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Research on the dynamics of the South Fergana landscapesscientific and theoretical issues

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Abstract. This study assesses the impact of hydro-climatic factors on the formation, transformation, and dynamics of landscapes in the Southern Fergana region. Particular attention is paid to long-term changes in air temperature, precipitation, humidity, and hydrological conditions, as well as their influence on natural and anthropogenic landscapes. Based on meteorological and hydrological data analysis, the research identifies recent trends in climate warming, changes in precipitation regimes, and increasing variability of water resources. The results indicate that rising temperatures and altered moisture conditions significantly affect soil properties, vegetation cover, and land use systems. These processes contribute to landscape degradation, increased aridity, and changes in ecosystem stability. The findings highlight the necessity of integrated landscape management and adaptive strategies to mitigate the negative impacts of hydro-climatic changes and to ensure sustainable development in the Southern Fergana region.

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Key words: Hydro-climatic factors; landscape dynamics; climate change; Southern Fergana; precipitation; temperature trends; water resources; environmental sustainability.

1. Introduction.

Despite the fact that in recent years a number of works have been carried out in the world in the field of water use, water supply and effective use of groundwater resources, including the implementation of comprehensive measures to ensure the rational use of water, its quality and safety, as well as modern innovative systems for accounting for water consumption, the problem of clean drinking water remains in some regions. To ensure effective regulation of water use, new structures have been created for water resources management, and active work is being carried out to attract the private sector to the field of drinking water supply and water production, however, "....due to global climate change, the duration of hot and dry seasons in some regions is increasing, the area of snow reserves in the mountains is decreasing, and the frequency of water shortages is increasing, which in turn leads to an increase in the risk of water shortages...." According to the United Nations, 40 % of the world's population lives in areas where there is a lack of clean drinking water. By 2025, 6 out of 10 people, or 5.5 billion people, will live in areas with limited access to clean drinking water, and more than 80% of infectious diseases will be associated with poor drinking water quality and poor sanitation.

Of the world's more than 7 billion people, about 3 billion consume contaminated water and 2 billion suffer from various diseases. The most tragic thing is that every day 6 thousand children in the world die prematurely due to drinking contaminated water. The imbalance between the anthropogenic load on water bodies and their ability to recover, ecological deterioration, which is practically characteristic of all large water bodies, insufficient financing of water management needs, leads to the emergence of a serious problem of drinking water supply. The above-mentioned assessment of the ecological and hygienic aspects of optimizing water supply to the population is one of the urgent problems facing preventive medicine workers.

In our country, certain measures are being taken to develop the medical sector, bring the medical system into line with world standards, including the elimination of diseases caused by water supply disruptions. In this regard, in accordance with the seven priority areas of the New Uzbekistan Development Strategy for 2022-2026, tasks such as "...improving the quality of qualified services to the population in primary medical and sanitary services..." have been

set to raise the level of medical services to a new level. Based on these tasks, it is appropriate to conduct research on optimizing, in particular, the assessment of the ecological and hygienic aspects of optimizing the water supply of the population.

Southern Fergana is located in the eastern part of Uzbekistan, occupying the central and eastern parts of the Fergana Valley, and is one of the most densely populated regions of the country. It is naturally and geographically rich with diverse landscapes, standing out as an area with a well-developed irrigation system and agriculture. This article analyzes the geographic location, relief, climate, hydrology, soils and landscapes, flora and fauna, as well as the unique characteristics of natural resources in Southern Fergana (see figure 1). The region mainly consists of plains, with mountain ranges located along its southern and northern edges. This area is favorable for irrigation and agricultural activities.

