in the heaviness of the mechanical composition.

Research results indicate that the main component of the mechanical composition consists of coarse silt (0.05–0.01 mm) particles. This fact once again confirms that these soils have been exposed to long-term physical weathering processes. As the irrigation period increases, notable changes occur both in the overall mechanical composition and in the relative proportions of particles of different sizes within the soil. Based on the analytical data on mechanical composition presented in Table 4.1.1, it can be concluded that in all soil profiles, regardless of the type or condition, the increase in the proportion of clay particles at certain depths indicates the presence of a leaching process within the soil profile.

In assessing the genetic characteristics of the region’s soil cover, as well as internal weathering and sedimentation processes, the proportion of clay particles plays an important role. Analyzing the data in Table 4.1.1, it can be observed that in all cases, the amount of clay particles in the sub-plow and subsequent layers (at depths of 30– 80 cm, and in some cases even in the upper plow layer) is higher than that in the parent material layers. This phenomenon can be regarded as a direct result of the irrigation process. It is commonly known as “mudding” (loyqalanish) and occurs as a consequence of irrigation, during which the soil profile remains moist for extended periods, and high air temperatures promote internal weathering processes.

In general, agro-irrigational deposits consist of fine sediments derived from river alluvium that are transported by water and deposited in specific locations, forming alluvial and overbank sediments. These sediments are primarily formed through water erosion on sloping terrains.

Following the principle of vertical zonation, irrigated agriculture facilitates the gradual development of the region’s soils. According to this principle, in irrigated soils, the amount of fine silt (0.01–0.005 mm) and clay (<0.001 mm) particles in the plow layer tends to increase progressively.

4.2. General Physical Properties of the Main Soils

The results of geographic comparative analysis, analytical and cartometric methods conducted in the studied area provide the foundation for examining the morphological structure, characteristics, and properties of the dominant soil types distributed across the region. According to the soil classification system adopted in the Republic of Uzbekistan, and based on the guidelines applied by the State Scientific Research Institute of Soil Science and Agrochemistry ("UzDaverLoyiha"), the following soil types were identified and studied in the research area:

- Newly developed dark brown soils;
- Newly irrigated dark brown soils;
- Old irrigated dark brown soils;
- Irrigated takir-meadow soils;
- Irrigated meadow soils.

The main soil groups listed above are widely distributed across the piedmont, deluvial, proluvial, proluvial-alluvial, and alluvial geomorphological units of the study area. In these geomorphological settings, various soil-forming processes take place, and the general physical properties of the soils play a crucial role in their development and fertility.

In the irrigated soils of this region, the evaluation of processes resulting from irrigation and intense anthropogenic activities, the determination of soil fertility, as well as the regulation of water and nutrient regimes, and the establishment of proper irrigation and leaching norms, are all carried out based on the general physical properties of the soils.

From the data presented in Table 4.2.1, it is evident that in irrigated light gray soils, the specific (bulk) density in the plow and sod layers ranges from 2.51 to 2.60 g/cm³. The lower specific density in the plow layer compared to deeper horizons is associated with the higher humus content in this layer. Therefore, this indicates that the upper horizon of the soil profile is richer in humus.

Table 4.2.1

General Physical Properties of the Main Irrigated Soils in the Studied Area *(Translated and adapted from A.U. Akhmedov, R.Q. Qoziyev, 1991; N.A. Yakubov, 1970)*

Soil Type and Profile (Author, Year)	**Layer Depth (cm)**	**Bulk Density (g/cm³)**	**Particle Density (g/cm³)**	**Porosity (%)**	**Maximum Hygroscopicity (%)**	**Total Moisture Capacity (%)**	**Water Permeability (10 hr/mm)**
Irrigated Light	0–28	1.13	2.51	50.20	3.5	25.10	115

Soil Type and Profile (Author, Year)	Layer Depth (cm)	Bulk Density (g/cm³)	Particle Density (g/cm³)	Porosity (%)	Maximum Hygroscopicity (%)	Total Moisture Capacity (%)	Water Permeability (10 hr/mm)
Gray Soils, Profile 2 (A.U. Akhmedov, R.Q. Qoziyev, 1991)							
	28–36	1.26	2.60	48.06	3.6	22.91	—
	36–59	1.35	2.64	47.74	3.8	24.80	—
	59–110	1.37	2.66	47.76	4.1	22.05	—
	110–150	1.41	2.71	47.77	3.3	21.80	—
Irrigated Dark Brown Soils, Profile 3 (A.U. Akhmedov, R.Q. Qoziyev, 1991)	0–28	1.35	2.69	45	2.3	14.4	187.4
	28–36	1.30	2.70	50	2.1	11.00	—
	36–59	1.42	2.71	47	4.5	11.00	—
	59–110	1.37	2.75	51	5.0	16.4	—
	110–150	1.35	2.80	55	5.8	16.3	—
Irrigated Takir-	0–28	1.22	2.67	54	5.3	12.0	98.5

Soil Type and Profile (Author, Year)	Layer Depth (cm)	Bulk Density (g/cm³)	Particle Density (g/cm³)	Porosity (%)	Maximum Hygroscopicity (%)	Total Moisture Capacity (%)	Water Permeability (10 hr/mm)
Meadow Soils, Profile 13 (N.A. Yakubov, 1970)							
	28–38	1.46	2.68	45	5.1	13.4	—
	38–60	1.48	2.71	45	4.6	12.2	—
	60–130	1.50	2.70	44	5.5	14.4	—
Irrigated Meadow Soils, Profile 4 (A.U. Akhmedov, R.Q. Qoziyev, 1991)	0–28	1.40	2.71	49	3.6	25.2	175.5
	28–38	1.42	2.73	48	3.4	22.6	—
	38–60	1.33	2.73	51	3.3	23.8	—
	60–130	1.37	2.73	50	3.5	26.7	—

- Bulk Density indicates the mass of soil per unit volume, including pore spaces.
- Particle Density refers to the mass per unit volume of the solid soil particles only.
- Porosity is calculated based on the relationship between bulk and particle density.
- Maximum Hygroscopicity and Total Moisture Capacity describe the soil's water retention properties.

- Water Permeability reflects the infiltration capacity, measured over a 10-hour period.

The specific (particle) density is considered a long-term stable physical indicator of the soil. Depending on the relationship between specific and bulk density, the soil porosity (ranging between 50.20–47.77%) gradually decreases from the upper to the lower horizons. This characteristic necessitates the implementation of all agrotechnical measures uniformly across these soils. However, particular attention should be directed toward improving the soil's aggregate structure, as enhancing soil aggregation simultaneously improves its porosity, thereby positively influencing its hydrophysical properties.

In irrigated dark brown soils, the bulk density reaches its maximum (up to 1.42 g/cm³) in the middle horizon, while in the remaining layers it varies between 1.30 and 1.37 g/cm³, decreasing again in the lower horizon (see Table 4.2.1). The particle density ranges from 2.69 to 2.71 g/cm³, and this indicator tends to increase from the upper layers downward. The soil porosity in these profiles varies between 45–50%. The maximum hygroscopic moisture and total moisture capacity also differ between the upper and gypsum-containing horizons.

In irrigated takir-meadow soils, the bulk density reaches its maximum (up to 1.46 g/cm³) in the middle horizon, while in other layers it varies between 1.48 and 1.50 g/cm³, increasing toward the lower horizon (Table 4.2.1). The particle density averages 2.71 g/cm³, showing a slight decrease from the surface layers to the deeper horizons. The porosity ranges between 54–45%, gradually declining downward through the soil profile. The maximum hygroscopicity values also vary across the horizons (Table 4.2.1).

In irrigated meadow soils, the bulk density is highest in the sub-plow horizon (up to 1.42 g/cm³), while in the remaining layers it ranges from 1.33 to 1.37 g/cm³ and decreases in the lower layers (Table 4.2.1). The particle density averages 2.71 g/cm³, gradually increasing downward to 2.73 g/cm³ and showing relatively uniform distribution throughout the profile. The porosity decreases from 54% in the upper layers to about 45% in the lower horizons.

In general, for all studied soils of the region, the bulk density, which characterizes the degree of compaction of genetic horizons and parent material, follows a common regularity — it increases progressively from the upper to the lower horizons of the profile. This increase in density in the lower horizons is associated with a decrease in humus content and with the accumulation of leached substances within soil pores as a result of long-term irrigation processes. Consequently, the overall porosity of these soils sharply decreases. To improve the hydrophysical properties of these soils in a positive direction, it is recommended to apply various biological agrophysical measures aimed at enhancing soil structure and porosity.

4.3. Field Moisture Capacity and Water Permeability of the Main Soil Types

A comprehensive study of the general physical and hydro-physical properties of soils serves as a scientific basis for developing measures aimed at increasing soil fertility. Indeed, without knowledge of the field moisture capacity and water permeability of the region's soils, it is impossible to accurately assess soil fertility or effectively implement reclamation measures in the field of soil salinity management.The field moisture capacity and water permeability of the main soil types within the Zarafshan Basin of the Navoi Region studied by us can be interpreted using the data presented in Table 4.2.1.

In irrigated light gray soils, the field moisture capacity in the upper and middle horizons ranges from 24.80% to 25.10%, gradually decreasing in the lower layers. The water permeability of these soils over a 10-hour period amounts to 115 mm. This indicates that all agrotechnical operations (such as plowing and irrigation) must be carried out uniformly across these soils. However, regardless of their density, it is essential to improve the soil aggregate structure, as this directly influences soil porosity and water retention capacity.

In irrigated dark brown soils, the total moisture capacity varies between the upper and gypsum-containing layers. In the middle and upper horizons, it ranges from 11.0% to 14.4%, with a slight increase in the lower horizons. The water permeability of these soils is 187.4 mm over 10 hours (Table 4.2.1). The reduced porosity in the upper layers, the presence of a highly compacted subsurface horizon, and a gypsum- enriched layer collectively contribute to decreased water permeability. These features reflect the distinct genetic, morphological, agrophysical, and meliorative- ecological characteristics of dark brown irrigated soils.

