Landscape-ecological assessment and meliorative status of the Shohimardonsoy River basin, Fergana Valley, Uzbekistan

Feruza Khamroeva[1,*], *Sadokatkhon* Uktamova[2], *Ozodkhon* Kuziboyeva[2], *Dilshoda* Abdiakhatova[3], and *Sharafat* Dusanova[4]

[1]Samarkand State Pedagogical Institute, 230044 Samarkand, Uzbekistan
[2]Kokand State University, 150700 Kokand, Uzbekistan
[3]Samarkand State University, 230100 Samarkand, Uzbekistan
[4]Urgench State University, 220100 Urgench, Uzbekistan

Abstract. This study presents a comprehensive landscape-ecological assessment of the Shohimardonsoy River basin in the Fergana Valley, Uzbekistan, focusing on meliorative conditions and geoecological status over the period 2013-2023. Using integrated field surveys, GIS technologies, and mathematical modeling, we identified 16 distinct landscape types across altitudinal zones from 4,500m to 500m elevation. Water chemistry analysis revealed systematic downstream mineralization increase from 0.143 g/dm³ in pristine mountain tributaries to 0.265 g/dm³ in lower reaches, with detection of antimony isotopes [$(6.3\pm0.608) \times 10^4$] linked to upstream mining activities. Soil salinity assessment demonstrated remarkable improvement across the basin, with salinized areas decreasing by 47-79% in different districts, from 45,273 ha (2013) to 17,387 ha (2023). Meliorative conditions improved significantly, with lands classified as "Good" increasing from 28-96% to 72-98% depending on location. Mathematical modeling using Poisson distribution established quantitative relationships between elevation, flow velocity (3.9-14.2 m³/s), and sediment composition. The integrated geoecological assessment categorized 38% of the basin as "Satisfactory," 41% as "Moderately Tense," and 21% requiring intervention. The study provides detailed landscape-typological, meliorative, and geoecological maps at 1:350,000 scale, offering a scientific framework for sustainable basin management and supporting policy development for water resource conservation in Central Asian mountain-fed river systems.

1 Introduction

The Fergana Valley represents one of Central Asia's most intensively cultivated and densely populated regions, with over 144,500 hectares of irrigated agricultural lands dependent on mountain-fed river systems. The Shohimardonsoy River basin, originating from the northern slopes of the Alai Mountain Range and flowing through six administrative districts of

*Corresponding author: xamroyevaferuza@gmail.com

Fergana Province, serves as a critical water source supporting agricultural production and domestic needs for approximately 850,000 inhabitants [1].

Mountain river basins in arid Central Asia face unprecedented environmental pressures from climate change, agricultural intensification, and population growth. Recent studies document systematic glacier retreat (8-12% mass loss over 2000-2020), altered precipitation patterns, and shifting hydrological regimes across the region [2]. These changes directly impact downstream water availability, agricultural sustainability, and ecosystem integrity, necessitating comprehensive scientific assessment to inform adaptive management strategies.

The concept of landscape-ecological research in Central Asia has evolved from classical Russian geographical traditions, emphasizing the integrated analysis of relief, climate, hydrology, soils, vegetation, and anthropogenic influences as interconnected components of territorial complexes [3]. The basin approach, first systematically developed by Dokuchaev and refined by subsequent researchers, provides a natural framework for understanding material and energy flows within hydrologically-defined units [4]. However, application of this approach to Central Asian river basins, particularly with modern analytical tools, remains limited.

Previous research on Fergana Valley landscapes has established fundamental knowledge about their formation, structure, and anthropogenic transformation [5, 6]. Studies have documented soil salinization processes, irrigation-induced landscape changes, and regional environmental problems. However, comprehensive assessments integrating landscape typology, meliorative status, water quality dynamics, and geoecological conditions using contemporary technologies are lacking for most individual river basins.

The Shohimardonsoy basin presents unique characteristics among Fergana Valley rivers. With a relatively compact catchment (1,420 km²), pronounced altitudinal zonation (4,000m relief amplitude), and mixed glacial-snow-rain feeding regime, the basin exhibits distinct landscape differentiation and environmental gradients. Known locally as the "Switzerland of Uzbekistan" for its scenic mountain landscapes, the basin also faces serious conservation challenges including upstream mining impacts, intensive agricultural development, and climate-induced hydrological changes [7].

