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Sustainable Earth Trends

Journal homepage: http://sustainearth.sbu.ac.ir

Morphological assessment and management interpretation of the Kal-E Shur Sabzevar using the Rasgen classification method

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ABSTRACT

Riverine systems are of significant morphological importance due to their key role in the management and protection of floodplains. This study aims to evaluate the morphological changes and management of the Kal-e Shur River in Sabzevar using the Rasgen classification system. Initially, morphometric parameters were calculated using HEC-RAS software, and 419 cross-sections across 40 river reaches were extracted from satellite imagery. Sediment samples were collected from the riverbed to characterize the local sediment types. Nineteen geomorphological parameters were analyzed, and the most influential factors controlling river type were identified using the Information Gain Ratio (IGR) index. Results indicated that land use, precipitation, elevation, soil type, drainage density, vegetation cover index (NDVI), lithology, topographic slope, distance from the channel, topographic wetness index (TWI), and sediment transport index (STI) exerted the greatest influence. Segments classified as type D, with gentle slopes and sandy beds, exhibited poor conditions regarding sediment supply and erosion, although vegetation cover in these areas remained relatively preserved. Type C reaches were characterized by significant channel incision and high potential for erosion and flooding. In type B rivers, changes in flow patterns and sediment input contributed to channel instability. Conversely, type A, E, and G segments showed stable beds, lower sensitivity to turbulence, and better-preserved vegetation cover. These findings demonstrate that the Rasgen classification aligns well with geomorphological and morphometric factors, supporting its application in river management, restoration, and the mitigation of erosion, sedimentation, and flood hazards.

ARTICLE INFO

Keywords:
Flood
HEC-RAS
Kal-e Shur Sabzevar
Morphology
Rasgen

Article history:
Received: 07 May 2025
Accepted: 27 August 2025

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Citation:
Naemitabar, N. et al., (2026). Morphological assessment and management interpretation of the Kal-E Shur Sabzevar using the Rasgen classification method, *Sustainable Earth Trends:* 6(3), (55-

DOI: 10.48308/set.2025.240729.1142

1. Introduction

In geomorphology, a fundamental principle asserts that “form dictates process.” This underlies the existence of numerous morphologic classifications related to landscapes, slopes, and rivers. The form–process paradigm serves as a highly effective tool for quantitative geomorphic investigations (Shroder, 2013). One of the crucial topics in engineering geomorphology and river management is the study of river channel morphology, which provides valuable information on geometric configuration, bed form, longitudinal profiles, cross-sections, and the temporal evolution and migration of rivers (Breech, 2008). Nowadays, fluvial geomorphology has entered a new era and serves as a fundamental basis for studying environmental changes, providing essential insights for river channel management (Kleinhans et al., 2011; Ariayi and Lashkar-Ara, 2018). Multiple factors, including climatic fluctuations, geological characteristics, active tectonics, and anthropogenic activities, drive changes in the geometric configuration, erosion, and instability of rivers. Consequently, these processes lead to outcomes such as intensified erosion, regional aridity, and land degradation (Baajzadeh et al., 2025). The classification of river forms holds significant importance in geomorphological and hydrological studies of rivers. The formation and structure of rivers reflect hydrodynamic and sedimentary processes, providing valuable insights into the diversity of riverine systems worldwide (Li et al., 2025).

Alterations in river channel morphology play a crucial role in controlling flood magnitude and the river's capacity to transport sediments such as sand and gravel; therefore, these changes serve as prominent indicators of a river's vitality (Wen et al., 2025). River restoration and ecological engineering have become essential for improving river conditions, especially when ecological habitats and connectivity have been altered by anthropogenic pressures. Among the various restoration approaches available, some specifically focus on reconstructing river forms and enhancing physical processes. The aim of this study is to demonstrate how geomorphological expertise and process-based thinking contribute to the success of river restoration (Piégay et al., 2023). The discussion of morphology (or the study of river behavior) determines the action and reaction or behavior of rivers in different situations (Talebi and Bayazidi, 2008). River morphology, particularly the structural fabric of river channels, represents a fundamental aspect of fluvial geomorphology. The geometric characteristics of rivers are essential for reconstructing historical hydrological conditions and for understanding the evolutionary development of fluvial systems (Dury, 1976).