In irrigated takir-meadow soils, the total moisture capacity also varies between the upper and gypsum-containing horizons, ranging from 12.0% to 12.2% in the upper and middle layers and increasing slightly to 14.4% in the lower horizon. The water permeability over a 10-hour period is 98.5 mm (Table 4.2.1). The relatively low permeability in these soils can be attributed to their heavy mechanical composition, the rapid disintegration of aggregates during irrigation, and the presence of soluble salts in the soil matrix.

In irrigated meadow soils, the field moisture capacity varies across horizons: it reaches 25.2–26.7% in the upper and lower layers and 22.6–23.8% in the middle horizon, showing uneven distribution throughout the soil profile. The water permeability of these soils is 175.5 mm over 10 hours (Table 4.2.1).

It should be emphasized that, according to the above data, the total porosity of all studied soil types in the region fluctuates around 45–50% in the upper horizon.

However, although high porosity represents a favorable physical characteristic, it does not by itself serve as the main indicator of soil water permeability. Therefore, the degree of water permeability in the main soil types of the region is determined not only by porosity but also by other agrophysical factors, including soil structure, texture, and compaction.

4.4. Moisture and Hygroscopic Moisture of the Main Soils

The ability of the soil to absorb water vapor from the air determines its hygroscopicity. Under natural conditions, any type of soil contains a certain amount of hygroscopic moisture. Earlier studies have established that the level of soil hygroscopicity varies depending on its mechanical composition and organic matter content. Soils rich in humus and fine fractions exhibit significantly higher hygroscopicity compared to sandy soils with low humus content. The hygroscopic nature of soils is therefore primarily influenced by the amount of humus and colloidal clay particles contained within them.

Moreover, it has been proven that in saline soils containing salts such as $CaCl_2$, $MgCl_2$, and NaCl, hygroscopicity tends to be higher than in non-saline soils. Soil hygroscopicity also varies with air humidity and temperature, reaching its maximum level when the soil is saturated with both air and water. These relationships have been further confirmed in our own research.

In our studies conducted in the Zarafshan Basin of the Navoi Region, data concerning soil moisture and maximum hygroscopic moisture are presented in Table 4.2.1. In the light gray soils of the region, due to their location in relatively arid piedmont plains with low annual precipitation, biomass accumulation on the soil surface is limited. Consequently, the accumulation of humus is also reduced. This, in turn, explains the relatively low moisture content and hygroscopicity of light gray soils compared to typical and dark gray soils. The maximum hygroscopicity (MH) in the arable and sub-arable layers of these soils ranges from 3.5 to 4.1%, which can be attributed to the proximity of groundwater and the gradual increase in soil texture heaviness with depth.

In irrigated dark brown soils, the maximum hygroscopicity varies between 2.3 and 4.3%, increasing downward through the profile (Table 4.2.1). The relatively low hygroscopicity in the upper horizons is associated with the persistent presence of dry and hot air near the surface, low humus content, proximity of groundwater, and the soils' general tendency toward salinization.

In irrigated takir-meadow soils, the maximum hygroscopicity varies across horizons. In the arable and sub-arable layers, it averages 5.3–4.6%, respectively (Table 4.2.1). The differences in hygroscopicity across horizons are related to the heavy mechanical composition of the soil and the vertical distribution of fine fractions.

Additionally, the relatively higher humus content in the upper layers and the greater degree of air and water saturation near the surface contribute to these variations.In the irrigated meadow soils of the region, the maximum hygroscopicity within the 0–60 cm layer ranges from 3.6 to 3.3%. This pattern reflects the influence of several factors: the heavy mechanical texture of the soil, the accumulation of organic matter and humus near the surface, improved air–water saturation in the upper horizons, and the upward movement of saline groundwater. As a result, plants are able to utilize water directly from the available soil moisture within the profile.

It was found that the moisture and maximum hygroscopicity of the studied soil types differ considerably from one another. To improve these physical properties, it is necessary to enhance the humus status of the soils, increase the quantity of clay colloidal particles, and improve the air–water regime and aggregate structure of the soil.

Information on the general physical properties of soils is of great practical importance for assessing the impacts of irrigation and intensive anthropogenic processes, determining soil fertility levels, and accurately characterizing the soil water and nutrient regime. These data are also essential for calculating soil water, nutrient, and salt reserves, as well as for establishing appropriate irrigation and leaching norms and planning the volume of work related to the collector–drainage system.

In the present period, as farm enterprises are rapidly developing in the region, knowledge of the physical and hydro-physical properties of soils—such as water permeability, field capacity, bulk density, and hygroscopicity—has become increasingly important. This information is crucial for addressing irrigation water management, evaluating soil bonitet (fertility scores), determining tillage depth, and implementing resource-saving and soil-protective technologies in agriculture. Therefore, it is necessary to develop and introduce scientifically grounded measures aimed at improving the fertility of these soils.

Chapter V. Chemical, Agrochemical, and Physico-Chemical Properties of Soils in Navoi Region and Their Evolution

5.1. Salinity Indicators of Soils Formed in Various Geomorphological Zones and Their Transformation Under Irrigation

In many regions of our Republic, including the Zarafshan basin, eluvial, deluvial, and proluvial deposits have been formed in the foothill areas as a result of the weathering of limestone, sandstone, schist, granite, and other rocks belonging to the Turkestan mountain system, the Qoratogʻ highlands, and the Ziyovuddin–Zirabuloq ranges under the influence of historical geological processes. These geological deposits, due to their genesis, geography, structure, composition, and the impact of soil-forming processes, give rise to various soil types. Soil-forming processes in the Zarafshan basin develop under the influence of factors typical of the foothill desert zone.

The location of the studied area at the foothills of the Qoratogʻ mountains in the west and the Turkestan mountain system in the north, the development of soils on eluvial, deluvial, and proluvial deposits under sparse vegetation cover, and the scarcity of precipitation combined with high temperatures have led to the formation of soil types characteristic of this region. These include typical and light gray-brown soils, newly reclaimed serozem-brown, irrigated serozem-brown, old irrigated grayish serozem- brown, takyr-meadow, and meadow soils. The soil cover of the region is highly complex, with numerous soil variants such as stony, gravelly, sandy, loamy-sandy, gypsiferous and non-gypsiferous, shallow, moderately layered, and weakly developed soils. In later periods, particularly during 1976–1980, large-scale land reclamation led to the rise of groundwater levels near the soil surface. As a result, secondary salinization processes began to develop in irrigated lands. The initial automorphic soil-forming processes gradually transformed into hydromorphic soil- forming processes.

The soil cover of the region has been studied by many scholars. S. Abdullayev [3], having investigated the agro-physical properties and salt regime of irrigated soils bordering Malikchuli in Navoi Region, concluded the following: these soils are poorly supplied with organic matter; irrigation alters their agro-physical properties; mineralized groundwater and salts in Neogene deposits of the region contribute to the salinization of soils in the Bukhara and Karakul oases.

Although the need for in-depth study of the periodic changes occurring in irrigated soils has long attracted the attention of scientists, comprehensive methodologies for their analysis had not been sufficiently developed. Therefore, beginning in 1975, researchers focused their efforts on developing methods for studying irrigated soils.

S. N. Rijov and M. M. Toshqo’ziyev [1978] identified significant increases in the main soil fertility elements in irrigated gray-brown soils under conditions of advanced agricultural management. They noted sharp changes also occurring in takyr soils (particularly increases in humus and nutrient contents), concluding that takyr and gray-brown soils differ considerably from each other in this regard.

B. V. Gorbunov, G. M. Konobeyeva, and A. I. Tverdostup [1978], studying the reclamation of areas with serozem-brown soils in the Kyzylkum using artesian well water and the construction of collector-drainage networks, as well as ways to increase fodder reserves for Karakul sheep breeding, observed that the proximity of groundwater to the soil surface and its low mobility lead to the development of salinization processes in certain areas.

R. Qo'ziev [1994], investigating the genetic structure of serozem-brown soils, noted the presence of clay illuviation and iron enrichment processes within the serozem horizon and demonstrated that these processes constitute major factors in the development of this soil as a distinct soil type.

A. E. Ergashev, U. K. Qosimov, and A. G. Joʻrayev [1976], studying the application of organic and mineral fertilizers in newly irrigated serozem-brown soils of Malikchul, investigated various application rates of N, P_2O_5 , and manure. The highest yield (39.6 c/ha) was recorded in the variant with 375 kg/ha nitrogen, 175 kg/ha phosphorus, and 20 t/ha manure, which provided an additional 7.0 c/ha compared to the control.

A. Z. Genusov [1981], analyzing the soils of Central Asia, particularly the serozem- brown, takyr, and takyr-like soils of the Turan province desert zone, theoretically and practically demonstrated changes in their morphological structure and decreases in fertility under the influence of humus accumulation, clay illuviation, and erosion processes. The research area—Malikchul—is classified by A. Z. Genusov as belonging to the foothill alluvial-proluvial plains and the alluvial plains of the Zarafshan Valley.

These geomorphological units occupy extensive areas within the Turan province and merge directly with the Qarshi desert. As a result, these units are formed by the connection of ancient and modern river terraces with the foothill plains and are lithologically composed of coarse material—stone, gravel, sand, and sandy loam in the lower part—and thin layers of loam and clay in the upper part. Considering this, irrigated soils distributed across the foothill proluvial-alluvial plains have been classified as distinct soil types based on their irrigation history and the duration of agricultural use. According to the author, irrigation fundamentally alters the water and thermal regimes of serozem-brown soils.

Although irrigated soils of the Zarafshan basin develop under conditions similar to those of sandy desert and takyr soils, they differ sharply from them. Unlike these soil types, serozem-brown soils exhibit a distinctly expressed two-layered genetic structure. Their upper part is slightly porous and light-colored, while the middle horizons consist of serozem-brown, calcareous, and gypsiferous layers.According to A. N. Rozanov [1951], the gypsum and carbonate compounds found in serozem-brown soils originate from the weathering of metamorphic sedimentary rocks.According to scientific theories, the formation of gypsum layers and serozem-brown horizons in the soils of the Zarafshan basin is associated with the upward movement of sulfate salts through groundwater and the accumulation of iron oxides through soil-forming processes. Moreover, due to geological variations in the foothill zones and deluvial-proluvial plains, the gypsum, carbonate, and compacted serozem- brown horizons characteristic of these soils appear in different thicknesses, quantities, and forms.