Recent national policy initiatives emphasize sustainable land and water management, with specific attention to soil reclamation, water quality protection, and climate adaptation in irrigated agriculture [8]. The 2019 Presidential Decree on efficient use of land and water resources established frameworks for ameliorative monitoring and assessment. However, implementation requires detailed scientific baselines and spatially-explicit information on current environmental status, which this study aims to provide.

This research addresses critical knowledge gaps by: (1) characterizing contemporary landscape structure and typology through integrated field and remote sensing analysis; (2) quantifying temporal dynamics of meliorative conditions in irrigated lands (2013–2023); (3) assessing water quality changes along the river continuum; (4) evaluating integrated geoecological status based on multiple environmental indicators; (5) developing mathematical models of landscape–relief–hydrology relationships; and (6) producing comprehensive thematic maps supporting management decision-making. In addition, the applied field-based and geospatial approaches provide an effective framework for engaging students in data collection, analysis, and interpretation, thereby contributing to the development of their research competencies.

The study objectives are to conduct systematic landscape-ecological analysis of the Shohimardonsoy River basin, assess meliorative status and improvement trends, evaluate geoecological conditions and anthropogenic impacts, establish quantitative models for scenario analysis, and develop policy-relevant recommendations for sustainable basin management.

2 Materials and methods

The Shohimardonsoy River basin is located in southern Fergana Valley (39°56' N, 71°51' E), extending from the Alai Mountain Range to the valley floor (Fig. 1). The basin covers approximately 1,420 km², with the river measuring 112 km from glacial sources to its distributary system. Administratively, the upper basin lies in Kyrgyzstan's Osh Province, while the lower portion traverses Fergana, Rishton, Quva, Oltiariq, Qo'shtepa, Yozyovon, and Toshloq districts of Uzbekistan's Fergana Province [9].

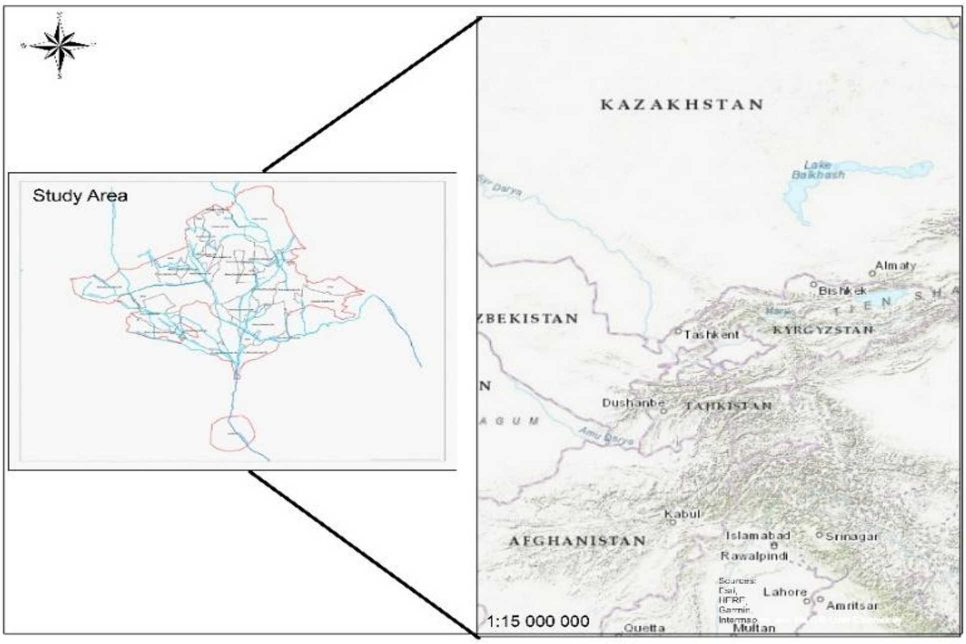

Fig. 1. Location map of Shohimardonsoy River basin showing altitudinal zones and administrative boundaries.

Field research was conducted during 2020-2023 through multiple expeditions encompassing reconnaissance surveys, detailed transect studies, and systematic observation at 47 representative sites across all landscape zones. Site selection employed stratified random sampling based on elevation, land use category, and administrative district to ensure comprehensive spatial coverage.