Davis (1899) was the first to classify rivers based on their developmental stage into three categories: youthful, mature, and old. Later, Leopold and Wolman (1957) categorized alluvial rivers into straight, meandering, and braided types using sinuosity and width-to-depth ratio. Schumm (1963) proposed a descriptive classification considering two critical factors: channel stability and sediment transport. While the Rosgen classification builds upon these foundational approaches, it emphasizes the importance of a river's ability to continuously convey its sediment load of varying sizes while maintaining local equilibrium between erosion and deposition. The Rosgen method not only provides a systematic framework for geomorphic assessment but also serves as a practical and widely adopted tool for river restoration and management. Its application enables researchers and practitioners to identify unstable reaches, understand sediment dynamics, and implement effective conservation and rehabilitation strategies (Rinaldi et al., 2012). River channel instability, due to its influence on erosion rates and channel characteristics, plays a critical role in floodplain development and water resources management (Minghui et al., 2010). The morphology of rivers is of particular importance for flood protection and mitigation, owing to its close linkage with natural habitats and its role in flood conveyance (Sear et al., 2003). The Rasgen method is currently the most comprehensive and complete approach available, encompassing many characteristics of previous river classification systems (Hosseinzadeh and Esmaili., 2019). Research has also been conducted in Iran and worldwide on river channel studies and the classification of rivers based on morphological characteristics and river management. Roostaei et al. (2013), in order to analyze the historical morphologic conditions of the Lighvan River channel based on the Rasgen classification, found that some channels were well-aligned with this classification while others were not. Consequently, this type of morphologic classification can be effectively utilized in engineering planning, river management, and restoration initiatives.

Layeghi and Karam (2014) applied the Rasgen classification system to predict hydrogeomorphological changes in the Jajrood River to guide river restoration and management measures. Their results indicated that upstream control measures and watershed management along the banks—such as gabion construction, riparian vegetation management, and soil stabilization—can significantly reduce potential degradation. Yamani et al. (2015) evaluated and classified the Talvar River based on the Rasgen model at secondary and tertiary levels. The tertiary-level stability assessment showed that the middle sections of the river exhibited weak stability, while other sections were classified as moderate to good. Moreover, the existing channel patterns and the parameters influencing channel classification aligned with the Rasgen model. Nayyeri et al. (2017), using the Rasgen method alongside the River Styles framework, conducted a geomorphological assessment of the Krowal River in Kurdistan. The results revealed that areas identified as high-capacity equilibrium by the River Styles method showed instability according to the Rasgen approach. Esfandiyari Darabad et al. (2021) analyzed the Hamzeh Khanlu River using the Rasgen model and concluded that it can quantitatively predict the geomorphology of the Hamzeh Khanlu River and similar rivers. Geravand et al. (2020) classified the Keshkan River geomorphologically using the Rasgen system, finding that river channel patterns and parameters affecting classification largely aligned with the Rasgen framework, although local variations existed due to specific influencing conditions. Roy et al. (2016) applied the Rasgen model to rivers in the West Bengal basin, India, revealing that sections with agricultural and forest land use exhibited variable erosion and bed material conditions, falling within type C and B classifications. Meehan and O'Brien (2019) examined riverbanks using hydraulic and geomorphologic analyses with the Rasgen model, indicating that river channel types (E, C, B, F, and G) correspond to differing stability conditions. Given the flood-prone nature of the watershed and the land-use changes in recent years, it is essential to assess the river in terms of stability and equilibrium. Since the study area is located in an arid and semi-arid region, and the occurrence of torrential rainfall makes the riverbed highly susceptible to flooding, significant damage is inflicted on surrounding infrastructure and lands, leading to erosion and increased sediment deposition along the riverbanks. Therefore, the present study aims to characterize the morphology of the Kal-e Shur Sabzevar, evaluate the river's stability across different reaches, and identify hazardous and vulnerable areas using the Rasgen model. By predicting river equilibrium, this research provides a crucial basis for flood risk management, erosion control, and informed land-use planning within the watershed. Rivers, as key agents in landform development and sediment transport, play a crucial role in the dynamics of aquatic ecosystems and water resources management. Morphological analysis and classification of rivers, particularly through the Rosgen Classification method, enable the identification of river types and the factors influencing their hydro-morphological behavior. The study area, with its distinctive geomorphic and hydrological characteristics, provides a valuable case for examining sedimentary processes and bank stability. Detailed investigation of this region not only enhances understanding of sediment distribution and transport but also offers critical information for water resource management, flood risk prediction, and the conservation of riverine ecosystems. Considering the importance of understanding the factors affecting river types in arid and semi-arid regions, this research employs statistical indices and standard sediment sampling techniques to analyze the relationships among hydrological, geomorphological, and sedimentary characteristics. The findings of this study are beneficial for watershed management, sustainable development policies, and river engineering projects.