Geographical comparative analysis, analytical methods, and cartometric techniques employed in the area form the basis for studying the morphological structure, characteristics, and properties of serozem-brown soils distributed in the region.According to the soil classification adopted in the Republic of Uzbekistan and the guidelines currently used by the Soil Science and Agrochemistry Research Institute ("O'zdaverloyiha"), the following soil types are present in the studied area: irrigated light gray-brown soils; newly reclaimed serozem-brown soils; newly irrigated serozem-brown soils; old irrigated serozem-brown soils; irrigated takyr-meadow soils; and irrigated meadow soils.

The major soil groups listed above are widely distributed in the foothill, eluvial, deluvial, proluvial, proluvial-alluvial, and alluvial geomorphological units of the studied area. Various soil-forming processes occur within these soils, including the formation of agro-irrigation horizons, their degree of cultivation, and patterns of salt accumulation.

Newly Reclaimed Grayish-Brown Soils

These soils occupy the main part of the newly reclaimed areas of Navoi Region, with a total area of 5,628 hectares.Geographically, the newly reclaimed grayish-brown soils are distributed across the lands located on the Kyzyltepa Plateau and the southern part of the Koratog mountain system, north of the 3rd terrace of the Zarafshan River, to the east between the "Uzbekistan" cooperative farm of Karmana District, and to the west between the "Bostan" cooperative farm of Kyzyltepa District.

The parent materials of the newly reclaimed grayish-brown soils are deluvial and proluvial deposits, and they are found on gently sloping, slope–wavy, and wavy plains (Figures 5.1.1 and 5.1.2).The newly reclaimed grayish-brown soils make up the main croplands of the above- mentioned districts of Navoi Region (Karmana and Kyzyltepa). Cotton, wheat, alfalfa, corn, and other crops are grown on the reclaimed lands, and vineyards and apple orchards have also been established.

Figure 5.1.1. General view of newly reclaimed grayish-brown soils developed on deluvial and proluvial parent materials.

Under the influence of irrigation, the morphological structure of these soils-particularly the characteristics of the AV humus horizon, the V transitional horizon, and the gypsic horizons-has undergone significant changes. As a result of applying agro-technical measures such as irrigation, tillage, and fertilization, clearly defined plow and sub-plow layers have formed within the profile of the newly reclaimed grayish-brown soils.

Due to irrigation, the groundwater table beneath these soils rises to about 2.0–3.0 meters from the surface. The upward movement of groundwater, along with its evaporation during the spring, summer, and autumn seasons, has led to the development of salinization processes in the strongly gypsified grayish-brown soils.

As noted above, the newly reclaimed grayish-brown soils have been subjected to salinization primarily due to the evaporation of relatively shallow groundwater. In their upper, non-saline horizons (Table 5.1.1, Profile 1 AK), the amount of dry residue in the 0–30 cm and 30–55 cm layers ranges from 0.113% to 0.073%, while in the deeper 90–120 cm and 167–200 cm layers it reaches 1.030–1.250%. According to these indicators, the upper parts of the profile are slightly to moderately saline, whereas the lower horizons fall into the category of moderately saline soils.

Thus, during the process of utilizing newly reclaimed grayish-brown soils for irrigated agriculture, it becomes evident that their morphological structure, as well as their physical, chemical, agrochemical properties and the quantity and composition of salts, undergo significant changes.

These changes include the following:

1. the formation of plow (Ax) and sub-plow (Axo) horizons, with their average thickness reaching 50–60 cm;
2. the development of agro-irrigational horizons, which differ from those of natural grayish-brown soils and represent the initial stage of anthropogenic soil formation;
3. the rise and evaporation of groundwater towards the upper soil layers, initiating salinization processes and causing salts to accumulate mainly in the middle and lower horizons.

Newly irrigated grayish-brown soils. These soils comprise the main soil group developed on the deluvial–proluvial, proluvial undulating, and sloping plains of the Malikchul region. The newly irrigated grayish-brown soils have formed on deluvial–proluvial and proluvial deposits, where the lower portions of these parent materials contain densely compacted and intermixed gravels, pebbles, and sands, above which a gypsic layer has developed. Typically, this gypsic layer extends from a depth of 50–80 cm to 150–240 cm.The results of laboratory analyses of the characteristics specific to newly irrigated grayish-brown soils are presented in Table 5.1.1.

Based on these indicators, the soils described differ from virgin and newly reclaimed grayish-brown soils. In various categories of irrigated grayish-brown soils, the highest amounts of dry residue and gypsum accumulate in the lower horizons, whereas in solonchak-like, moderately, and strongly saline variants, these indicators are observed in the upper soil profile.

The amount of easily soluble salts varies across the soils studied, with their values increasing in moderately and strongly saline groups. Salinization in the studied soils is characterized as chloride–sulfate, with magnesium–sodium dominance.Furthermore, due to the duration of irrigation, soil-forming processes in irrigated grayish-brown soils undergo dramatic changes compared to their non-irrigated and newly reclaimed counterparts. These changes include:

1. in the morphological structure of Ax and Axo horizons, grayish and dark-gray features develop instead of the typical grayish-brown color, and the mechanical composition becomes somewhat heavier;
2. in the upper part of the Ax horizon, weakly to moderately saline patches are formed due to the evaporation of groundwater that has risen to shallow depths (2–3 m), resulting in increased amounts of dry residue, chloride and sulfate ions, and a reduction in the thickness of the gypsic layer.

Long-term irrigated grayish-brown soils. Within the study area, long-term irrigated grayish-brown soils are distributed on the proluvial–alluvial deposits west of the settlements of Karmana, Hazora, and Dorman, as well as in the northeastern part of the “Bo‘ston” cooperative farm in Qiziltepa District. The total area of these soils amounts to 652 hectares.

The soils described differ significantly from newly reclaimed and newly irrigated grayish-brown soils in terms of their morphological structure, physical, chemical, and agrochemical properties, as well as salt accumulation processes. These differences are attributed, on the one hand, to the long history of irrigation, and on the other hand, to the proximity of groundwater to the soil layers and the intensification of salinization processes.

In the main areas where long-term irrigated grayish-brown soils are distributed, nonsaline and weakly saline soils dominate. However, in some locations, soils with moderately saline upper horizons and strongly saline lower horizons are also encountered (Table 5.1.1).

In moderately and strongly saline soil groups, the amounts of dry residue (1.374– 3.578%), easily soluble salts (NaCl, Na_2SO_4, $MgSO_4$), and gypsum (0.13–0.30%) are low. In some soil variants, the amount of salts ranges from 0.0675–0.781%. Chloride and sulfate ion contents at a depth of 30–60 cm are recorded at 0.0816% and 0.424%, respectively. The increase in water-soluble salts (chloride, sulfate ions, and Na^+, Mg^{2+} cations) in long-term irrigated grayish-brown soils is the result of evaporation from shallow groundwater levels.

Data in Table 5.1.1 show that, due to autumn and winter leaching and spring precipitation, salts in the upper and middle soil layers are washed downward and accumulate in the lower horizons.

In inadequately leached and saline grayish-brown soils, the dry and hot climate, along with the evaporation of mineralized groundwater rising through soil capillaries, leads to seasonal salt accumulation in the upper and middle layers. During autumn and winter, these saline soils are leached again. Some of the easily soluble chloride and sulfate salts accumulated in the upper and middle layers dissolve and are removed from the soil profile. However, in certain cases, because some chloride and sulfate compounds have low solubility, a portion of them remains in the lower horizons. As these processes continue year after year and due to the slow movement of groundwater, gypsum accumulates more intensively in strongly saline soils below the 50 cm layer than in nonsaline soils.

Thus, long-term irrigated grayish-brown soils of the region differ from other soil groups distributed in the same area due to the following altered morphogenetic features, properties, and characteristics resulting from prolonged irrigation:

1. the development of agro-irrigational layers in the lower parts of the Ax and Axo horizons;

2. the variable nature of salinization processes, with the soil profile containing primarily easily soluble salts such as NaCl, Na_2SO_4, and $MgSO_4$, and in some cases, $CaSO_4$ occurring in the deeper horizons.

Irrigated Meadow Soils

This soil group has formed under the influence of hydromorphic soil-forming processes and human activity. For this reason, long-term irrigated meadow soils have developed through highly complex pedogenic processes throughout their evolutionary stages and possess distinctive characteristics.

The studied soils are mainly distributed on the floodplain and terrace surfaces of the Zarafshan River. At present, long-term irrigated meadow soils have been directly transformed over many centuries by human activities such as drainage, tillage, and irrigation, while the groundwater table plays a crucial role in their development. Groundwater occurs at a depth of 1.0–2.0 m, giving rise to hydromorphic features associated with gleying, oxidation–reduction processes, and salinization, which foster elementary soil-forming processes characteristic of meadow soils.These soils are distributed across the areas between and around the villages of Hazora, Yangirabot, Toshrabot, and Armijon, covering a total area of 2,452 hectares. Due to their proximity to the Zarafshan River, these lands have been used for irrigated agriculture for many centuries.

Despite the shallow groundwater table (1.5–2.5 m), salinization processes are relatively weakly developed in these soils. The limited expression of salinization in some parts of the territory is directly related to the sufficient drainage (permeability) of groundwater. This is evidenced by the fact that the dry residue and sulfate ion content in the lower horizons is 2.4–7.2 times lower compared to the upper and middle layers. For example, while the amount of dry residue in the 0–60 cm layer ranges between 1.540–1.860%, its content in the lower horizons decreases to 0.450– 0.645%. Sulfate salts also occur in relatively high quantities. Because groundwater beneath these irrigated meadow soils is sufficiently mobile on the one hand, and on the other hand, salts in the upper and middle horizons are periodically leached downward by winter–spring precipitation and leaching practices, salinization processes exhibit a periodic or cyclic character.