Soil sampling (n=156) followed standard pedological protocols, collecting samples from 0-50 cm depth at georeferenced locations using GPS receivers (±3m accuracy). Laboratory analysis at the Fergana Province Melioration Department determined: soil texture (hydrometer method), salinity (electrical conductivity and soluble salt content), organic matter (Walkley-Black method), pH (potentiometric), and major ions (standard titration and spectrophotometric methods). Salinity classification followed national standards: non-saline (<0.1 g/l soluble salts), slightly saline (0.1-0.2 g/l), moderately saline (0.2-0.4 g/l), strongly saline (0.4-0.8 g/l), and very strongly saline (>0.8 g/l).

Water samples were systematically collected from six strategic locations along the river continuum in August 2023: (1) Dugoba tributary, (2) Oksuv tributary, (3) Oksuv-Dugoba confluence, (4) Ko'ksuv tributary, (5) main channel formation point (Oksuv-Ko'ksuv junction), and (6) Qizilqiya (downstream). Samples were analyzed at the "GIDROINGEO" Research Institute laboratory following ISO standards for mineralization, total hardness, major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (HCO_3^{-}, CO_3^{2-}, SO_4^{2-}, Cl^{-}, NO_3^{-}), turbidity, and pH. Trace element and isotope analysis, including antimony (Sb), zinc (Zn), nickel (Ni), and other heavy metals, employed inductively coupled plasma mass spectrometry (ICP-MS) at the Nuclear Physics Research Institute.

Meteorological data (2013-2023) were obtained from Fergana and Yordon weather stations, providing daily records of temperature, precipitation, humidity, wind, and solar radiation. Groundwater monitoring data (124 observation wells) were acquired from the Fergana Province Melioration Department, documenting water table depth and mineralization across irrigated zones. Historical data on irrigated land areas, crop patterns, and ameliorative interventions were compiled from district agricultural departments.

Multitemporal satellite imagery analysis utilized Landsat 8 OLI (2013-2023, 30m resolution) and Sentinel-2 MSI (2017-2023, 10m resolution) data acquired from USGS Earth Explorer and Copernicus platforms. Cloud-free images during peak vegetation season (April-June) were selected for consistent phenological conditions. Preprocessing included atmospheric correction (DOS1 algorithm), geometric correction, and layer stacking in ENVI 5.3 software.

Land cover classification employed supervised maximum likelihood algorithm with seven categories: water bodies, bare land, sparse vegetation (<30% cover), moderate vegetation (30-60%), dense vegetation (>60%), agricultural lands, and urban/settlement areas. Training samples (n=280) were collected using high-resolution Google Earth imagery and field GPS points. Classification accuracy was assessed through confusion matrix analysis, achieving overall accuracy of 87.3% and Kappa coefficient of 0.84.

Normalized Difference Vegetation Index (NDVI) was calculated from near-infrared and red bands to assess vegetation vigor and temporal dynamics: NDVI = (NIR - Red)/(NIR + Red). Time series analysis identified seasonal patterns and multi-year trends in vegetation cover across landscape types [10].

Digital elevation models (DEM) derived from SRTM data (30m resolution) provided topographic parameters including elevation, slope gradient, aspect, and curvature. Hydrological analysis tools in ArcGIS 10.8 delineated watershed boundaries, drainage networks, and sub-basin hierarchies following Strahler stream ordering. Slope classification followed FAO guidelines: level (0-2°), gentle (2-5°), moderate (5-10°), rolling (10-20°), hilly (20-35°), and steep (>35°).

Landscape-typological mapping integrated field observations, topographic analysis, soil maps, land use data, and remote sensing products following the morphological-genetic approach. The hierarchical classification system employed was: landscape class → landscape subclass → landscape type → landscape complex, adapted from established Central Asian landscape schools [10].

Landscape boundaries were delineated through overlay analysis of thematic layers: (1) geomorphological units based on relief and lithology; (2) soil types and properties; (3) vegetation cover patterns from NDVI; (4) land use/cover from classification; (5) hydrological conditions including groundwater depth; and (6) anthropogenic modification degree. Minimum mapping unit was set at 25 hectares to balance detail with cartographic clarity at 1:350,000 scale.

Field verification involved traversing representative transects across landscape boundaries, photographically documenting transitions, and recording landscape characteristics using standardized protocols. Expert consultation with 12 specialists from research institutes validated preliminary landscape delineations and nomenclature.

Meliorative condition assessment integrated soil salinity, groundwater characteristics, drainage adequacy, erosion susceptibility, and agricultural productivity following established methodologies. Five-point rating systems evaluated each indicator, with composite scores determining meliorative condition categories: (1) "Good" – no additional ameliorative measures required; (2) "Satisfactory" – light ameliorative interventions needed; (3)

"Unsatisfactory" – complex ameliorative programs required; (4) "Poor" – intensive reclamation necessary; (5) "Unsuitable" – requires major investments or land use change.