2. Material and methods

2.1. Case study

The area under study is located between 56◦ and 27′ to 59◦ and 37′ east longitudes around the 36◦ north latitude, and its area is 21343 square kilometers. This basin, expanding east-west, is limited to the Juyin basin from the north and the basins overlooking the Bajestan and Bardaskan deserts from the south. The highest point in the Kal-Shur basin is 3250 meters high in Binalud, and the lowest point is 830 meters in the Mazinan desert. The Kal-e Shur River originates from the heights of the Fariman leopard ridge at the easternmost point of the basin and flows westward, ending in the Mazinan desert in the west of the basin. During the floods and overflows of the Mazinan pit, it ends in the eastern pits of the desert plain through the Abrisham River. In terms of country divisions and political situation, the study area includes parts of Fariman, Mashhad, Torbat Heydariyeh, Neyshabur, and Sabzevar counties (Pourhamzeh et al., 2019). This region has an arid to semi-arid climate according to the modified de Marten method. The vegetation cover of the region is sparse, and short-term and heavy rainfall often causes runoff and flooding. The seasonal Kalshur River of Sabzevar, with a length of more than 310 kilometers, originates from the height's northeast of Neyshabur (Yal-Palang Mountain) and, after passing through the Neyshabur-Sabzevar plains, ends in the Khartouran Desert and is the entire conduit created in the region in question (Farzaneh, 2015). The average annual flow volume of this river has been reported to be 47 million cubic meters (Fig. 1).

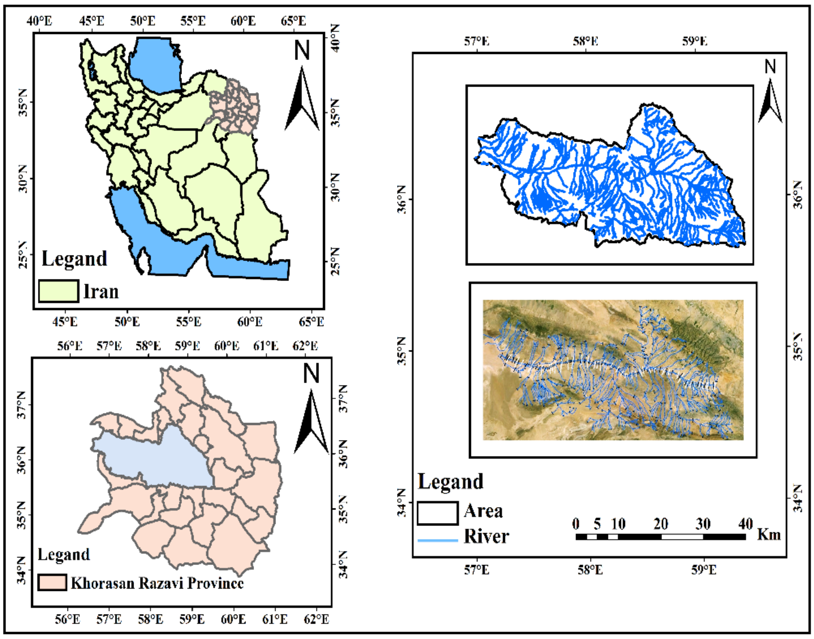

Fig. 1. Location of the study area.

2.2. Research data preparation

Firstly, Google Earth satellite images were used to determine the intervals and sections. To investigate geomorphological studies, a 1:50000 topographic map, a 1:100,000 geological map, a 1:25000 land use map, and a soil map of the General Directorate of Natural Resources and Watershed Management of Khorasan Razavi Province were used, and to prepare the precipitation layer, 30-year data (1990-2000) from the regional meteorological stations were used. A digital elevation model (DEM (Digital Elevation Model) represents a regular grid (raster) or an irregular network (TIN) of elevation data, where each cell or node corresponds to the ground surface elevation at a specific location) Information Gain Ratio (IGR), proposed by Quinlan, normalizes information gain with intrinsic information to minimize bias toward multi-valued attributes in decision trees) with a resolution of 12.5 meters was used to extract the basin boundary from the topographic map and draw the waterways. In the second step, the IGR index was used in Weka 3.9.2 software to determine the most important factors affecting the river type. Then, HEC-RAS 5.0.3 hydraulic software was used to calculate the morphological parameters.

This model was developed by the Hydraulic Engineering Center (HEC) in the U.S. Army Corps of Engineers. The model's distinctive capability lies in its ability to calculate and simulate parameters and water surface profiles in subcritical, supercritical, and mixed flows. This comprehensive model provides a powerful tool for managing and analyzing complex water systems and provides valuable insight into the hydraulic behavior of water flows (Mehrvarz et al., 2020).