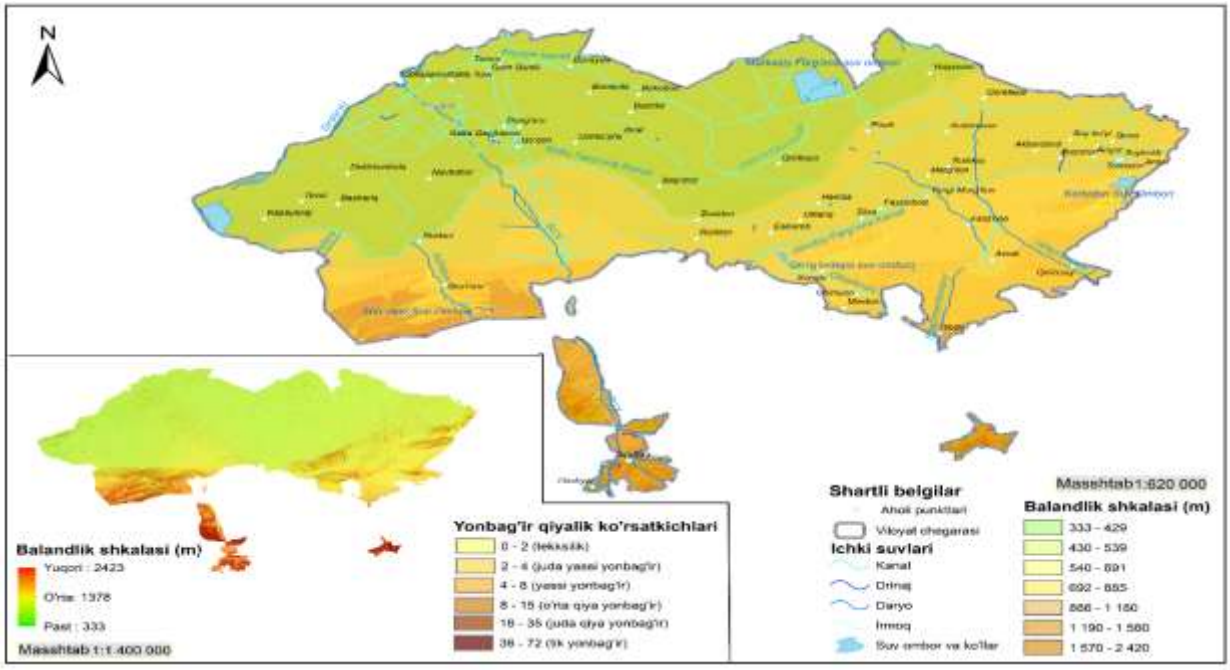

Figure 1. Altitude regions of South Fergana map

2. Material and Methods.

The general climatic features of the Fergana Valley depend on its geographical location, the fact that it is surrounded by high mountain ranges, the fact that the territory belongs to the continental type of the subtropical climate zone and is located in the middle of a vast arid region. Due to the fact that the Fergana Lowland is located in the central part of a vast arid climate region, the dry period here lasts a long time, and the lack of natural moisture in the soil cover during the vegetation period of cultivated plants requires the use of artificial irrigation in agro-landscapes. The climatic features of the Fergana Valley are widely covered in the studies of A.A.Skvortsov and Yu.A.Skvortsova, B.P.Alisov, L.N.Babushkin, E.N.Balashova, F.Hikmatov, V.E.Chub, B.A.Kamalov, O.Kuzibaeva, E.A.Soliyev, I.K.Mirzahmedov and others, as well as in the reference books of agro-climatic resources of the Namangan, Andijan, Fergana regions.

The Fergana Valley is extremely rich in climatic resources and has favorable natural conditions for the development of almost all branches of agriculture and achieving high yields. The sum of average daily temperatures above +10 °C in this region is 3800 -4600 °C per year. From an agroclimatic point of view, the sum of useful temperatures above +10 °C is about 2200-2400 °C, which allows ensuring the full vegetation period of almost all agricultural crops. In particular, for early-ripening cotton varieties, 1720 °C, for late-ripening cotton varieties - 1960 °C, for peanuts - 1400 °C, and for sesame - 1450 °C. Also, the climatic conditions of the Fergana Valley allow for the production of many crops twice a year, which further increases the agroclimatic potential of the region. The climate of South Fergana, in general, is sharply continental, like that of the Northern, Central and Eastern Fergana regions, which is explained by its geographical location and the fact that it is surrounded by the Tien Shan and Hissar-Olay

mountain ranges. In some years, wind speeds reach 30-35 meters per second, causing the formation of dust. The average number of windy days per year is 42, but strong winds weaken significantly as they reach the eastern regions.

The annual precipitation is unevenly distributed over the territory, averaging 100-170 mm. At the same time, in the foothills, especially in the eastern part, the amount of precipitation reaches up to 270 mm, and in some areas up to 447 mm. This indicates a sharp difference in hydroclimatic conditions in the Fergana Valley. The growing season lasts an average of 210-220 days, and the sum of useful temperatures during this period is 4300-4700 °C. Such agroclimatic conditions are extremely favorable for growing cotton, grapes, vegetables, melons and fruit crops, and demonstrate the agricultural potential of the Fergana Valley at a high level. In order to analyze the climatic features and their changes in South Fergana, data from the South Fergana meteorological station and adjacent areas, located in the central part of the oasis, were analyzed. The average monthly temperatures observed at the Kokand meteorological station were calculated in accordance with the climate change periods for the years 1995-2005, 2006-2015 and 2016-2025 (see figure 2).