Temporal analysis compared 2013 and 2023 conditions to assess trends and ameliorative intervention effectiveness. Data sources included: annual reporting from district melioration departments, systematic groundwater monitoring records, soil survey databases, and agricultural statistics on crop yields and land productivity.

Geoecological status assessment synthesized multiple environmental indicators: (1) atmospheric quality based on monitoring data from Fergana Province Environmental Protection Department; (2) soil degradation including erosion, deflation, compaction, and contamination; (3) water quality based on physical-chemical parameters; (4) biodiversity status from vegetation surveys; and (5) anthropogenic pressure indices. Each indicator was scored and weighted to derive integrated geoecological status categories: Satisfactory, Moderately Tense, Tense, Critical, and Catastrophic.

Three thematic maps at 1:350,000 scale were produced using ArcGIS 10.8: (1) Landscape-typological map showing 16 landscape types; (2) Landscape-meliorative map depicting meliorative conditions, soil salinity patterns, and groundwater characteristics; (3) Landscape-geoecological map integrating environmental status indicators.

Spatial interpolation of point data employed Inverse Distance Weighting (IDW) for groundwater depth and mineralization, with appropriate power parameters (p=2) determined through cross-validation. Cartographic design followed international standards including comprehensive legends, scale bars, north arrows, and data source citations. Maps were produced in digital format (geodatabase) and print-ready layouts.

3 Results and discussion

Comprehensive landscape analysis identified 16 distinct landscape types distributed across five geomorphological zones (Table 1). The classification reflects complex interactions between relief, climate, hydrology, soils, vegetation, and land use intensity, with pronounced altitudinal differentiation.

Table 1. Landscape types of Shohimardonsoy River basin.

		Glacial-nival, sparse alpine vegetation		
		Mountain brown soils, subalpine meadows		
		Gray-brown soils, sagebrush-ephemeral		
		Irrigated meadow soils, agricultural oases		

The landscape-typological map (Fig. 2) reveals clear spatial organization corresponding to altitudinal-zonal principles. High mountain landscapes (>3,000 m) occupy 10% of basin area, characterized by Paleozoic crystalline substrates, thin skeletal soils, and sparse vegetation adapted to harsh climatic conditions. The 74 glaciers concentrated in this zone represent critical water reserves, though recent monitoring documents systematic retreat (8% mass loss 2000-2020).

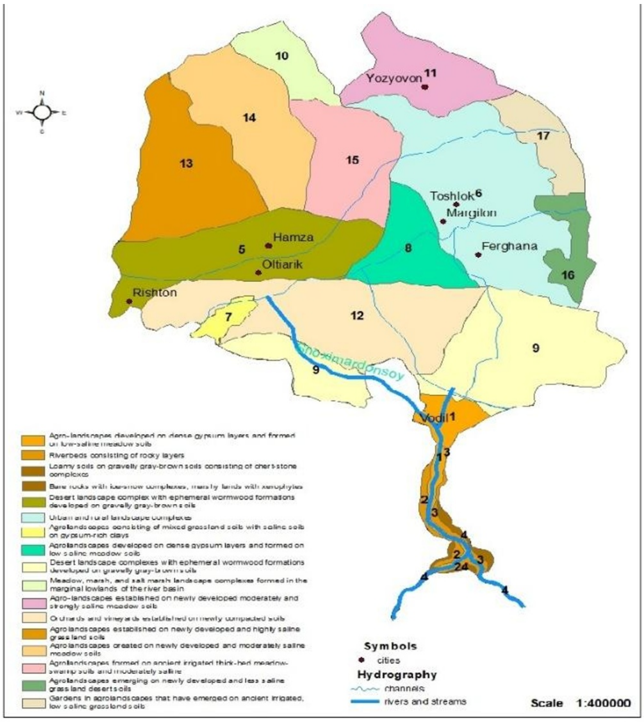

Fig. 2. Landscape-typological map of Shohimardonsoy River basin.

Middle mountain zone (1,500-3,000 m, 20% of area) features deeply incised V-shaped valleys with well-developed terrace systems. Mountain-brown and mountain-meadow soils support subalpine grasslands utilized for seasonal pasturing. Organic matter content ranges 1.7-5.0%, decreasing with elevation. Natural vegetation includes diverse herb communities with medicinal species, though overgrazing in accessible areas causes localized degradation.