In this model, the morphological characteristics of the river were examined by cross-sections, and the distance between the sections and all hydraulic parameters were calculated in each cross-section. Then, the Rasgen classification was extracted using the region's TIN (triangular irregular network). The layers created as (RAS) were read in Arc gis 10.4 and HEC-RAS software. Finally, the river type, stability, and vulnerability of the river were determined based on the Rasgen model. Also, to complete the basin information, a field visit was carried out, and sediments were collected from the riverbed in several parts of the basin. Then, measurements were taken from all samples, and the sediment type was determined.

For sample collection, sediment transects were established based on Rosgen stream types and varying levels of bank stability. These transects were located across the upstream, midstream, and downstream reaches of the river, covering sections with diverse channel geometries to fully represent the range of hydraulic and geomorphological conditions. At each sampling stage, parameters such as instantaneous discharge, wetted cross-sectional area, velocity variations, and flow depth along the cross-sectional profiles were measured,

while the precise sampling locations were recorded using GPS and leveling instruments. Suspended sediments were collected using depth-integrating samplers under isokinetic conditions (e.g., DH-59, D-74, and other standard devices). For each transect, three to five verticals (including the left bank, thalweg, right bank, and, where necessary, additional quarter points) were considered, and samples were taken from multiple depths of the water column and composited to represent a depth-integrated mean. Furthermore, bed material grain size distribution was assessed using the Wolman pebble count method, conducted along a systematic grid across the channel transect.
The recorded particle sizes were classified into coarse, medium, and fine fractions using statistical software, and sedimentary indices such as hydraulic diameter, median grain size (D50), and mass percentage distribution were calculated. These indices were analyzed for each stream type according to the Rosgen classification, with the aim of identifying the relationships between sediment characteristics and channel typology. In this way, the influence of hydrological and geomorphic attributes on sediment composition and behavior across different river reaches was quantitatively and comparatively evaluated, providing a more precise basis for interpreting stream type and assessing bank stability.

2.3. HEC-RAS model

This model is a one-dimensional framework designed to simulate flow and sediment dynamics, focusing on long-term changes in the longitudinal bed profile driven by processes of deposition and erosion. The continuous flow series is discretized into smaller segments based on discharge and time variables. For each flow segment, the water surface profile is computed, from which hydraulic parameters such as velocity, energy slope, depth, and related cross-sectional characteristics are derived. By simulating channel bed adjustments, the model provides valuable insights into sediment transport and erosion processes, offering a practical tool for understanding river dynamics and informing management strategies. To implement the model, the study reach must be represented by multiple cross-sections. In order to achieve a realistic and reliable geometric representation, the number and spacing of these cross-sections should be determined according to established technical principles and standards. For large rivers, the spacing between cross-sections can extend up to approximately 300 meters (Aziziyan et al., 2017).

2.4. IGR index

This index was first used by Quinlan in 1993 to identify the quantitative predictive ability of influential factors. High values of this index indicate a higher predictive ability of that influential factor for modeling (Shirzadi et al., 2017).

2.5. Rasgen model

The Rasgen classification predicts river behavior based on morphology and the relationship of flow and sediment flow with specific morphology. The morphological characteristics of rivers are examined at four different levels, but it focuses more on two levels: level one, general geomorphic characteristics, and level two, morphological description (Rasgen, 1994). In this method, by determining the type of river based on the classification of its types at each level of assessment, its morphological characteristics are predicted (Khaleghi et al., 2019). This method is classified into four levels. At level 1, geomorphic characteristics, including topography, landform, and valley morphology, are obtained, which are used on a large scale, dimensions, pattern, and profile to determine the type of river. At level 2, morphological description is examined based on field surveys of interval information. At level 3, the river's condition, which is related to its stability, response potential, and performance, is examined, and at level 4, measurements are taken to verify and confirm the morphological relationships inferred from the previous stage (Ward et al., 2008). In this study, the Rasgen level 1, 2, and 3 classifications were used to assess each cross-section. The river level was then classified from A to G. According to the studies carried out, there is no type F river in the region.
Within the framework of the Rasgen stream classification system, analytical emphasis was primarily placed on Levels I to III. These levels, which are grounded in large-scale morphological criteria, channel pattern, and