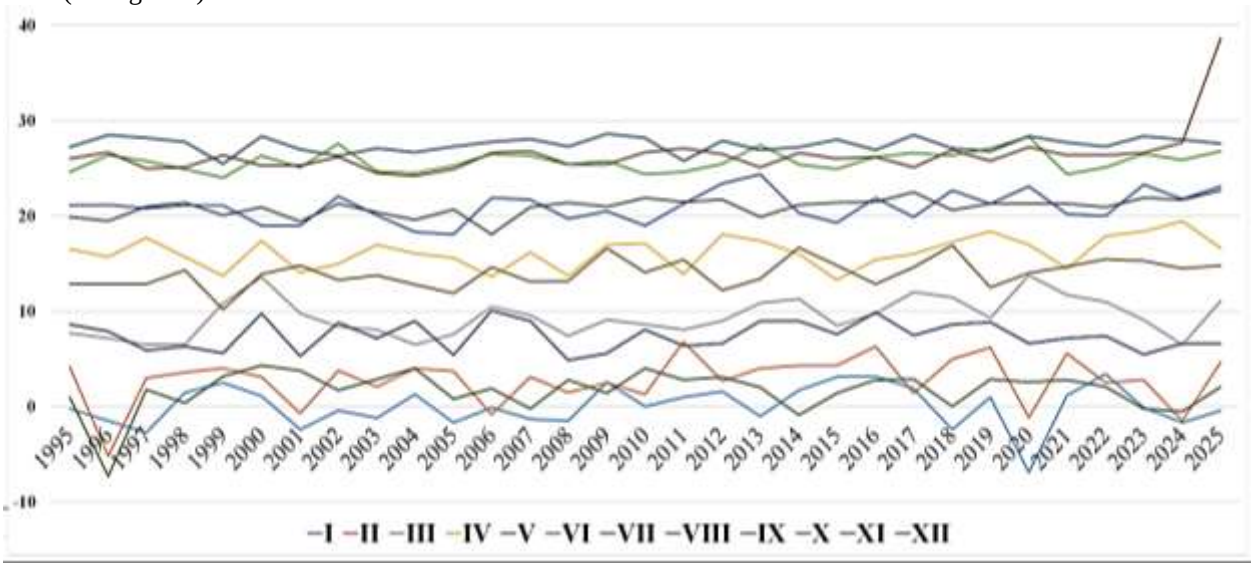

Figure 2. Changes in average annual air temperature observed at meteorological stations in South Fergana and adjacent regions (in ^{0}C)

Calculation results 1995-2025 during annual average at temperature noticeable growth For example, in 1995, it was 14,1°C . average temperature to 16,2°C in 2025 This is the global climate change under the influence temperature general the rise shows , in particular , the South In Fergana annual average temperature by about 2°C We can see that the temperature has increased . If we analyze the changes in seasonal air temperatures, winter temperatures are variable, but the overall coldness has remained. In 2020, a record cold January (-6,9°C) was observed, which indicates an increase in extreme weather events, while in the spring season, temperatures show a steady increase, especially in March, when the temperature rose by 3,4°C. This may lead to an early start to the growing season. Summer temperatures have increased significantly, especially in 2025, when an extreme temperature of 38,7°C was recorded in August.

This means that heat waves are becoming more frequent as a result of climate change. Autumn temperatures also increase to the trend , by 2,8°C in September This is autumn . vegetation of the era to extend impact to do This is possible. analysis this shows that over the last 30 years more than in the period South Fergana climate slowly heater is progressing , especially winter in season softening speed high. These changes village farm and water resources under the management separately attention demand Atmospheric precipitation is considered a source of moisture, which directly affects the formation, development and dynamics of landscape complexes. Especially in geographically complex regions such as South Fergana, precipitation is one of the main factors of landscape zonation and ecosystem change .

South Fergana to the landscapes atmosphere of precipitation contribution important ecological factor as is considered. At temperature changes , especially growth trend with precipitation quantity , distribution and seasonality between directly dependency Therefore , South Fergana landscapes climate change under the influence noticeable to changes face is coming. The temperature growth , heat waves and of precipitation shortage desertification and erosion,

especially in agrolandscapes soil salinity and water shortage strengthens. Vegetation of the era extension village farm for opportunities created although ecological problems far term to stability danger gives birth to. South Fergana to the landscapes The contribution of atmospheric precipitation is also significant. Therefore, in order to determine the relationship between temperature changes and atmospheric precipitation, the average monthly precipitation observed at meteorological stations in South Fergana and adjacent regions was analyzed (see figure 3).