Due to the proximity of groundwater and the long history of agriculture in these areas, seasonal variations in salt content across soil horizons are frequently observed. As lower horizons possess good groundwater movement, leaching of salts occurs more readily, classifying these soils as easily leachable. Summarizing the morphological–genetic features of the irrigated meadow soils discussed above, their main characteristics can be described as follows:

1. the (Ax) and (Axo) horizons are distinctly expressed in dark-gray and grayish colors;
2. the transitional horizon (AV) consists of two agro-irrigational layers, whose lower parts exhibit signs of gleying;
3. the shallow groundwater table (approximately 180 cm) plays an important role in shifting soil-forming processes toward meadow formation;
4. sulfate salinization processes are highly developed.

Irrigated Light-Colored Serosem Soils

These soils represent one of the main soil types of the piedmont zone of Navoi Region and occupy certain irrigated areas in the foothills of the Qoratog Mountains, located in the northwestern extension of the Turkestan mountain range, within the Xatirchi and Karmana districts.

According to recent studies, moderate and strong salinization processes are observed in these soils. Earlier research by N.I. Felitsiant (1984) reported that irrigated light- colored serosem soils were either unaffected or only weakly affected by salinization. However, over the past 30–40 years, various salinization processes have developed within this soil group. Soil samples collected from profile AK–7 in the Zarafshan Massif of Xatirchi District show that dry residue in the 0–30–60 cm layer ranges from 1.25–2.320%. Based on chloride salinity, the soils exhibit moderate to strong salinity levels (0.0604–0.0781%), while deeper horizons show moderate salinity around 0.0568%. In recent years, the rise of groundwater levels and the inflow of collector and wastewater into the upper reaches of the Zarafshan River have contributed to the development of moderate and strong sulfate salinization in these areas. For example, in the 0–30 cm layer, sulfate salts reach 0.750% (strong), and in the 0–60 cm layer, they reach 0.633% (moderate), as shown in Table 5.1.1.

The development of salinization processes in this area is associated with the following factors:

- the distinctive natural and anthropogenic conditions, as well as the varying effectiveness of the drainage (collector-drainage) systems and groundwater movement;
- the presence of initial (primary) salt reserves in various soil–substrate layers, which, under irrigation, transition from passive to active states;
- the increase in the inflow part of the regional water balance, causing groundwater to rise closer to the soil surface and enhancing evaporation;
- the evaporation of groundwater leading to an increase in mineralization, the upward movement of salts into poorly moistened and dry horizons, the accumulation of toxic salts, and acceleration of salinization processes.

Irrigated Takyr–Meadow Soils

These soils form the main cropland areas of Karmana and Qiziltepa districts of Navoi Region. Cotton, wheat, alfalfa, maize, and other crops are cultivated on reclaimed lands, and vineyards and orchards have also been established.Under the influence of irrigation, significant changes occur in the morphological structure of these soils, particularly in the AV humus horizon, the V transitional horizon, and the gypsic horizons.

The application of agro-technical practices such as irrigation, tillage, and fertilization has resulted in the formation of well-defined plow and sub-plow layers within their profiles.Due to irrigation, groundwater beneath these soils rises to about 2.0–3.0 m from the surface. The approach of groundwater toward the surface, coupled with its evaporation during spring, summer, and autumn, leads to the development of chloride salinization processes.

As noted earlier, newly reclaimed grayish-brown soils also become saline due to the evaporation of relatively shallow groundwater. In their upper horizons (Table 5.1.1, Profile 3 AK), the dry residue content ranges between 2.123% in the 0–30 cm layer and 1.115% in the 30–60 cm layer. Chloride salts reach 0.0888% in the 0–30 cm layer (strong salinity), while in the lower horizons, chloride salts are evenly distributed at 0.0568%, producing moderate salinity. Sulfate salinity is not observed in these soils. Thus, the upper horizons exhibit strong salinity, whereas the lower horizons show uniform moderate levels.

Such salt distribution patterns within the soil profile are directly linked to the region's persistently arid climate, the movement of groundwater, and soil texture. Due to rapid evaporation in the surface horizons of takyr–meadow soils, a greater accumulation of salts occurs in the upper layers, leading to pronounced salinization.

5.2. Chemical and Agrochemical Properties of Soils and Their Transformation Under Irrigation

The principal soil types distributed within the Navoi Region of the Zarafshan Basin differ significantly from one another in their morphological structure, agrochemical, physicochemical, agrophysical, and especially ameliorative properties. The light- colored serosem soils formed in the study area occupy parts of the Zarafshan Massif of Xatirchi District and certain lands of Karmana District.

These soils represent a sub-type of serosem soils and, in comparison with the two previously described sub- types and their adjacent irrigated grayish-brown soils, irrigated takyr–meadow soils, and irrigated meadow soils, they differ sharply in their chemical and agrochemical characteristics. Because the humus content of light-colored serosem soils is relatively low, the concentrations of nutrient elements—total nitrogen and, to some extent, phosphorus—are also expressed in low numerical values (Table 5.2.1). In particular,the total nitrogen content in the plow and sub-plow layers ranges from 0.113– 0.079%, while in deeper layers it declines to 0.050–0.035%. The total phosphorus content is also low compared to other soil sub-types, amounting to only 0.113– 0.095% within the genetic horizons. Based on the data presented in Table 5.2.1, it can be concluded that the total phosphorus content increases with the duration of irrigation. The primary reason is that phosphorus fertilizers applied to agricultural crops interact with the abundant calcium in the soil, forming water-insoluble compounds.

Total potassium ranges between 190–211 mg/kg within the soil layers, and this relatively high potassium content is attributed to the parent material. The deluvial–proluvial–alluvial deposits forming the soil contain potassium-bearing minerals (such as micas). Generally, potassium compounds in soil occur in forms that are sparingly soluble in water.A characteristic feature of all irrigated soils is their high carbonate content, and irrigated light-colored serosem soils are no exception, as the soil-forming deposits of the region originate from carbonate-rich parent rocks. Consequently, increasing soil fertility requires the application of substantial amounts of mineral and organic fertilizers. It is therefore recommended to enrich farmlands with natural nitrogen sources and to extensively use local organic amendments such as manure and compost.

Newly Reclaimed Grayish-Brown Soils

Newly reclaimed grayish-brown soils comprise the primary cultivated lands of Karmana and Qiziltepa districts of Navoi Region. Although the development of agro-irrigational horizons is not yet pronounced in these soils, their plow and sub-plow layers are clearly formed. Data on humus, nitrogen, phosphorus, potassium, and CO_2 carbonates in these soils are provided in the study.In these soils, humus content decreases from the plow horizon downward. Nitrogen is highest in the plow layer (0.049–0.055%), with a C:N ratio of 5.5–5.8 and rH of 7.3–7.4. The amounts of available phosphorus and potassium vary but remain generally low, placing these soils in the poorly supplied category for these nutrients.

Carbonate content ranges from 7.8–8.56% and is distributed rather uniformly across soil horizons. Slight increases in carbonate content within the plow and sub-plow layers are associated with the accumulation of carbonates from irrigation water.Thus, the use of newly reclaimed grayish-brown soils in irrigated agriculture demonstrates their evolution under anthropogenic influence. These transformations include:

1) the formation of plow (Ax) and sub-plow (Axo) horizons reaching 50–60 cm in thickness;
2) the emergence of agro-irrigational horizons typical of newly and long-term

irrigated soils, with development occurring at the initial anthropogenic stage of soil formation;

3) the onset of salinization processes caused by the upward movement and evaporation of groundwater, leading to salt accumulation mainly in the upper horizons.

Newly irrigated grayish-brown soils have developed on deluvial–proluvial and proluvial deposits. These materials are compacted with gravel and sandy layers in the lower parts of the soil profile, above which a gypsum-enriched layer has formed. According to Table 5.2.1, the main quantities of humus and nitrogen accumulate in the plow and sub-plow layers (0.49–0.58% and 0.048–0.050%, respectively), while in deeper horizons these values decline to 0.16–0.17% and 0.015–0.020%. The C:N ratio is 5.8–6.0, and rH varies between 7.2–7.5.

Available phosphorus in the plow layer is 28.40–31.00 mg/kg, classifying these soils as poorly supplied, while deeper horizons exhibit very low levels (6.12–12.0 mg/kg). Potassium ranges from 151.8–185.3 mg/kg, also indicating low nutrient status. Carbonates range from 11.34–13.40% and are fairly uniform across soil horizons. This distribution is associated with the accumulation of carbonates from irrigation water in the upper layers, followed by periodic leaching into middle and deeper horizons.

Thus, with increasing irrigation duration, grayish-brown soils undergo pronounced pedogenic changes compared to non-irrigated and newly reclaimed grayish-brown soils. These changes include the replacement of natural grayish-brown colors in the Ax and Axo horizons with gray and pale-gray hues, the development of compact, blocky–dusty, and porous structures, and slight textural changes toward heavier compositions.

Long-term Irrigated Grayish-Brown Soils

Long-term irrigated grayish-brown soils differ sharply from newly reclaimed and newly irrigated grayish-brown soils in their morphological structure, physical, chemical, and agrochemical properties, as well as in their salt accumulation processes. These differences stem both from the ancient history of irrigation and from the close proximity of the groundwater table to the soil surface, which intensifies salinization processes.

According to research findings, changes in the amounts of humus, nitrogen, phosphorus, potassium, and other nutrients in the genetic horizons of long-term irrigated grayish-brown soils are closely linked to human activity. Due to their heavy texture and centuries of irrigation and anthropogenic pressure, these soils contain significantly higher levels of humus and nitrogen than those observed in other grayish-brown soils (Table 5.2.1).

In particular, the humus content in the plow layer (Ax) ranges from 0.812–0.944%, decreasing to 0.630–0.843% in the sub-plow layer (Axo). In the middle part of the profile, humus ranges from 0.320–0.570%, and in the lower horizons, it decreases to 0.120–0.320%. Nitrogen follows the same distribution pattern across soil horizons, directly corresponding to humus content. These soils remain poorly supplied with phosphorus (12.50–15.50 mg/kg) and potassium (198.7–200.0 mg/kg).