generalized hydro-geomorphic attributes, enable the identification of stream types at basin and regional scales with a reasonable degree of accuracy. In contrast, Level IV requires detailed evaluations of hydraulic processes and sediment transport, relying on long-term datasets of discharge, sediment load, and hydrodynamic conditions. The acquisition of such datasets is particularly challenging—if not infeasible—for rivers in arid and semi-arid regions. Consequently, for management and planning purposes in these environments, focusing on Levels I to III represents a more practical and effective approach. Nevertheless, the application of the Rosgen method in dryland settings is subject to inherent limitations. Among these are the episodic nature of flood-driven flows, pronounced hydrological variability, the high susceptibility of channels to aeolian erosion and land-use changes, all of which can induce rapid adjustments in channel form and dynamics, thereby diminishing classification reliability. Moreover, the lack of persistent riparian vegetation and weak biotic feedbacks in such regions reduce the applicability of key indicators employed in the method, such as depth-to-width ratio or bank stability. Therefore, while the Rasgen classification provides a valuable framework for analyzing stream typologies, its interpretation in arid and semi-arid contexts should be undertaken with caution and, where feasible, integrated with complementary approaches such as geomorphic analyses or hydrological modeling.

3. Results and discussion

In this study, the Information Gain Ratio (IGR) was employed to assess the relative importance of variables and to identify the key factors influencing stream types within the Rasgen classification framework. The advantage of IGR over other feature selection metrics lies in its ability to address the inherent biases of traditional information gain. By normalizing the obtained values based on the entropy of each attribute, IGR provides a more balanced and equitable comparison among variables. This approach enables the precise identification of critical variables that play the most significant role in distinguishing stream types while mitigating the exaggerated influence of attributes with numerous categories or extensive scales.

Then 19 geomorphological parameters including land use, slope direction, profile curvature, surface curvature, precipitation, elevation, soil, drainage density, vegetation index (NDVI), lithology, topographic wetness index (TWI), slope, distance from the watercourse, sediment transport index (STI), topographic roughness index (TRI), topographic position index (TPI), slope length index (SFL) and watercourse power index (SPI) were investigated. Based on the results obtained, 11 land use parameters, precipitation, elevation, soil, drainage density, vegetation index (NDVI), lithology, topographic slope, distance from the watercourse, topographic wetness index (TWI) and sediment transport index (STI) are among the most important factors. This index is calculated from Eqs. 1 to 4:

$$\text{Info (S)} = -\sum_{i=1}^{2} \frac{n(\text{Li S})}{|S|} \log_2 \frac{n(\text{Li S})}{|S|} \quad (1)$$

S is a training data set with n input samples, and n (Li, S) is the number of samples in the training data set S belonging to class Li. Entropy quantifies the level of uncertainty or disorder in a dataset. A value of zero indicates complete certainty, occurring when all samples belong to the same class, whereas maximum entropy corresponds to a uniform distribution of classes. In this study, entropy was applied to assess the variability and distribution of stream types within the observational data.

Considering the factors affecting the type of stream, the amount of information required to divide S into the set (S_1, S_2, S…m) is calculated from Eq. 2; This measure represents the amount of information required to partition the dataset based on a specific attribute. Attributes with a larger number of categories or a wider scale tend to exhibit higher Split Information (S_I) values.

$$\text{Info (S, A)} = \sum_{j=1}^{m} \frac{Sj}{|S|} \log_2 \text{Info (S)} \quad (2)$$

The IGR index for a specific effective factor is obtained from Eq. 3; In essence, a greater Information Gain (IG) signifies that the attribute exerts a stronger influence in differentiating river typologies, highlighting its critical role in river classification analyses.

$$\text{IGR (S, A)} = \frac{\text{In f o (S)} - \text{In f o (S.A)}}{\text{Split In f o (S.A)}} \quad (3)$$

Split Info represents the information generated by dividing S training data into m subsets of Split Info, which is calculated from Eq. 4; A normalized form of Information Gain (IG) is applied here based on the Split Information (SI). This normalization eliminates bias toward attributes with numerous categories, ensuring that feature selection reflects their true significance.

$$SplitInfo(S, A) = -\sum_{I=1}^{m} \frac{Sj}{|S|} \log_2 \frac{Sj}{|S|} \quad (4)$$

According to Table 1, land use parameters, precipitation, elevation, soil, drainage density, vegetation cover index (NDVI), lithology, topographic slope, distance from the watercourse, topographic wetness index (TWI), and sediment transport index (TPI) are among the most important factors affecting river type.

Table 1. Determining the most important factors affecting river type using the IGR index.