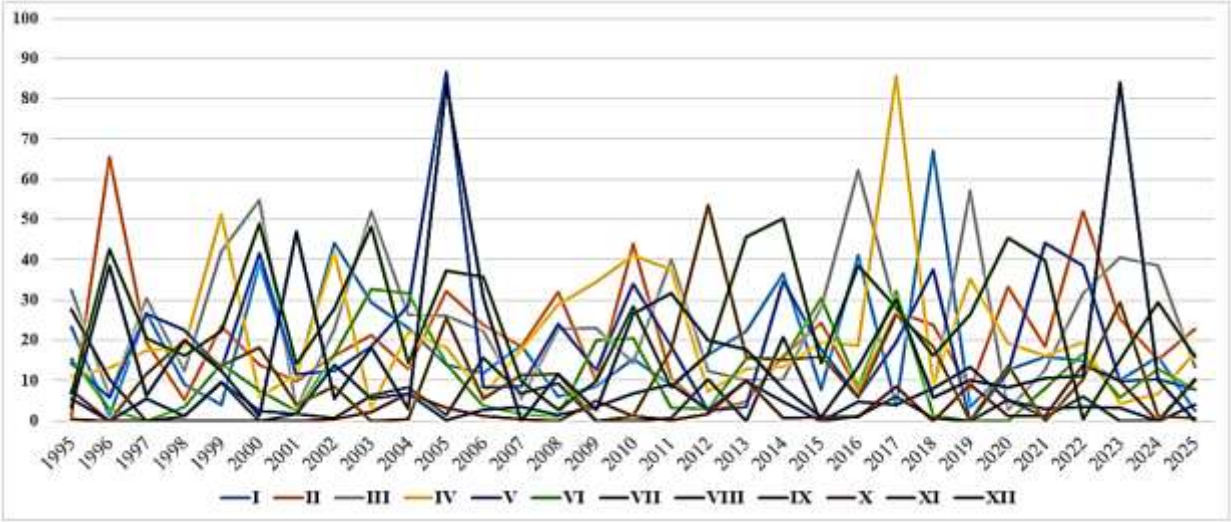

Figure 3. Changes in average annual precipitation (in mm) observed at meteorological stations in South Fergana and adjacent regions

The calculation results show that there is a significant fluctuation in the annual precipitation in South Fergana during 1995-2025, but as a general trend, the amount of precipitation has decreased by 2025 (from 139,4 mm in 1995 to 112,2 mm in 2025). This indicates an increase in aridity under the influence of climate change, but in some years (for example, 2000 and 2010) high precipitation indicates an increase in extreme weather events. Such characteristics of landscape complexes are associated with the state of their climatic elements. It is appropriate to assess landscapes according to 3 components that are considered important from an agricultural point of view for both irrigated and rainfed agriculture: climate, soil, and relief. The conducted research shows that it is possible to determine the energy flow and its changes from the climatic elements in the landscapes of South Fergana , but this is a very complex issue, requiring a lot of time and effort. We can see from the table below how some elements of the heat energy flow in the landscape complexes distributed in South Fergana look. Because, in all landscape types distributed in the research object , the rate of accumulation of heat energy changes daily, hourly, and even minutely. These changes depend on many factors. All climatic elements (mainly temperature and precipitation) are the most basic ones that ensure the dynamics and activity of the landscape, and other meteorological, hydrological, geomorphological, biogeochemical processes are one of the main factors that form a whole natural geographical situation.

The sum of the indicators that make up the heat balance and heat flows (cal/cm.kv)

Name of the observed location	A	R	R	Yes	Yes			R	V	Yes
The landscape of the forest	0.25	337	289	48	0	86	0.78	0.4	014	000
Bushy landscape	0.20	381	255	38	88	67	0.92	0.69	0.09	0.14

***A** -albedo; **R** -radiation balance flux index at night; **R** -turbulent heat exchange; **V** -heat flux in the soil; **E** - aggregate coupling.*

Agrolandscapes located in the Beshariq, Furqat, Dangara and Buvayda districts of South Fergana, especially areas with light granulometric soils, are very vulnerable to wind erosion and have been one of the main centers of agricultural production since ancient times. The sufficient level of internal water resources has made it possible to widely develop the foothill prolluvial plains, conical expanses, shale and subshale terraces, inter-hill and sub-shale

plains, and even the Central Fergana deserts of the region and turn them into irrigated oasis landscapes. Fresh groundwater reserves are also of great strategic importance for our republic. If their amount is 10% of the total amount of water resources, then the population uses 60 % of the water for drinking purposes. Therefore, it is natural that groundwater reserves will be used as the main source of drinking water supply, both now and in the future.

A number of studies conducted in different countries of the world show that there is a statistically significant, high negative correlation between cardiovascular diseases and water hardness. Thus, magnesium (Mg) is required for the normal functioning of the heart, leads to dilation of the heart vessels and reduced blood clotting, affects the functioning of the kidneys, biliary tract, and nervous system. Its deficiency in the body leads to chronic fungal damage to the intestines. Magnesium preparations are effective in some pathological conditions, for example: magnesium eliminates muscle tremors in the calves and reduces the level of glucose and cholesterol in the blood in diabetes.