Carbonate content is distributed nearly uniformly across the profile (9.68–11.02%). As a result, rH values (7.2–7.4) show little variation throughout the soil profile.Thus, under long-term irrigation, the long-term irrigated grayish-brown soils exhibit the following evolutionary morphogenetic features:

1) agro-irrigational layers develop in the lower parts of the Ax and Axo horizons;
2) their mechanical composition is characterized by heavy sandy loam and clay fractions;
3) compared with newly reclaimed and newly irrigated soils, they are richer in humus and nitrogen: humus content in Ax and Axo horizons reaches 0.944% and 0.843%, respectively, while nitrogen reaches 0.056% and 0.053%, enhancing soil fertility.

Irrigated Takyr–Meadow Soils

The irrigated takyr–meadow soils of the region form the primary agricultural lands of the G‘ardiyon Massif in Qiziltepa District of Navoi Region. Their chemical and agrochemical properties are presented in Table 5.2.1.Long-term agricultural use has contributed to the formation of thick agro-irrigational layers, with well-developed plow and sub-plow horizons.

Analysis of humus, nitrogen, phosphorus, potassium, and CO_2 carbonates indicates that humus content decreases from the plow horizon to lower layers (0.94–0.35%). Nitrogen is highest in the plow layer (0.086–0.058%), with a C:N ratio of 5.5–5.8 and rH of 7.3–7.4. Available phosphorus and potassium vary across horizons but generally decrease with depth. Carbonates amount to 8.11–8.67% and remain almost uniformly distributed in the profile, although increased accumulation occurs in the plow and sub-plow layers due to irrigation water inputs.

Irrigated Meadow Soils of the Region

The irrigated meadow soils of the study area have formed under hydromorphic soil- forming processes and long-term human influence. As a result, these soils have undergone complex evolutionary development. The soils are mainly distributed on the floodplain and terrace surfaces of the Zarafshan River. In narrow areas adjacent to the river, meadow soils are locally developed.

Present-day irrigated meadow soils have changed substantially due to centuries of human activity—drainage, tillage, irrigation, and others. Relief and groundwater play key roles in their development.The humus content is considerably higher in the plow layer. In the irrigated meadow soils, the accumulation of nitrogen in the Ax and Axo horizons reaches 0.073– 0.082%. The total phosphorus content varies, ranging from 0.100 to 0.120%, with the highest values recorded in the plow layer. The amount of carbonates constitutes 9–11%, and the rN value ranges between 7.3 and 7.5.

An increase in nitrogen and phosphorus in the plow and sub-plow layers of these soils is observed. This indicates that long-term irrigation and agricultural activities in the area, as well as the systematic application of mineral and organic fertilizers, have played an important role. The increase in nitrogen content across soil horizons varies depending on the degree of anthropogenic modification of these soils. Therefore, the accumulation of these nutrients indicates improvements in the cultural state of the soil and a positive enhancement of the soil's nitrogen status.

5.3. Certain Physicochemical Properties and Adsorption Characteristics of the Soils

In the conducted studies, the cation-exchange capacity (CEC) of the soils is determined by their mechanical and mineralogical composition, degree of humification, and several physicochemical properties. The productivity and fertility of irrigated soils largely depend on their CEC and the composition of exchangeable bases (cations). The exchange complex of soils typically includes the cations Ca^{+}, Mg^{2+}, K^{+}, Na^{+}, NH_4^{+}, Al^{3+}, and Fe^{3+}. In the soils of the studied region, Ca^{+} and Mg^{2+} occupy dominant positions.

An increase in sodium content in the soil's exchange complex above 5% negatively affects the chemical and physical properties of the soil and reduces fertility, whereas levels above 10% render the soils unsuitable for irrigated agriculture. Light gray soils have a relatively high CEC, reaching 14–16 mg-eq per 100 g of soil, while the values decrease in the lower horizons. In the composition of exchangeable bases, calcium accounts for 51.75–45.3% and magnesium for 31.89–43.88%. A decrease in exchangeable calcium and increase in magnesium toward the lower horizons are observed (Table 5.3.1).

Typically, the exchange complex of light gray soils is saturated with alkaline earth metals. Numerous researchers have demonstrated that with increasing soil depth, the proportion of calcium decreases while the magnesium content increases—a pattern that was established 30–35 years ago. For example, studies conducted by I.N. Felitsiant and G.A. Konobeva (1984) found that calcium accounts for 65–63% and magnesium for 23.2–53.7% of the exchangeable bases, confirming the trends identified in the present research.

V.M. Molodsov (1968) reported that in the Zarafshan Valley, the agro-irrigational horizons of irrigated gray soils are poorly saturated with exchangeable bases, and prolonged irrigation increases the proportion of magnesium up to 20–30%. Overall, the mineralogical and total chemical composition of the gray soil types and subtypes discussed above are similar and correspond well with one another.

According to V.A. Molodsov (1968), meadow soils of the Zarafshan Valley have a relatively high proportion of magnesium in the exchange complex, although its amount does not exceed 50% of the total exchangeable bases. Researchers such as M.A. Molodsov (1968), A. Maqsudov (1971), U.B. Mirzayev (2000), and A.U. Akhmedov et al. (2001) have argued that the dominance of magnesium over calcium in these soils is associated with hydromorphic conditions, particularly the rise in groundwater levels. Under such conditions, magnesium becomes more strongly hydrated than calcium, and the hydrated magnesium is more strongly retained on clay particles through hydroxyl bond formation.

Because these soils contain low amounts of humus, their CEC is relatively modest, typically ranging between 10.19 and 12.0 mg-eq. The dominant cations in the exchange complex are Ca^{+} and Mg^{2+}. In conclusion, these soils are widely used in irrigated agriculture. Despite their low humus content and limited reserves of nutrients, they are characterized by saturation with calcium and magnesium and low salinity. To maintain soil fertility and increase crop productivity, comprehensive agro-technical measures must be implemented.

In the newly reclaimed and irrigated dark gray soils, prolonged irrigated agriculture has led to an increase in Ca^{2+} in the exchange complex (58.05–82.82%) and a decrease in Mg^{2+} content (28.0–8.39%). In the old irrigated dark gray soils, calcium dominates in both the plow and sub-plow layers, accounting for 69.64–77.7% of the total exchangeable bases. In these soils, the proportion of magnesium is 22.4–13.0%, while sodium does not exceed 2–3% (Table 5.3.1).

The accumulation of these ions in the soil follows a consistent pattern related to the movement of carbonate-rich irrigation water, which leads to the accumulation of carbonates in the upper horizons and their periodic leaching to deeper layers.

The duration of irrigation influences the Ca^{2+} and Mg^{2+} contents in the exchange complex. Thus, the increase in Ca^{2+} and decrease in Mg^{2+} in the dark gray soils under irrigated agriculture can be explained by the decomposition and leaching of $MgCO_3$ compounds due to irrigation. In the irrigated takyr-meadow and meadow soils of the studied area, Ca^{2+} and Mg^{2+} dominate the exchange complex, while K^{+} and Na^{+} play a minor role in soil formation.Long-term irrigation, tillage, and fertilization result in fluctuations in the amounts of exchangeable cations. In the profile of irrigated takyr-meadow soils, the amount of calcium decreases from 81.41 to 59.33% toward the lower horizons, whereas magnesium content increases from 3.18 to 31.89%. In the plow and sub-plow layers, calcium and magnesium remain dominant among exchangeable cations. This is attributed to the heavier mechanical composition and higher humus content of these soils compared to newly irrigated and newly reclaimed dark gray soils, which in turn promotes greater accumulation of exchangeable cations, particularly Ca^{2+} and Mg^{2+} .

Mandatory Measures for the Reclamation of Salinized Lands in the Region

It is necessary to implement the following mandatory measures for the reclamation of salinized lands in the region. Each farm's water use should be planned according to natural and irrigation-agricultural conditions (based on hydro-modules and crop types).

1. **Improvement of IrrigationTechniques** Crops should be irrigated through short furrows, with lengths not exceeding 50–70 meters. This ensures uniform soil moisture, reduces water consumption, and prevents water wastage in irrigated plots. Irrigation furrows should be laid according to the optimal slope of the fields to avoid soil erosion and accumulation of excess water at the end of the furrows.
2. **Restoration of Soil Structure** Timely and thorough soil cultivation is required to restore the porous, granular state of the soil, which ensures moisture retention.
3. **Leveling of Irrigated Areas** Deep autumn plowing of salinized soils contributes to periodic desalination. Post-irrigation deep cultivation reduces soil evaporation by 20–30%, preventing salt accumulation. In highly evaporative months (July–August), when salt accumulation peaks, the interval between irrigations should not exceed 10–12 days. Watering during the winter facilitates the leaching of easily soluble salts in the root zone. Autumn-winter irrigations, combined with natural precipitation, accelerate soil desalination. Spring sectional irrigations help reduce salt content in the plow layer and subsoil. Spring sectional irrigation is most effective at a rate of 1,500–3,000 m^3/ha.
4. **Addressing Soil Salinization in Various SoilTypes** Field research indicates that irrigated sandy brown, saline-alkali, and meadow soils require measures to prevent salinization and mitigate its effects. To address reclamation problems, annual inspections are necessary to identify lands requiring reclamation, restore their fertility, and implement a set of agro-meliorative and other measures. Reclaimed lands should be monitored regularly.
5. **Mitigation of the Impact of Groundwater** To reduce the impact of ground water on soil reclamation, the operation of hydro-meliorative systems must be ensured. Strict adherence to irrigation and leaching norms is essential. Leaching is most effective when soil temperature has not yet decreased, and

the groundwater level reaches its maximum (October–December).

6. **Leaching of Salts from Soils** Leaching norms should account for soil texture, salinity degree, and permeability. For the top 100 cm layer:

- Slightly salinized irrigated sandy brown, saline-alkali, and meadow soils with up to 100 tons of salt reserves: 3.5–4.0 thousand m³/ha
- Moderately salinized soils with 100–200 tons of salt reserves: 6–8 thousand m³/ha
- Strongly salinized soils with 200–300 tons of salt reserves: 10–12 (up to 15) thousand m³/ha Leaching should be carried out in several stages. Currently, the most effective method is sectional autumn-winter leaching, which is labor-intensive and includes numerous mechanical and manual operations (furrow preparation, cutting irrigation ditches, constructing ridges, water distribution, monitoring, and field leveling).