Influencing factors	Average IGR
Land use	**0.624**
Altitude	**0.612**
Lithology	**0.901**
Slop	**0.571**
Aspect	0.000
Distance from river	**0.264**
Rainfall	**0.182**
Soil	**0.789**
Surface curvature	0.000
Profile curvature	0.000
Drainage density	**0.899**
TWI	**0.154**
SPI	0.000
STI	0.000
TRI	0.000
TPI	**0.102**
LS	0.000

3.1. River classification by Rasgen model

Using satellite imagery, field surveys, and data analyses in HEC-RAS and GIS software, 40 river reaches and 419 cross-sections were delineated. As illustrated in Fig. 2, the river types were classified from A to G. Subsequently, all necessary parameters for channel morphological classification and characterization were calculated for each reach (Table 2). A significant portion of the study basin exhibits slopes ranging from 0 to 10%. The primary factors influencing river type formation in the region include natural conditions such as low slope, catchment area, geologically sensitive formations, soil characteristics, and land-use changes along the riverbed, as well as anthropogenic impacts like sand and gravel extraction within the basin. The occurrence of sporadic, intense rainfall events contributes to sediment transport from upstream to downstream areas. Given that the riverbed land use is predominantly agricultural, especially dryland farming, maximum soil erosion occurs, which in turn promotes the development of floodplains. Additionally, the Kalshur River in Sabzevar exhibits poor drainage conditions, and sparse riparian vegetation in many sections exacerbates the degradation of plant cover along the riverbanks. In this study, the river morphology assessment and management analysis were conducted following Rasgen Level 3 classification.

Based on Table 2 and Fig. 2, the sections of the river classified as types E and A exhibit low width-to-depth ratios and high meandering, indicating relatively stable channel conditions. Field observations show that the sediments in these sections are primarily clayey, with moderate cohesion, contributing to high resistance against bank erosion. The vegetation cover is characterized as moderately dense grassland, playing a key role in stabilizing the channel banks. Flood events in these river types are limited. In sections classified as type D, the bed material is predominantly sandy, with high sediment supply. Vegetation is sparse, and due to the non-cohesive soil texture, bank erosion and sediment transport are significant. The incision index in these sections is high, promoting floodplain development. These areas are highly dynamic throughout most of the year, particularly during flood events, which can induce substantial morphological changes. For type C, the incision index remains high, while vegetation cover is weak due to anthropogenic pressures, resulting in poor channel stability. The bed sediments correspond to type D, and the floodplain continues to expand. Sediment supply from the bed and banks is considerable, leading to notable bank erosion. In type D sections, given the sandy bed material, both sediment supply and lateral erosion potential are elevated. Vegetation is minimal due to recent land-use changes, which destabilizes the channel pattern and drives morphological alterations. Type G sections exhibit relative stability in both sediment deposition and vegetation control. Flood extent in these reaches is lower compared to types C and B, and the flow regime is generally balanced.