About 79% of the total iron (Fe) in the human body is contained in hemoglobin, the rest is stored in iron proteins, cytochromes and enzymes. Iron is an essential element that plays a key role in the processes of transporting oxygen from the lungs to tissues and removing carbon dioxide from the body. It is known that the element zinc is the “main inorganic hormone”, and in a number of pathological conditions (hypoxia, hypochromic anemia) it increases the amount and activity of carbonic anhydrases, passes from plasma to erythrocytes, thereby accelerating the faster binding and excretion of carbon dioxide. Carbonic anhydrases and zinc are of great importance in the process of tissue respiration, comparable to the role of hemoglobin and iron. Iodine deficiency in food and water leads to hyperfunction of the thyroid gland (hypoteriosis and Graves' disease), which is reflected in the function of the hypothalamic-pituitary system in humans. 30-40 % of iodine consumed daily with food and water is accumulated in the thyroid gland, the rest is excreted in the urine. It regulates the level of calcium and reduces the level of phosphorus in the blood plasma.

Sanitary inspection of water sources and water treatment plants, as well as water supply networks, is carried out in three different directions:

- Sanitary - topographic inspection.
- Sanitary and technical inspection.
- Sanitary and epidemiological inspection.

These methods are applied equally to both open and underground water sources, but they also have their own specific aspects. During the sanitary topographic examination of underground water sources, the geological structure of the site was studied. In this case, special attention was paid to the depth of groundwater, soil properties, groundwater horizon, water quality, water flow, reserves, type and condition of groundwater intake, and the presence of groundwater accumulation sites. In addition to the above, during the sanitary topographic examination of underground water, the location of the drilled well, the condition of the well intake, all types of pollution sources located around this water intake facility, and their impact on the water in this well were fully studied.

The groundwater of South Fergana is located at different depths in the soil, in areas with ordinary gray soil, groundwater is located at a depth of 15-20 meters, in areas with light gray soil - at a depth of 4-6 meters. Also, the initial hydrogeological studies identified 5 groundwater sources, the estimated water reserves of which totaled 8169.1 thousand cubic meters/day of these, 2706 thousand cubic meters/day (33 percent) are considered to have a mineralization of up to 1.0 g/l. According to the state monitoring of groundwater, 9290 exploitation wells (of which 6823 are in working condition) are registered in the region, the total amount of groundwater extracted from them is 5087.8 thousand cubic meters/day (Figure 4).

This distribution shows that the main part of groundwater is directed to agriculture and land reclamation , which requires sustainable and effective management of water resources. As can be seen from the table, the largest share falls on the areas of land reclamation (32,8 %) and irrigation (30,3 %) . Drinking and technical and technological needs account for 24,3 % and 12,4 % , respectively, while other areas are almost insignificant (0,01 %).

Figure 4. Distribution of water use by area

According to the information provided by the Fergana field hydrogeological expedition of the State Enterprise "Uzbekgidrogeologiya", 5 groundwater sources were identified in South Fergana during the initial hydrogeological studies, the total estimated water reserves of which amount to 8169.1 thousand cubic meters/day of these, 2706 thousand cubic meters/day (33 percent) are considered to have mineralization up to 1,0 g/l. According to the state monitoring of groundwater conducted by the Fergana field hydrogeological expedition of the State Enterprise "Uzbekgidrogeologiya", 9290 exploitation wells (of which 6823 are in working condition) are registered in the region, and the total amount of groundwater extracted from them amounts to 5087.8 thousand cubic meters/day of these:

- for drinking – 1236,45 thousand m^3/day;
- for technical and production - 629.64 thousand m^3/day;
- for land irrigation – 1539,87 thousand m^3/day;
- for land reclamation – 1669,32 thousand m^3/day;
- and for others – 0,36 thousand m^3/day.

At the same time, in recent years, due to the development of agriculture and other economic facilities and the lack of adequate measures aimed at nature protection, negative changes in the quality of groundwater have been observed in some regions. Below, detailed information is provided in the section on groundwater sources.

3. Results.

The estimated reserves of Sokh groundwater resources are 3126 thousand cubic meters/day of these, 1207 thousand cubic meters/day (38,6 %) are considered to have a mineralization of up to 1,0 g/l. This water source is used to supply water to the population and economic facilities of the cities of Kokand, Yaypan, Rishton and the districts of Uzbekistan, Furkat, Dang'ara, Uchku'prik, Buvayda, Baghdod and Rishton. An ecological and geographical analysis of the landscape features of South Fergana is also presented based on groundwater quality indicators for 2023–2025 (Figure 5).