Foothill landscapes (700-1,500 m, 23% of area) represent the transition to arid conditions, with gray-brown soils developed on loess-like and proluvial deposits. Natural vegetation comprises xerophytic shrubs (Artemisia, Salsola, Ferula species) and spring ephemerals. Anthropogenic modification for rain-fed agriculture and orchards is intensive in lower portions, while upper areas maintain semi-natural conditions used for extensive grazing.

Piedmont plains (500-700 m, 28% of area) exhibit highest landscape diversity due to intensive agricultural development. Six landscape subtypes were distinguished: (1) ancient irrigated meadow soils with thick (50-150 cm) irrigation deposits; (2) newly reclaimed desert soils with thin anthropogenic layers; (3) moderately saline meadow-swamp soils requiring drainage; (4) stony desert undergoing kolmataj (burial with fine sediments) for orchard establishment; (5) established orchards and vineyards on reclaimed lands; (6) urban-rural settlement complexes.

Lower plain landscapes (<500 m, 19% of area) show increasing hydromorphism with meadow-swamp and swamp-meadow soils affected by shallow mineralized groundwater. These marginal lands exhibit most severe salinity problems and require intensive drainage management for agricultural viability.

Systematic water sampling along the river continuum revealed progressive hydrochemical changes reflecting natural processes and anthropogenic inputs (Table 2). Upper tributary waters exhibit low mineralization (0.143-0.249 g/dm³) and soft to moderately hard characteristics, typical of pristine mountain sources draining carbonate-rich substrates.

Table 2. Water chemistry along Shohimardonsoy River continuum (August 2023).

Ca^{2+} (mg/dm^3)						
Mg^{2+} (mg/dm^3)						
SO_4^{2-} (mg/dm^3)						
Cl^- (mg/dm^3)						
NO_3^- (mg/dm^3)						

Downstream progression shows mineralization increase of 85% (Dugoba to Qizilqiya), total hardness increase of 85%, and compositional shift from calcium-bicarbonate toward sulfate-chloride types. While parameters remain within irrigation quality standards, the trends reflect cumulative impacts of agricultural return flows, domestic wastewater, and evaporative concentration.

Critical findings from trace element analysis detected antimony isotopes [$(6.3\pm0.608) \times 10^4$], zinc [$(8.7\pm1.6) \times 10^4$], nickel [$1.5\times10^4$], and europium [$8.2\times10^4$] in downstream samples. Antimony presence links directly to upstream Kadamjai mining operations in Kyrgyzstan territory. While concentrations remain below acute toxicity thresholds, chronic exposure concerns warrant continued monitoring. Field observations documented dense aquatic macrophyte communities (Potamogeton, Myriophyllum species) providing natural phytoremediation through heavy metal sequestration in plant biomass.

Comprehensive assessment of soil salinity across irrigated lands (144,500 ha total) revealed remarkable improvement trends over the 2013-2023 period (Table 3). All six districts demonstrated substantial reductions in salinized areas, ranging from 47% improvement in Fergana district to 79% in Toshloq district.

Table 3. Soil salinity dynamics by district (2013-2023).

District	**Irrigated area (ha)**		**Non-saline area (ha)**		**Total saline (ha)**		**Change (%)**
	2013	**2023**	**2013**	**2023**	**2013**	**2023**	
Fergana	29,17	29,505	28,68	29,244	497	261	-47
Toshloq	18,75	18,812	13,01	17,632	5,735	1,18	-79
Qo'shtepa	27,74	27,982	10,84	19,8	16,9	8,182	-52
Oltiariq	23,81	23,798	15,83	21,113	7,978	2,685	-66
Yozyovon	22,63	22,517	12,48	17,638	10,16	4,879	-52
Basin total	144,5	144,91	99,23	127,52	45,27	17,39	-62

Basin-wide, salinized area decreased from 45,273 ha (31.3% of irrigated lands) in 2013 to 17,387 ha (12.0%) in 2023, representing 62% improvement. This positive trend reflects successful implementation of ameliorative programs including: expanded collector-drainage networks (18% increase in coverage), adoption of water-efficient irrigation technologies (drip, sprinkler systems), improved leaching practices during non-vegetation periods, crop rotation with salt-tolerant species, and better water quality management.