7. **Maintenance of Internal Drainage Canals** Internal drainage canals surrounding leaching plots must be inspected and cleaned if necessary. Ineffective canals must be restored; otherwise, leaching operations will be ineffective. The technical condition of existing internal drainage channels for removing saline water must be satisfactory.
8. **Soil Moisture Accumulation for Leaching** In non-salinized and slightly salinized areas, pre-irrigation in spring aims to accumulate moisture at a high rate (1.5–2.0 thousand m³/ha). This is most effective in areas where groundwater is deep, as crops can germinate without additional watering, reducing vegetative irrigations and overall water consumption. In sandy or gravelly slightly salinized soils at 0.5–1.0 m depth, water for moisture accumulation may be applied at 1.0–1.5 thousand m³/ha. In fields with small slopes, moisture accumulation is achieved by flooding furrows. In medium and large fields, water is supplied through furrows, which are shorter (1.5–2 times shorter than usual) and closed at the end to prevent runoff.
9. **Leaching Salts throughFurrows** During furrow leaching, soil should be loosened to a depth of 30–35 cm using a plow and disk harrow. In compacted soils, moistening should be adjusted according to density, gypseous layers, and soil horizon depth. Loosening should be done along both the length and width of the furrows at the required depth. After deep loosening, the field surface is leveled, and short furrows of 50–100 m with row spacing of 45–60 cm are established for irrigation.
10. **Irrigation Norms during Leaching** During the first irrigation after soil loosening, the water application rate should be 3.0–3.5 thousand m³/ha, adjusted according to the soil's infiltration capacity.

11. Application of Biosolvent Compounds in Soil Salinity Management

The biosolvent compound was developed by scientists of the O.Sodiqov Institute of Bioorganic Chemistry under the Academy of Sciences of the Republic of Uzbekistan. The components of the biosolvent exhibit biodegradable properties and fully comply with the standards for biodegradable materials. Biosolvent is a polymer (polyanion) with a molecular weight of 2,000–5,000 Daltons. It decomposes under environmental conditions such as sunlight, rain, and snow.

In the leaching of salinized irrigated lands, before initiating leaching, the field is prepared and divided into sections. Using the Appalon sprayer tractor (OVX), the biosolvent compound is applied according to the soil salinity level: 5.0–6.0 liters per hectare for slightly salinized soils, 7.0–8.0 liters per hectare for moderately salinized soils, and 11.0–12.0 liters per hectare for highly salinized soils. Subsequently, the soil is leached. The application of biosolvent improves the efficiency of salt removal from the soil by 30%, saves 30–35% of water resources, reduces the leaching period by 15–18 days, and allows for an earlier start of spring agricultural activities.

Studies conducted in the irrigated meadow soils of Navoiy region, which are moderately salinized (dry residue – 0.414%, chloride ion – 0.027%, sulfate ion – 0.075%), demonstrated that the use of biosolvent accelerates the dissolution of salts, increases soil porosity 2–3 times, improves water permeability, and increases leaching efficiency by 30% compared to leaching without biosolvent. The dry residue after leaching decreased from 0.230% (without biosolvent) to 0.161% (with biosolvent). Additionally, the leaching duration shortened by 15 days, and river water consumption decreased by 38% (leaching rate without biosolvent – 4,010 m^3/ha; with biosolvent – 2,500 m^3/ha).

12. Phytomelioration Measures for Salinity Reduction

Studies indicate that phytomelioration measures are highly effective for desalinization of soils in Konimex and Karmana districts. The use of various types of biomeliorants in rotation with other crops on salinized soils provides significant benefits. Currently, numerous ecotypes of biomeliorant plants have been developed, adapted for growth in salinized soils.

Halophytes capable of dissolving soil salts possess specific properties. In the top 1- meter soil layer of strongly salinized, medium-sandy semi-desert soils, salt content can reach 48 t/ha. When the phytomass on the soil surface reaches 18–20 t/ha, halophytes are capable of removing 8–10 tons of salt per hectare per year.

Scientific Conclusion and Recommendations on the Salinity Status and Ecological-Meliorative Measures of Irrigated Soils in Navoiy Region

When implementing monitoring measures aimed at improving the meliorative condition of irrigated lands in Navoiy region, it is crucial to first correctly identify soils requiring reclamation. The following scientifically grounded practical measures are recommended:

1. The irrigated lands of Karmana, Qiziltepa, Konimex, and Navbahor districts exhibit varying degrees of salinization, different mechanical compositions, and types of salinity. To prevent soil salinization, maintain soil fertility and productivity, and enhance the yield of agricultural crops, hydro-technical, agro-technical, and reclamation measures must be systematically and scientifically implemented.
2. In the main irrigated areas of Navbahor, Qiziltepa, and Konimex districts, the groundwater regime in hydromorphic soils (groundwater at 1.0–2.0 m) should be regulated to a semi-hydromorphic regime (2.5–3.0 m). In regions where shallow groundwater and saline soils are present, hydro-meliorative systems should be thoroughly cleaned every 2–3 years. Groundwater levels must be maintained at the "critical depth" (2.5–3.0 m), and additional ditches or channels should be excavated if necessary.
3. To prevent groundwater rise and associated secondary salinization, irrigation water should be used judiciously. Canal networks must be repaired, and irrigation schedules should consider soil and climatic conditions, crop type, growth stages, water demand, groundwater depth, and other factors. Proper irrigation timing, frequency, and rates must be strictly adhered to.
4. Soil leaching operations must be carried out on time and with high quality. The procedures should be adapted according to local soil and climatic conditions, following established recommendations.
5. During leaching, the degree of soil salinity, mechanical composition, water permeability, and salt content in the root zone (0–1 m) must be considered. Leaching water rates vary depending on soil texture:
    - Light-textured soils: 3000–3500 m^3/ha on average.
    - Moderately saline soils: 2–3 leaching applications, 3500–5000 m^3/ha.
    - Strongly saline soils: 3 applications, 4000–5000 m^3/ha.
    - Very strongly saline soils with varying textures: 3–4 applications along borders, 5000–6500 m^3/ha.
    - Heavy-textured, strongly and very strongly saline soils: 3–4 applications,6000–7500m^3/ha. The goal is to reduce soil chloride ions to 0.01% and total salts to 0.4– 0.6% after leaching.
6. Among the factors causing soil salinization, special attention should be paid to the "critical depth" and "critical mineralization" of groundwater. Due to the hot climate of the region, evaporation from the soil surface is several times higher than precipitation, making salinization inevitable. Primary reclamation measures should focus on preventing this negative process and minimizing its impact on crops.
7. Effective and rational use of existing irrigated lands, improving soil meliorative-ecological status, and maintaining and increasing productivity require annual inspection of crop fields by farmers and district agricultural specialists. Priority should be given to identifying soils in need of reclamation, planning the necessary reclamation measures, and implementing them in

practice.

8. To prevent salt accumulation and secondary salinization, drainage systems must function efficiently. Land leveling and proper leaching are essential. Efficient operation of the ditch network, ensuring groundwater flow, timely execution of leaching, correct rates, and adherence to leaching technology and techniques are critical for achieving optimal results.
9. In areas where groundwater is shallow (1.0–2.5 m) and permanent waterlogging occurs, crops susceptible to root rot, such as cotton, should be avoided. Low-yield areas previously cultivated with cotton are suitable for saline-tolerant, perennial forage, leguminous, oilseed, and vegetable crops grown according to high agro-technical standards. This approach helps prevent salinization while improving fertility and productivity.
10. Irrigation with mineralized ditch water should be avoided, as it adversely affects soil physico-chemical properties, disrupts soil structure, increases osmotic pressure in the soil solution, impairs photosynthesis, accelerates secondary salinization and alkalinization, and significantly reduces crop yield.

11. In Karmana and Konimex districts, irrigated lands with low crop yields, challenging reclamation conditions (6–8 years for full melioration and re-cultivation), gypsum layers located near the surface (0–50 cm), and low fertility should be improved by applying local (organic) fertilizers (30–40 t/ha), deep loosening (60–70 cm), leaching of salts, and planting “absorbing” crops within 1–2 years. Green manure crops should be grown and incorporated into the soil as “green mass” to improve fertility.
12. In Konimex, Karmana, and Navbahor districts, where strong dust and sand-laden winds frequently occur, protective shelterbelts should be established to prevent wind erosion and protect crops. Drought- and salt-tolerant tree species such as oak, black pine, pine, tamarisk, plane, acacia, poplar, willow, elm, birch, wild date, maple, and chestnut should be planted. These shelterbelts reduce wind speed and its effect, moderate the microclimate near the soil surface, maintain soil moisture at stable levels, and prevent acceleration of soil salinization.
13. Considering the varying degree of salinity in irrigated soils, leaching schedules, water application rates, and the number of leaching events should be determined based on local soil and climatic conditions.
14. During leaching operations, irrigation water should be used efficiently to remove as much salt as possible from the soil, with particular attention to chloride ions, which are highly toxic to crops. In chloride-sulfate and sulfate-chloride soil types, high-quality leaching is achieved when chloride content is reduced to 0.01% and total salt content does not exceed 0.4–0.6% of dry residue.
15. To remove harmful salts from the 0–1 m root zone, the total volume of water applied should equal the field capacity of this layer, applied once or multiple times. Recommended volumes based on soil texture are:

- Light soils: 2200–2500 m^3/ha

- Medium-textured soils: 2800–3000 m³/ha
- Heavy soils:3500–3800m³/ha Maximum efficiency is achieved when approximately 40% of the total volume required to fill field capacity of the 0–1 m layer is applied in one irrigation. This corresponds to:
- Light soils: 900–1100 m³/ha per irrigation
- Medium soils: 1100–1300 m³/ha
- Heavy soils: 1300–1500 m³/ha

- Leaching schedules and water rates should be based on field-tested recommendations from the Uzbek Research Institute of Irrigation and Water Management (O'zPITI):

- Weakly saline soils: 3000–3500 m³/ha
- Moderately saline soils: 4000–5000 m³/ha
- Strongly saline soils:6000–6500 m³/ha For some very strongly saline, gypseous soils with dense upper layers (0–50 cm), recommended leaching rates may reach 8–10 (12) m³/ha.