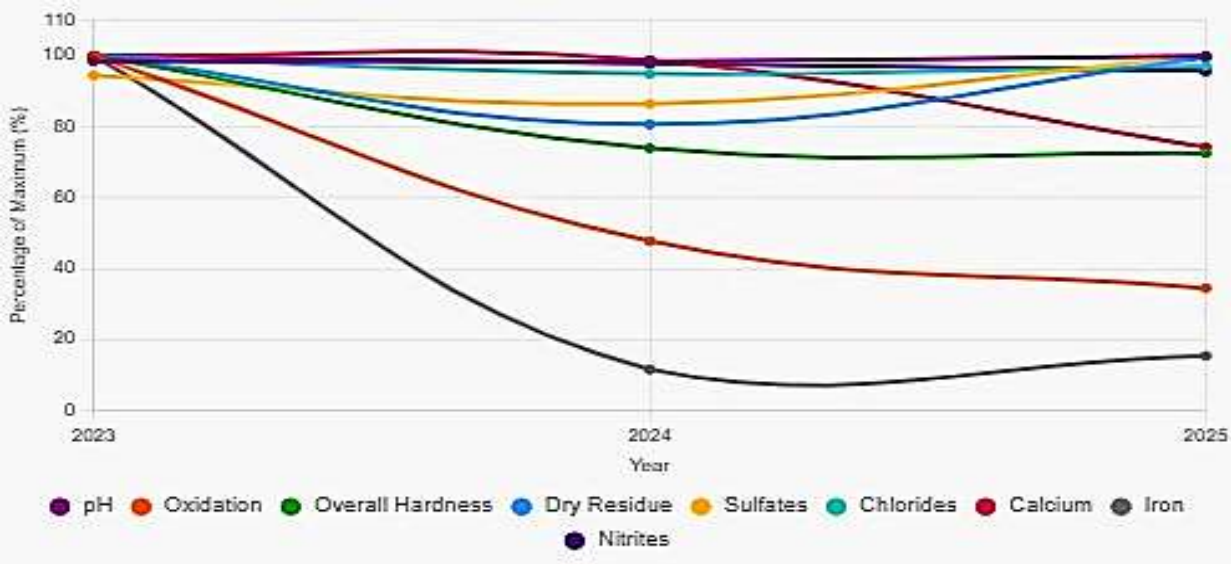

Figure 5. Water quality indicators from the Sokh groundwater source

Analyzing the table, it was determined that landscapes are also changing as a result of changes in groundwater quality and was analyzed as follows:

– The pH indicator is at a neutral level, which indicates a stable hydrochemical environment in the riverbeds, selitabs, and agrolandscapes of South Fergana.

– The oxidation index is decreasing sharply, which indicates a decrease in water pollution in recreational zones and agricultural areas, that is, an improvement in the ecological situation.

– Total hardness decreased from 2023 to 2025, indicating a decrease in calcium-magnesium ions in irrigated agrolandscapes.

– the dry residue decreased in 2024, it increased again in 2025. This indicator is due to the mineralized composition of the foothill rivers of the Fergana Valley, especially the Sokh and Isfayramsay rivers.

– of sulfates increased significantly in 2025, which was caused by the use of fertilizers and other chemicals in agricultural fields.

– Chloride levels have remained virtually unchanged, indicating that salinity levels are under control, and the decrease in calcium levels indicates that soft waters predominate, which is associated with the improvement of the agro-landscape reclamation.

– Iron levels have dropped dramatically, indicating the effectiveness of the new waterworks and filtration systems, and nitrite levels are at a consistently low level, indicating that sources of nitrogen pollution are being controlled.

According to him, various landscape types of the South Fergana region directly affect the formation of water quality. In general, positive changes in water quality indicators were observed during 2023-2025. In particular, the efficiency of ecological management in the seliteb and agro-landscapes has increased. At the same time, the increase in indicators such as sulfates and dry residue requires increased precautionary measures in the future. As can be seen from the above data, the quality of water supplied to the population in a centralized manner is experiencing negative changes in its mineral composition from year to year.

The estimated reserve of the Isfara groundwater source is 719,7 thousand cubic meters/day, of which 443.2 thousand cubic meters/day (62 percent) have a mineralization of up to 1,0 g/l. This water source mainly supplies water to the population and economic facilities of the city of Beshariq and Beshariq district (Figure 6).