Spatial patterns show strongest improvements in lower basin districts (Qo'shtepa, Yozyovon, Oltiariq) that historically suffered most severe salinization. Upper districts (Fergana, Toshloq) maintained predominantly non-saline conditions throughout the period due to favorable hydrogeological settings: deep groundwater (5-12 m), low mineralization (0.5-2.5 g/l), and adequate natural drainage.

The landscape-meliorative map (Fig. 3) visualizes spatial distribution of meliorative conditions, integrating soil salinity, groundwater depth, drainage adequacy, and erosion status. The map reveals clear zonation from excellent conditions in piedmont zones to progressively challenging conditions approaching the Fergana Valley center.

 https://doi.org/10.1051/e3sconf/202671903001

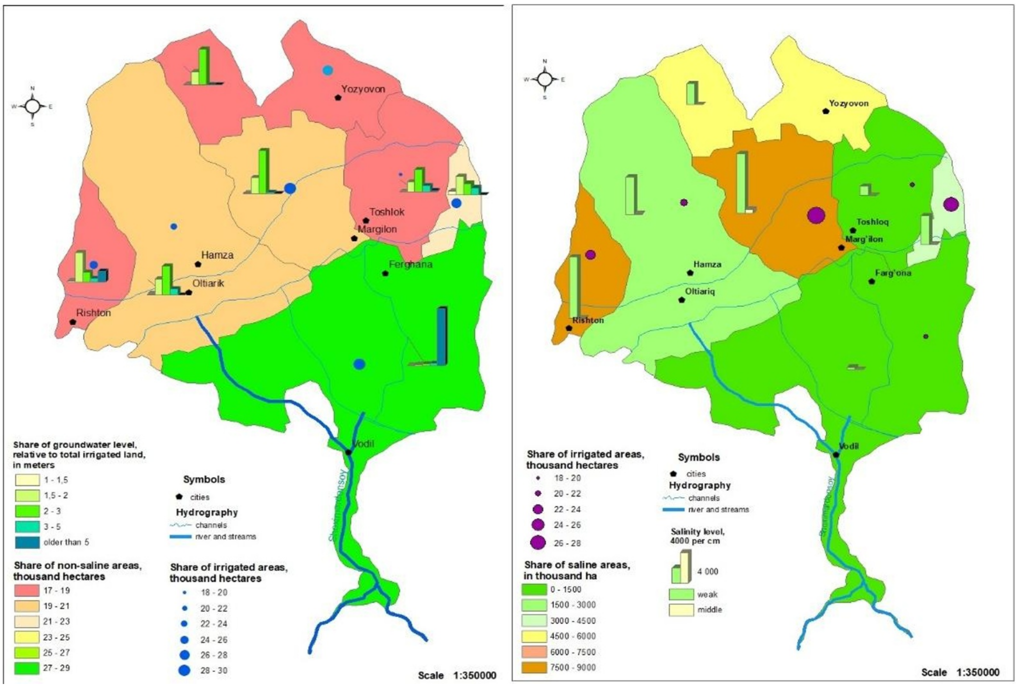

Fig. 3. Landscape-meliorative map showing soil salinity patterns and groundwater.

Meliorative condition classification showed dramatic improvements (Fig 4). Lands in "Good" category increased from 24-96% (2013) to 26-98% (2023) depending on district. "Unsatisfactory" category decreased from 1-20% to 0-2% basin-wide, with most districts achieving near-elimination of severely degraded lands.

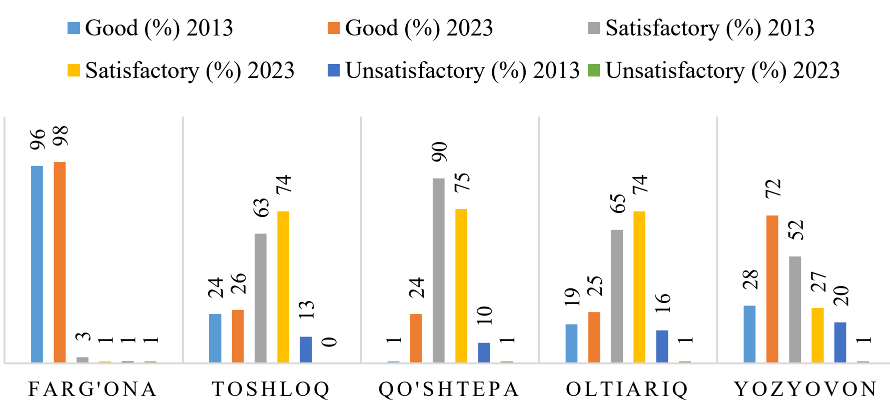

Fig. 4. Meliorative condition dynamics by district (2013-2023).