16. In Xatirchi and Nurota districts, secondary salinization resulting from artesian well irrigation should be prevented by organizing farming practices that account for soil conditions, properties, chemical composition, and local climate.
17. Additionally, in districts where drip irrigation systems are implemented, the irrigation schedule should be organized considering soil water regime and balance, soil texture, groundwater depth, and crop type to optimize water use and maintain soil health.

1. Normative Legal and Methodological Sources

1.1 Mirziyoyev, Sh. M. (2017). By steadfastly continuing our path of national development, we will raise it to a new stage. Tashkent: Uzbekistan Publishing House. 592 p.

1.2 President of the Republic of Uzbekistan. (2017, February 7). Decree No. PF-4947 "On the Strategy of Actions for the Further Development of the Republic of Uzbekistan."

1.3 President of the Republic of Uzbekistan. (2019, June 17). Decree No. PF-5742 "On measures to ensure the efficient use of land and water resources in agriculture."

1.4 President of the Republic of Uzbekistan. (2020, February 28). Resolution No. PQ-4575 "On implementation of the tasks defined in the Strategy for Agricultural Development of the Republic of Uzbekistan for 2020–2030 during the year 2020."

1.5 History of Uzbekistan. (2006). In National Encyclopedia of Uzbekistan (Vol. 12, pp. 89–189). Tashkent: State Scientific Publishing House.

1.6 Qo'ziev, R. Q. (2010). Development of the new classification of soils of Uzbekistan (Project No. BV-F4-002 + 006). Tashkent: TAITDI. 23 p.

1.7 Dospekhov, B. A. (1985). Methods of field experimentation. Moscow: Agropromizdat Publishing House. 351 p.

1.8 Kachinskiy, N. A. (1965). Soil physics (Part I). Moscow: Academy of Sciences of the USSR Press. 318 p.

1.9 Genusov, A. Z., Gorbunov, B. V., & Kimberg, N. V. (1971). Soil mapping and its application in the agriculture of Uzbekistan. In History and current state of soil science in Uzbekistan (1920–1970) (pp. 13–22). Tashkent: Fan Publishing House.

1.10 Gerasimov, I. P. (1937). Main features of the development of the modern surface of Turan. Proceedings of the Institute of Geography, Vol. 25. Moscow–Leningrad.

1.11 Glukhova, T. P., & Strelnikova, G. A. (1983). Mineralized waters of Uzbekistan as a reserve for irrigation. Tashkent: Fan Publishing House. 125 p.

1.12 Gorbunov, B. V., & Kimberg, N. V. (1971). Classification of soils. Soils of Uzbekistan. Tashkent.

1.13 Kimberg, N. V. (1974). Soils of the desert zone of Uzbekistan. Tashkent: Fan Publishing House. 296 p.

1.14 Atlas of Land Resources of the Republic of Uzbekistan. (2001). Tashkent, pp. 3–48.

2. Monographs, Scientific Articles, Patents, Conference Proceedings

2.1. Abdullaev, S. A., & Sattarov, D. S. (2002). Main soil problems of Uzbekistan requiring urgent solutions. In Proceedings of the scientific-practical conference on restoring and improving soil fertility in the Aral Sea basin under desertification processes (pp. 10–15). Tashkent.

2.2. Abdullaev, S., Zikryaeva, S., Sidiqov, S., Abdraxmanov, T., & Abdushukurova, Z. (2001). Meliorative state and improvement measures for newly irrigated gray-brown soils. In Proceedings of the scientific-practical conference on rational use of land resources and soil protection. Tashkent.

2.3. Azimbayev, S. A., & Begimqulov, N. R. (2002). Meliorative state of soils in the desert zone of the Surkhan-Sherabad valley. In Proceedings of the scientific-practical conference on restoring and improving soil fertility in the Aral Sea basin under desertification processes (pp. 199–203). Tashkent.

2.4. Amanov, O. S., & Tojiev, U. (2002). Improvement of the meliorative state of saline soils in the middle course of the Zarafshan delta. In Proceedings of the scientific-practical conference on restoring and improving soil fertility in the Aral Sea basin under desertification processes (pp. 211–218). Tashkent.

2.5. Artikova, X. T. (2005). Soils of the Bukhara oasis and changes under irrigation [PhD dissertation abstract]. Tashkent.

2.6. Axmedov, S. H. M., Abduraxmanov, T., & Tursunov, L. T. (1997). Changes in agrochemical properties of gray-brown soils due to irrigation. In Proceedings of the scientific-practical conference (pp. 34–36). Tashkent.

2.7. Axmedov, S. H. M. (1999). Gray-brown soils of Malikchulya and the influence of lead contamination on their properties [PhD dissertation abstract]. Tashkent.

2.8. Baygildina, E. X., Ismatov, D. R., & Smolina, L. B. (1978). Physicochemical nature of structural-sorption properties of main soil types in southern Uzbekistan. In Soil resources of Uzbekistan and problems of their melioration (pp. 10–23). Tashkent.

2.9. Bo’riyev, X. CH., & Gafurova, L. A. (2000). Main directions of agroecological monitoring in farming. In Conference proceedings on ecological problems in agriculture (pp. 6–8). Bukhara.

2.10. Butskov, N. A., & Nasыrov, Ya. M. (1961). Soils of southwestern Kyzylkum. Tashkent, 4–158.

2.11. Valiev, V. V., & Tolstova, L. N. (1978). Gross chemical composition of hydromorphic soils in typical serozem zones. In Soil resources of Uzbekistan and problems of their melioration (pp. 23–27). Tashkent.

2.12. Gorbunov, B. V., Konobeeva, G. M., & Tverdostup, A. I. (1978). Experience in developing gray-brown soils of Kyzylkum using artesian water. In Soil resources of Uzbekistan and problems of their melioration (pp. 43–48). Tashkent.

2.13. Guidelines for conducting soil surveys and preparing soil maps for state land cadastre. (2005). UzErgeodezkadastr. Tashkent.

2.14. Ikramov, J., & Saidmurodova, J. (1989). Dynamics of soil density and differential porosity of takyr soils in the Karshi steppe. Transactions of the Institute of Soil Science, Uzbek SSR, 36. Tashkent.

2.15. Isaev, V. A. (1983). Gypsum soils of the Ziadin-Zirabulak foothills and their meliorative characteristics [PhD dissertation abstract]. Moscow.

2.16. Ishpulatov, T. M., & Kurvantoev, R. (2002). Qualitative assessment of the structural state of light serozems in the Karshi steppe. In Proceedings of the scientific-practical conference on restoring and improving soil fertility in the Aral Sea basin under desertification processes (pp. 207–211). Tashkent.

2.17. Kalashnikov, A. I., Kamilov, O. K., & Sharipov, X. SH. (1978). Experience of combined use of horizontal and vertical drainage in the melioration of saline lands. In Soil resources of Uzbekistan and problems of their melioration (pp. 62–70). Tashkent.

2.18. Kamilov, O. K. (1972). Changes in the meliorative state of soils in the new development zone of Golodnaya Steppe. In Genesis, geography, and melioration of soils of Uzbekistan (pp. 130–137). Tashkent.

2.19. Karimova, M. U. (1968). Gray-brown and desert sandy soils of the Karshi steppe and their fertility [PhD dissertation abstract]. Frunze.

2.20. Kats, D. M., & Plutitskiy, N. M. (1957). Balance of groundwater in the Bukhara oasis. Reports of the Academy of Sciences of Uzbek SSR, 9, 14–17.

2.21. Kim, A. V. (1978). Soil salinity cartograms as a basis for differentiating irrigated fields. In Saline soils of Uzbekistan and problems of their development and melioration (pp. 95–100). Tashkent.

Kuziev, R. (1978). Genetic and production characteristics of main soils of Central Kyzylkum. In Saline soils of Uzbekistan and problems of their development and melioration (pp. 100–110). Tashkent.

2.22. Kuziev, R. (1978). Some issues of the genesis of gray-brown soils. In Soil resources of Uzbekistan and problems of their melioration (pp. 70–80). Tashkent.

2.23. Kuziev, R. K. (1991). Vohali gray soils, their evolution and fertility. Tashkent, 86.

2.24. Kuziev, R. K. (1994). Irrigated soils of the serozem zone of Uzbekistan: ecological condition and fertility [Doctoral dissertation abstract]. Tashkent, 42.

2.25. Kuziev, R. K., & Sektimenko, V. E. (2001). Organization and monitoring of lands in the Republic of Uzbekistan. In Proceedings of the International Scientific-Practical Conference on Biological, Ecological, and Agro-Soil Education and Prospects (pp. 313–314). Tashkent.

2.26. Kuziev, R. K., & Bobomurodov, SH. M. (2004). Irrigated soils of desert regions and their changes under intensive farming systems. In Soil Science and Agrochemistry in the 21st Century: Proceedings of the International Scientific-Practical Conference (pp. 261–267). Tashkent.

2.27. Kuziev, R. K. (2005). Fertility problems of irrigated soils of Uzbekistan. In Proceedings of the IV Congress of Soil Scientists and Agrochemists of Uzbekistan (pp. 51–60). Tashkent.

2.28. Kurvantaev, R. (2000). Optimization and regulation of agro-physical state of irrigated soils in the desert zone of Uzbekistan [Doctoral dissertation abstract]. Tashkent.

2.29. Kurvantaev, R., Abdullaev, S., Abdushukurova, Z., & Axunov, B. (2003). Physical properties of serozem-meadow soils of the Djizak oasis. Problems of Ecology in Agriculture, Bukhara, 49–53.

2.30. Kushakov, A., Tojiev, U., Baxromov, A., & Ergasheva, M. (2000). Aeroecological state of newly irrigated soils in Navoi region. In Proceedings of the International Scientific-Practical Conference on Ecological Problems in Agriculture (MDH countries) (pp. [no page]). Bukhara.

2.31. Kushakov, A., Tojiev, U., Karimov, E., & Nafetdinov, SH. (2001). Newly irrigated gray-brown desert saline soils of the Malikchul steppe. In Proceedings of the FAO-supported Scientific Conference in Tajikistan. Dushanbe.