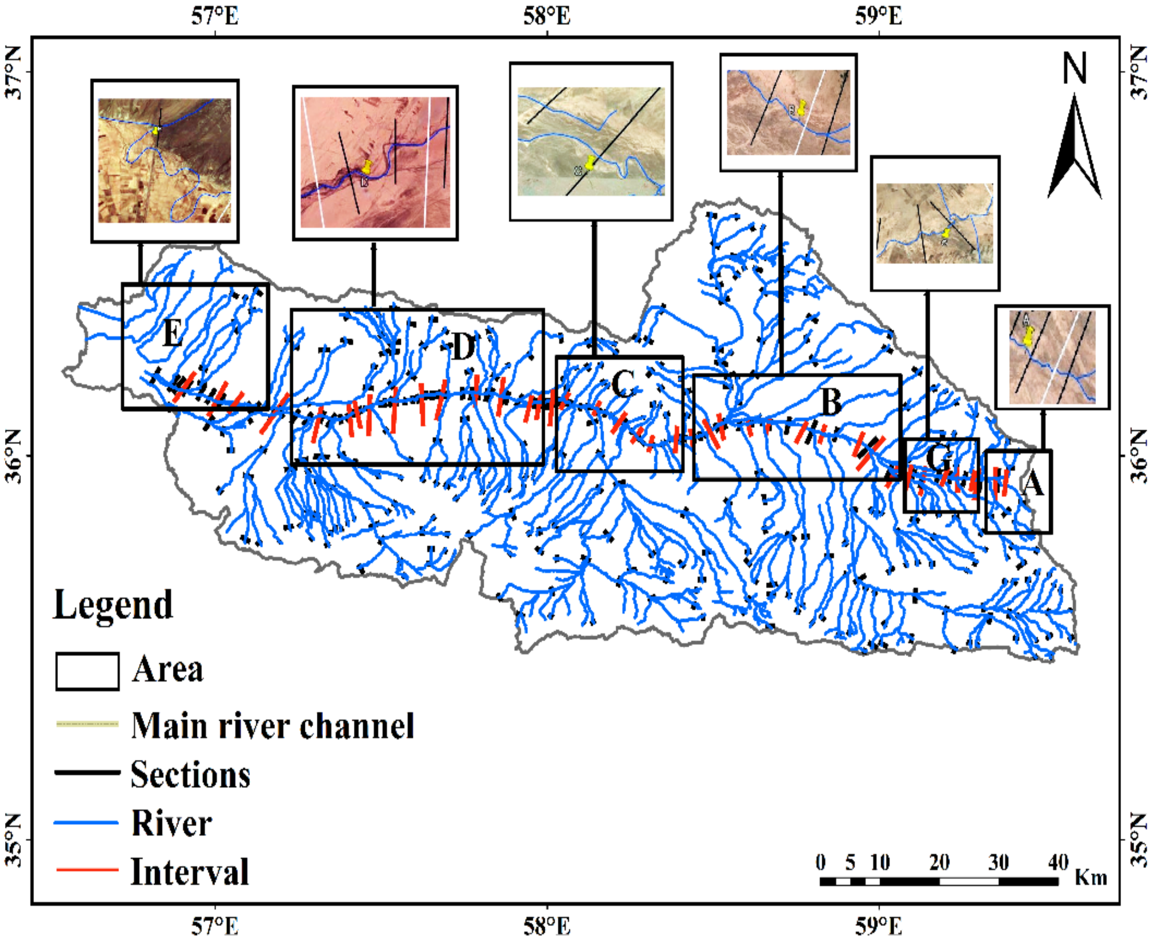

Fig 2. Classification of cross-sections and intervals based on Rasgen classification.

The current state of the river, the flow, and the channel are examined in terms of stability and field factors at the third level of Rasgen. Factors such as vegetation type, river stability and sustainability, bank erosion, turbulence, and turbulence are described at this level. These factors at the second level introduce the assessment of the morphology and physical form of the channel and indicate the current state and trend of river morphology. There are many criteria related to hydrological, biological, ecological, and human issues that affect river morphology. At the third level of the Rasgen classification, all the mentioned factors are analyzed. Each type of river shows a specific response to natural and human disturbances with the classification of levels one and two. At the third level, the river morphology is analyzed in relation to the three factors of stability, potential, and performance. The results of the assessment are presented in Table 3. According to Rasgen, the lower the total score, the more stable the river is, and the higher the score, the more unstable the river is (Rasgen, 1996). The set of scores in Table 3 is calculated based on the criteria for assessing river stability conditions at the third level of Rasgen (Rasgen, 1996). After calculating the scores resulting from calculating the parameters related to each of the intervals in the study basin; the analysis was carried out for each of the intervals. In Table 4, the scores related to the erosion-sensitive condition are shown.

Table 2. Morphological characteristics of the Kal-e Shur river channel in Sabzevar.