Yozyovon district demonstrated most dramatic transformation, with "Good" category increasing from 28% to 72%, attributed to intensive ameliorative program implementation (2015-2020), collector-drainage rehabilitation, reduced rice cultivation, and improved farm management practices.

Quantitative analysis established strong relationships between basin elevation, hydrological parameters, and sediment dynamics (Table 5). Flow velocity showed positive correlation with altitude ($r = 0.89$, $p < 0.01$), while sediment concentration exhibited complex non-linear patterns reflecting erosion-transport-deposition processes.

Table 4. Modeled relationships between elevation and river parameters.

				χ^2 (Poisson)

Regression modeling yielded: $v = 0.0031h + 0.52$ ($R^2 = 0.84$), where v = velocity (m^3/s), h = elevation (m). Suspended sediment concentrations peaked at middle elevations (2,000 m: 23.56 mg/l) where steep gradients and exposed substrates maximize erosion, decreasing both upstream (limited sediment sources despite high energy) and downstream (deposition of coarser fractions).

Comparative analysis with adjacent Sokh River basin revealed systematic differences: Shohimardonsoy exhibits 10-15% lower flow velocities at comparable elevations, 20-25% reduced sediment loads, and distinct chemical signatures (higher calcium-bicarbonate, lower sulfate concentrations). These differences reflect: steeper gradients and more erodible substrates in Sokh basin; larger Sokh catchment area (2,480 km^2 vs. 1,420 km^2); greater proportion of resistant limestone bedrock in Shohimardonsoy; and varying land use intensities.

Comprehensive geoecological evaluation synthesizing atmospheric quality, soil degradation, water quality, and anthropogenic pressure indicators categorized basin areas into five status classes (Fig. 5). The assessment reveals 38% of basin area in "Satisfactory" condition, 41% "Moderately Tense," 17% "Tense," 3% "Critical," and 1% "Catastrophic."

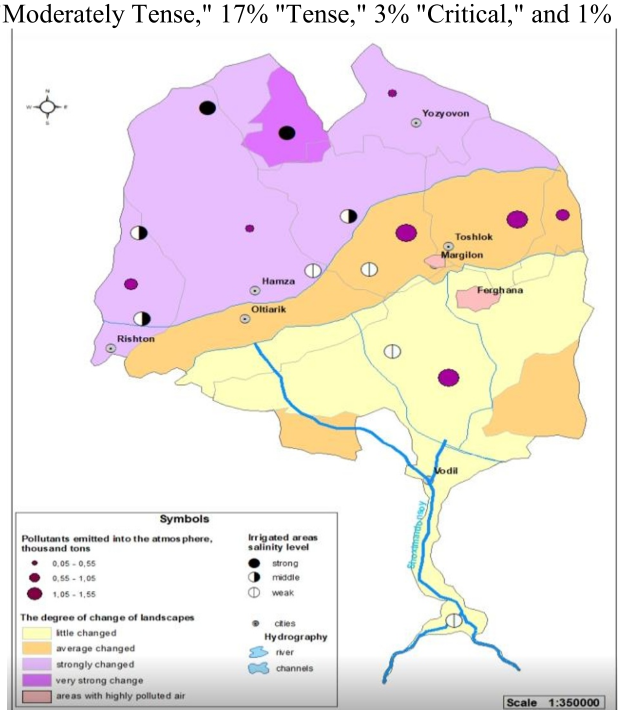

Fig. 5. Landscape-geoecological map showing integrated environmental status.

"Satisfactory" zones predominantly occupy upper mountain areas (>2,500 m) with minimal human impact, intact ecosystems, and pristine water quality, plus Fergana district agricultural lands benefiting from favorable hydrogeological conditions and effective management.

"Moderately Tense" zones encompass middle mountains, foothills, and most irrigated areas where localized environmental problems remain manageable through current ameliorative practices. This category includes Toshloq, Rishton, and portions of Oltiariq districts.

"Tense" zones concentrate in Qo'shtepa and Yozyovon districts where, despite significant salinity improvements, shallow mineralized groundwater (1-3 m depth, 2.0-4.0 g/l mineralization) requires continued intensive drainage management. These areas show persistent vulnerability to secondary salinization and waterlogging.