2.32. Kushakov, A. (2003). Repeated cropping on newly irrigated gray-brown soils of the Malikchul. In Proceedings of the International Scientific-Practical Conference on Ecological Problems in Agriculture (pp. 21–22). Bukhara.

2.33. Kushakov, A., & Tojiev, U. (2006). Methods to improve fertility of newly developed gypsum gray-brown soils in the piedmont. In Proceedings of the Republican Scientific-Practical Conference on Ecological Problems in Agriculture, Part 1. Bukhara.

2.34. Kushakov, A. J. (2006). Meliorative state of Malikchul. Uzbekistan Journal of

Agriculture, 11.

2.35. Kushakov, A. (2005). Improvement of meliorative state of saline-alluvial pastures of Malikchul. In Achievements in Science and Prospects for Agricultural Development (pp. 311–312). Samarkand.

2.36. Kushakov, A. J. (2005). Geomorphological and hydrogeological structure of Malikchul and their impact on saline soil formation. In Achievements in Science and Prospects for Agricultural Development: Proceedings of the Scientific-Practical Conference. Samarkand.

2.37. Kushakov, A. (2006). Meliorative-ecological state of newly irrigated gray-brown soils of Malikchul piedmont. In Proceedings of the Republican Scientific-Practical Conference on Ecological Problems of Biological Diversity of Uzbekistan (pp. 206–207). Navoi.

2.38. Kushakov, A. (2006). Historically irrigated alluvial pastures of Malikchul. In Proceedings of the Republican Scientific-Practical Conference on Ecological Problems of Biological Diversity of Uzbekistan. Navoi.

2.39. Lagunova, E. P. (1963). Organic matter of serozems of the Zarafshan valley. In Effect of Irrigation on Soils of Central Asian Oases (pp. 133–146). Moscow: AN SSSR.

2.40. Lebedev, YU. P. (1954). Soils of irrigated oases of the lower Zarafshan. Transactions of the Aral-Caspian Complex Expedition. Moscow: AN SSSR.

2.41. Lobova, E. V. (1960). Soils of the desert zone of the USSR. Moscow.

2.42. Maksudov, D. M., Tursunov, A. A., & Kamilov, B. (2002). Saline seedbed of Khorezm region and changes in the meliorative state of lands. In Proceedings of the Scientific-Practical Conference on Soil Fertility in the Aral Sea Basin (pp. 41–45). Tashkent.

2.43. Malygin, V. S. (1939). Deep closed drainage. Tashkent.

2.44. Mamytov, A. M., & Makarenko, V. A. (1962). Experience of stationary study of high-mountain soils (Aksai station example). Bishkek.

2.45. Mansurov, N. X., Axmedov, A. U., & Umirzakov, A. X. (1989). Salinity of soils and groundwater in Paxtakor sovkhoz. Transactions of the IAA, Academy of Sciences of Uzbek SSR, 36. Tashkent.

2.46. Mannanov, N. M., Kobzeva, G. I., & Lifshits, E. A. (1978). Ways to increase productivity of newly irrigated lands in Central Fergana. In Saline Soils of Uzbekistan and Problems of Their Development and Melioration (pp. 118–126). Tashkent.

2.47. Maxsudov, A., Mamajonov, M., & Ibragimov, I. (1995). On the role of anthropogenic factors in oasis soil formation. In Proceedings of the I Congress of Soil Scientists and Agrochemists (p. [no page]). Tashkent.

2.48. Kushakov, A. J. (2018). Processes and forms of salinization of gray-brown soils in the desert zones of Uzbekistan. Monograph. Navoi, 80–93.

2.49. Minashina, N. G. (1975). Gypsum soils, features of their development and analysis. Soil Science, 8.

2.50. Minashina, N. G. (1963). Microstructure features of saline serozems and irrigated soils of the Zarafshan valley. In Effect of Irrigation on Soils of Central Asian Oases (pp. 112–132). Moscow: AN SSSR.

2.51. Mikhaylov, S. P. (1994). Comparative characteristics of typical gray-brown and highly gypsum soils (Malikchul example) [PhD dissertation abstract]. Tashkent, 6–18.

2.52. Molodsov, V. A. (1963). Irrigation deposits of the Zarafshan and Murgab delta oases. In Effect of Irrigation on Soils of Central Asian Oases (pp. 44–110). Moscow: AN SSSR.

2.53. Nafetdinov, SH., Ortiqova, X. T., Tojiev, U. T., & Kushakov, A. (2003). Ways to improve productivity of newly irrigated desert sandy soils in the lower Zarafshan. United Scientific Journal, 17(75), 64–65.

2.55. Rasulov, A. M., & Karimova, M. U. (1967). Meliorative state, agrochemical properties, and productivity of main soils of the Karshi steppe. Cotton Growing, 10, 28–31.

2.56. Ruziev, SH. M., Rakhmatov, M. Z., & Khakimov, O'. X., et al. (2002). Scientific foundations of farming systems in Navoi region. Navoi, 210.

2.57. Rustamov, N., & Kushakov, A. (2003). Effect of soil water deficiency on nitrogen compound transformations in ephemeral plant bars. In Proceedings of the International Scientific-Practical Conference on Ecological Problems in Agriculture. Bukhara.

2.58. Sabitova, N. I., Axmedov, A. U., Amanov, O. S., Juraev, G. A., & Parpiev, G. T. (2003). Proposed principles for meliorative soil assessment in the middle and lower Zarafshan. In Proceedings of the International Scientific-Practical Conference on Problems of Ecology in Agriculture (pp. 53–55). Bukhara.

2.59. Tadjiev, U., Yunusov, R., Nafetdinov, SH., Kushakov, A., Ortiqova, X., et al. (2003). Ways to improve fertility of newly irrigated gray-brown soils in the lower Zarafshan. In Proceedings of the International Conference on Improvement of Cotton and Winter Wheat Cultivation Technologies (pp. 146–148). Tashkent.

2.60. Tadjiev, U., Nafetdinov, SH., Zikryaeva, M., Muxtorov, M., Karimov, E., Artikova, X., Ramazonov, B., Kushakov, A., Yunusov, R., & Asatov, S. (2001).

2.61. Preparation of the "Meliorative State of Lands" map of Bukhara region. In Proceedings of the International Scientific-Practical Conference on Biological, Ecological, and Agro-Soil Education and Prospects. Tashkent.

2.62. Tojiev, U., Nafetdinov, SH., Qo'shoqov, A., Yunusov, R., Zikryaeva, M., & Karimov, E. (2001). Desert-sandy soils of the Zarafshan river delta. In Proceedings of the Scientific-Practical Conference on Rational Use of Land Resources and Soil Protection. Tashkent.

2.63. Tojiev, U., Nafetdinov, SH., Namozov, X., & Kushakov, A. (2003). History of scientific ideas on genesis, geography, classification, and cartography of Turan and Pamir-Alay soils. In International Conference on Soil History, Philosophy, and Sociology, Pushchino.

2.64. Tojiev, U., & Qo'shoqov, A. (2006). Salt accumulation processes and salinization forms in newly irrigated gray-brown soils of the piedmont in the desert zone. In Proceedings of the Republican Scientific-Practical Conference on Ecological Problems of Biological Diversity of Uzbekistan, Navoi.

2.65. Toshqo'ziev, M. M., Ziyamuhammedov, E. A., Yunusova, D., & Usmanova, D. (2003). Biomass yield and soil fertility improvement potentials. In Proceedings of the International Scientific-Practical Conference on Ecological Problems in Agriculture (pp. 34–37). Bukhara.

2.66. Tinina, G. A. (1978). Gray-brown soils of the Sherabad steppe. In Saline Soils of Uzbekistan and Problems of Their Development and Melioration (pp. 167–175). Tashkent.

2.67. Tursunov, L. T. (1988). Soil physics, Volumes I–II. Tashkent, 156.

2.68. Umarov, M. U. (1962). Some features of lower Zarafshan relief. Proceedings of the Uzbek Branch of the Geographical Society of the USSR, Tashkent, 23–29.

2.69. Umarov, M. U., & Kurvantaev, R. (1987). Increasing fertility of irrigated soils by regulating their physical properties. Tashkent: Fan, 96.

2.70. Felitsiant, I. N., Konobeeva, G. M., Gorbunov, B. V., & Abdullaev, M. A. (1984). Soils of Uzbekistan (Bukhara and Navoi regions). Tashkent: Fan, 148.

2.71. Hamroev, T. R., & Karimova, M. U. (1978). Changes in properties of gray-brown soils of Malikchul steppe under irrigation. In Saline Soils of Uzbekistan and Problems of Their Development and Melioration (pp. 175–183). Tashkent.

2.72. Ergashev, A. E., Kasimov, U. K., & Juraev, A. T. (1978). Application of organic and mineral fertilizers on gray-brown soils of Malikchul. In Soil Resources of Uzbekistan and Problems of Their Melioration (pp. 165–169). Tashkent.

2.73. Colibas, M., Maianu, A. N., & Colibas, I. (1974). Effect of irrigation waters with low salinity and high sodium adsorption ratio on soil salinization and alkalization. In Proceedings of the 10th International Congress of Soil Science, Vol. 10, Moscow, 202–209.

2.74. Dregne, M. E. (1974). Predicting soil salinity from irrigation water salinity. In Proceedings of the 10th International Congress of Soil Science, Vol. 10, Moscow, 198–201.

2.75. Claser, B., Guggenberger, G., & Zech, W. (2001). Consequences of anthropogenic disturbances on organic matter of soils in high-mountain ecosystems. In Proceedings of FAO-supported Scientific Conference, Tajikistan (pp. 53–54). Dushanbe.

2.76. Rahbar, G. R., Kowsar, S. A., & Khalili, D. (2001). Soil modification by freshly laid sediment and sowbug colonies (Hemilepistus schuttz) in a sandy desert. In Proceedings of FAO-supported Scientific Conference, Tajikistan (pp. 37–39). Dushanbe.

2.77. Buol, S. W., Hole, F. D., & McCracken, R. (1973). Soil genesis and classification. Ames: Iowa State University Press, 365.

2.78. Butler, B. E. (1980). Soil classification for soil survey. Oxford: Clarendon Press, 129.

CONTENTS