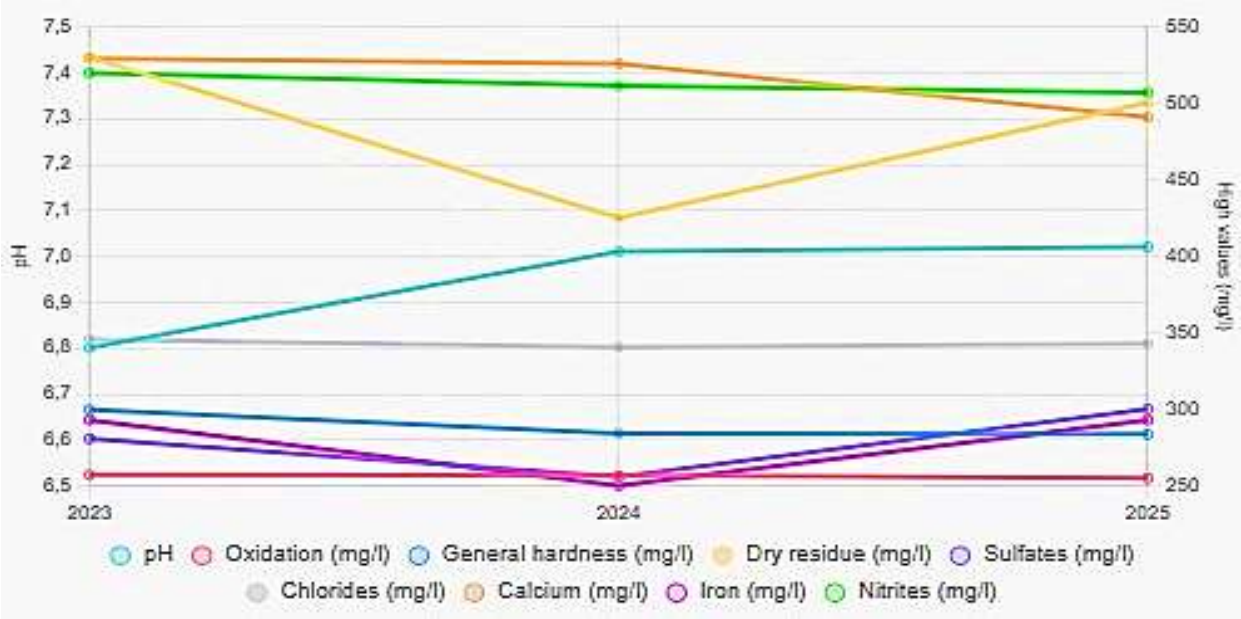

Figure 6. Indicators of Isfara groundwater source

Analyzing the table, it was determined that landscapes are also changing as a result of changes in groundwater quality and was analyzed as follows:

– The pH values were 6.8 in 2023 and increased to 7.02 by 2025. This indicates that the aquatic environment is becoming more neutral. A neutral pH (6.5-8.5) is considered an acceptable standard for drinking and irrigation water.

– The oxidation level decreased from 2.07 in 2023 to 1.42 in 2025. This decrease in the indicator means that the water is relatively free of organic pollution.

– The total hardness recorded a very high value (14.85) in 2023, but has decreased to normal in subsequent years (10.04 in 2025). High water hardness, especially in agro-landscapes, can lead to salinization of the soil and failure of hydraulic equipment.

– The dry residue had its lowest value in 2024 (425.2), and increased again in 2025 (500.6). This indicates the variability of the concentration of mineral salts and impurities. Exceeding the norm of the indicator poses a risk of salinization.

– The sulfate content increased in 2025 (299.9 mg/l), which is associated with man-made pollution or hardening of groundwater. This process can negatively affect crop growth in agrolandscapes.

– Chloride levels are almost stable, indicating that anthropogenic impact is minimal or under control.

– The calcium content has decreased year by year (83.85 in 2023 - 72.30 in 2025), which is inextricably linked to water hardness. In irrigated areas, the decrease in calcium may affect soil composition.

– Iron has remained almost unchanged, within regulatory limits (0.04 mg/l). This is a positive situation for water quality.

– The level of nitrites is very low, which indicates the absence or limited contamination with nitrogenous compounds.

The development of industry in South Fergana, in particular, cotton ginning, chemical industry, construction of building materials and other industries, has had an impact on natural resources. The acceleration of urbanization, the construction of new settlements and the growth of industrial production have increased the environmental impact. Air and water pollution are one of the negative consequences of this process.

The Oltiaryk-Besholish groundwater source is mainly used for domestic and drinking water supply of Oltiaryk, Kuva, Yozyavon, Toshlok, Qoshtepa districts and other purposes. The estimated reserve of the groundwater source is 2492.6 thousand cubic meters / day, of which 285.1 thousand cubic meters / day (11 percent) have mineralization up to 1.0 g / l. The estimated reserves of the water source are 1,226,000 cubic meters/day, of which 518.4 thousand cubic meters/day (42 percent) have mineralization up to 1.0 g/l.