"Critical" zones (4% of area) include: (1) urban-industrial pollution hotspots in Fergana and Margilan cities (textile industry impacts: elevated particulates 0.3-0.5 mg/m³, sulfur dioxide 0.081-0.513 mg/m³); (2) Quvasoy cement plant vicinity (dust pollution); (3) severely degraded abandoned salinized fields; (4) eroded foothill slopes (187 km² classified high erosion risk).

"Catastrophic" status (1% of area) applies to localized degraded sites including: illegal waste dumps, severely eroded gullies, abandoned heavily contaminated industrial sites, and critically salinized plots (>0.8 g/l soluble salts).

4 Conclusions

This study provides an integrated landscape-ecological, meliorative, and geoecological assessment of the Shohimardonsoy River basin based on field observations, GIS analysis, remote sensing, and mathematical modeling for the period 2013–2023. The basin is characterized by pronounced altitudinal zonation, within which 16 distinct landscape types were identified, reflecting strong interactions between relief, hydrology, soils, vegetation, and land use.

The results show a clear downstream increase in river water mineralization and hardness, while overall hydrochemical parameters remain within acceptable limits for irrigation. Detection of antimony and other trace elements confirms the influence of upstream mining activities, emphasizing the need for transboundary monitoring and preventive measures. At the same time, the presence of natural aquatic vegetation indicates a certain self-purification capacity of the river system.

One of the most important findings is the substantial improvement in meliorative conditions across irrigated lands. Between 2013 and 2023, the total area affected by soil salinization decreased by more than 60%, and lands classified as having “Good” meliorative status increased significantly in all districts. These positive changes reflect the effectiveness of drainage rehabilitation, improved irrigation management, and targeted reclamation measures.

Mathematical modeling confirmed strong relationships between elevation, flow velocity, and sediment dynamics, demonstrating the controlling role of relief in hydrological and geomorphological processes within the basin. The integrated geoecological assessment shows that most of the basin is currently in satisfactory or moderately tense condition, while environmentally critical areas are limited in extent and spatially localized.

Overall, the study establishes a comprehensive scientific baseline for the Shohimardonsoy River basin. The produced landscape-typological, meliorative, and geoecological maps and quantitative assessments can support sustainable land and water management, environmental monitoring, and policy development. Continued attention to water quality protection, maintenance of drainage systems, and mitigation of anthropogenic pressures is essential to ensure long-term ecological stability and agricultural sustainability in this mountain-fed river basin.

References

1. M. Qadir, E. Quillérou, V. Nangia et al., Economics of salt-induced land degradation and restoration, Natural Resources Forum **38(4)**, 282–295 (2014).
2. I. A. Soliyev, Urgency of studying Fergana Valley water resources in the climate warming period, Uzbekistan Geographical Society Bulletin **44**, 112–118 (2019).
3. V. B. Sochava, *Introduction to the Theory of Geosystems* (Nauka, Novosibirsk, 1978).
4. S. Khasanov, R. Kulmatov et al., Impact assessment of soil salinity on crop production in Uzbekistan and its global significance, Agriculture, Ecosystems & Environment **342**, 108262 (2023).
5. S. Song, X. Chen et al., Deciphering the impact of wind erosion on ecosystem services: An integrated framework for assessment and spatiotemporal analysis in arid regions, Ecological Indicators **154**, 110693 (2023).
6. Z. NiNi, S. S. Zamir et al., Electrospun MXene–Sericin Nanofibers for Carbonated Recycled Aggregates: Toward Intelligent, Durable, and Low-Carbon Cementitious Composites, Materials Today Communications, 113221. (2025).
7. E. Khazieva, Ž. Malek, P. H. Verburg, A multi-data approach to evaluate progress towards land degradation neutrality in Central Asia, Ecological Indicators **154**, 110529 (2023).
8. M. Ibrakhimov, U. K. Awan, B. George, U. W. Liaqat, Understanding surface water–groundwater interactions for managing large irrigation schemes in the multi-country Fergana valley, Central Asia, Agricultural Water Management **201**, 99-106 (2018).
9. A. Khusanov, O. Sabirov et al., Microplastic pollution of the Zrafshan river tributary in Samarkand and Navoi regions of the Republic of Uzbekistan, Green Analytical Chemistry **12**, 100200 (2025).
10. S. Sadyrov, E. Isaev et al., High-resolution assessment of climate change impacts on the surface energy and water balance in the glaciated Naryn River basin, Central Asia, Journal of Environmental Management **374**, 124021 (2025).