Also, the total area of the area covered for leaching of salts from the soil of South Fergana is 22904.7 ha, of which 5941.5 ha are located in the Sokh-Pop vertical direction, 8292.2 ha in the Vadil-Nanay and 8671.0 ha in the Khanabad-Beshariq horizontal direction, the duration of groundwater flow is 80.2 and 245.0 km, respectively.

In 86 main sections and 30 groundwater samples at depths of 0–30, 0–50, 0–100, 0–200 cm, the content of easily soluble salts in groundwater and the content of HCO_3, Cl, SO_4, Ca, Mg, Na and dense sediment were determined.

The groundwater of the South Fergana region is located at different depths in the soil. In areas with ordinary gray soil, groundwater is located at a depth of 15-20 meters, in areas with light gray soil - at a depth of 4-6 meters, while groundwater in the hydromorphic soil of Central Fergana is located at a depth of 0.5-2.0 meters from the surface (Figure 7).

Analysis of the data presented in Table 3.1 shows that groundwater in the meadow soils of Central Fergana is located at a depth of 106-170 cm underground, their mineralization level varies within the range of 2.395-3.605 g/l for dense sediments, and 0.056-0.224 g/l for chlorides. Groundwater here is characterized by salinity mainly due to the high content of sulfates. In the qualitative composition of salts, $CaSO_4$ predominates, followed by $MgSO_4$, and the content of toxic salts in them varies, making up 30-44 % of the total content of easily soluble salts.

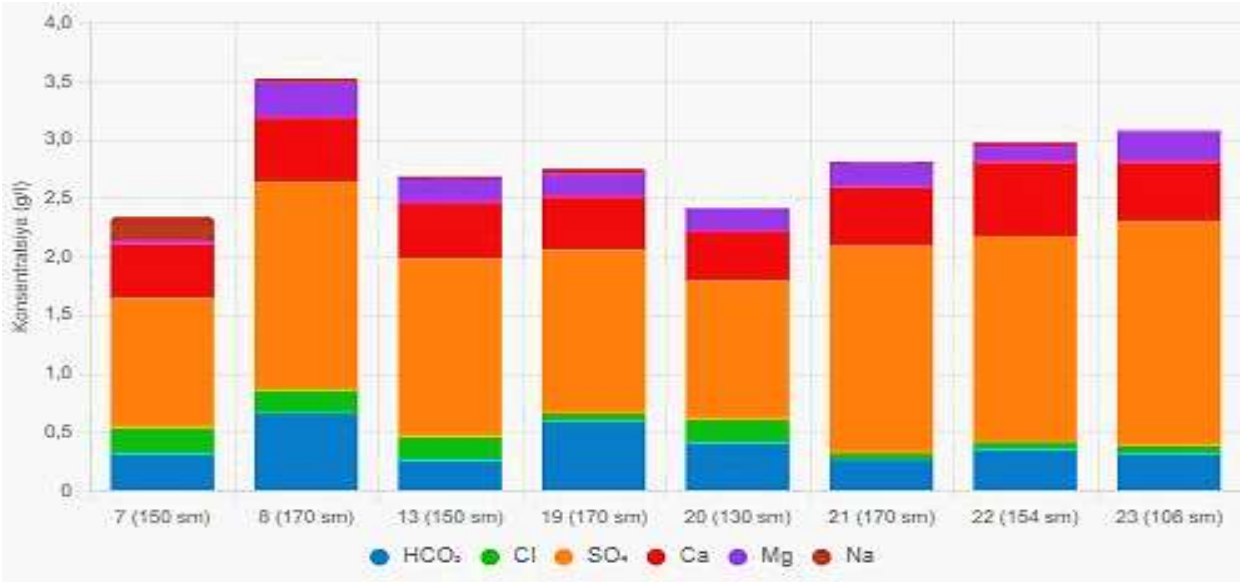

Figure 7.The degree of mineralization and chemical composition of groundwater in hydromorphic soils of South Fergana

The content of mineral substances and dry residue in the water is several times higher than the established standards. The content of nitrate and nitrite elements in the drinking water consumed by the majority of the population living in South Fergana is several times higher than the established REM level (according to DavST 950:2011, the content of nitrites in drinking water is 0.3 mg/l the content of nitrates is 45,0 mg/l). The content of nitrates in the drinking water supplied to the population varies from 51,2 mg/l to 18,8 mg/l, while nitrites vary from 7,20 to 1,90 mg/l.

4. Conclusion.

At the same time, the analysis of the data obtained showed that the water from boreholes, which is centrally supplied to the population, is polluted mainly as a result of technogenic and human activities, and this situation indicates that groundwater does not meet the requirements in terms of regular mineralization indicators, dry residue, and microelements (calcium, iron).

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