Interval	Rasgen classification	Slop	Sinuosity	Width/Depth Ratio	Bed depression	Floodplain width	Average depth	Maximum depth	Width overflowing	area overflowing	Discharge overflowing	Distance from downstream (Km)	Bed digging ratio	E-ratio	Section number
1	B	0.011	1.15	23.5	4.09	43	0.4	0.57	8.18	3.69	7.66	15.46	3.71	3.46	23
2	C	0.015	1.17	22.78	4.41	31	0.7	0.63	26.02	10.22	17.21	12.55	3.21	2.21	11
3	E	0.01	1.10	11.06	3.56	34	0.81	1.17	9.26	6.77	17.54	12.68	3.01	2.11	36
5	C	0.008	1.13	13.08	6.17	38	0.59	18.59	8.29	6.11	16.23	11.55	3.86	2.78	42
6	E	0.004	1.12	12.09	5.63	44	0.37	1.12	9.24	11.64	57.11	13.68	2.17	3.41	76
9	E	0.006	1.16	24.55	4.66	42	0.6	0.79	9.01	11.12	56.24	13.97	2.06	3.38	105
10	A	0.02	1.04	12.89	3.78	35	0.79	1.03	6.36	5.06	7.13	12.22	5.4	2.54	201
11	G	0.006	1.11	21.76	4.06	40	0.3	0.21	8.7	3.22	4.24	14.36	3.25	3.16	211
12	B	0.002	1.02	12.64	3.11	30	0.79	1.08	9.65	12.24	59.24	13.70	2.26	2.01	279
13	C	0.012	1.19	12.54	5.24	49	0.37	0.56	15.44	9.87	17.14	12.77	2.11	2.04	84
15	E	0.003	1.09	10.01	3.36	36	0.81	1.19	10.13	9.33	16.22	12.01	2.01	3.74	301
16	E	0.001	1.03	36.87	7.11	51	0.16	0.32	8.17	3.64	7.22	14.56	2.28	2.27	333
17	A	0.013	1.29	41.17	2.25	22	0.26	0.35	9.19	11.78	58.12	14.44	4.78	2.07	341
18	C	0.03	1.08	15.34	6.54	39	0.39	0.57	5.66	2.77	4.64	14.78	4.74	2.69	281
20	C	0.004	1.12	12.09	5.63	55	0.41	0.59	16.26	5.79	7.87	15.11	13.03	3.02	316
21	D	0.015	1.54	61.03	2.69	26	0.28	0.38	10.15	9.21	46.24	7.15	1.99	2.77	316
22	C	0.012	1.26	59.44	3.41	42	0.84	1.16	10.75	9.54	44.51	7.01	1.36	3.64	96
23	C	0.008	1.13	39.78	7.88	55	0.74	1.07	6.54	1.26	1.78	10.22	4.22	2.31	254
24	C	0.017	1.13	39.44	7.25	52	0.71	1.04	6.12	1.09	1.33	10.01	4.12	2.12	321
25	A	0.06	1.23	46.16	2.26	21	0.23	0.29	30	3.42	7.88	15.64	4.03	2.13	396
26	E	0.008	1.13	39.72	7.91	58	0.75	1.01	5.44	2.14	4.54	14.14	3.89	2.78	402
27	G	0.011	1.06	11.74	3.15	41	0.42	0.58	15.14	9.09	38.66	9.26	2.02	3.55	269
28	B	0.018	1.15	38.72	7.95	59	0.78	1.05	6.02	1.04	1.42	9.78	4.36	3.13	154
29	D	0.003	1.02	12.64	3.16	36	0.64	0.96	7.11	1.29	1.77	10.15	2.45	2.89	241
30	G	0.006	1.16	24.55	5.14	38	0.39	0.87	7.25	1.66	1.99	11.13	2.97	2.97	364
31	A	0.014	1.13	39.78	7.98	60	0.71	0.99	9.64	11.24	57/16	13.14	3.99	4.74	219
32	C	0.017	1.22	45.19	3.75	43	0.83	0.90	9.15	10.27	18.45	11.54	4.11	3.26	178
33	E	0.02	1.16	23.87	4.81	44	0.51	0.81	13.45	3.09	4.56	11.02	3.68	3.16	222
34	C	0.016	1.15	42.5	2.97	27	0.26	0.36	9.22	9.13	36.21	17.74	3.91	2.87	317
35	A	0.09	1.29	18.04	6.74	37	0.44	0.56	14.03	13.54	59.16	6.87	3.22	2.18	419
36	D	0.021	1.74	60.41	2.88	25	0.27	0.34	9.02	1.08	1.54	1.99	1.08	2.64	387
37	C	0.018	1.20	41.17	3.91	33	0.44	0.53	15.16	7.56	46.6	7.12	2.98	3.19	401
38	E	0.04	1.06	13.54	6.56	69	0.48	0.69	7.65	9.88	39.55	8.16	5.12	2.89	396
39	C	0.019	1.09	16.63	6.63	71	0.51	0.72	13.48	8.98	13.78	4.66	5.28	2.96	379
40	B	0.02	1.04	9.56	3.49	37	0.42	0.59	5.79	2.77	5.26	9.98	3.78	2.77	412

Table 3. River channel stability ranking.

River type	Total points	Status
A	77	Good (stable)
B	97	Weak (unstable)
C	91	Weak (unstable)
D	95	Weak (unstable)
E	71	Moderate (limited volatility)
G	79	Good (stable)

For the management interpretation of river types in the study area, the management interpretations of the Rasgen river model have been used (Rasgen, 1994). The management interpretation of river types is examined in terms of the degree of sensitivity to disturbance, restoration potential, sedimentary nutrition, bank erosion potential, and the controlling effect of vegetation cover. Based on the results obtained from Table 4, sedimentary nutrition is high in types B, C, and D, which increases the degree of sensitivity to disturbance. In this section, the riverbed load increases and bank erosion is high due to the turbulence of the flow. The vegetation cover in this section is in a weak and unstable condition due to land use changes caused by human activities (overgrazing of livestock, conversion of pasture lands to agriculture, and construction near the river). In parts of the river where management plans have been adopted, the restoration potential is relatively good. However, in general, the vegetation cover in the region is in an inappropriate condition. Morphologically, the riverbed has a high sinusoidal coefficient, and the floodplain extends on a low slope. In type G, a relatively stable situation exists. The sediments of the riverbed are of the type of rubble and sand. The coarse-grained texture as a surface protective layer of the bed causes the resistance of the walls to be lower than the bed bottom. The increase in sediment load resulting from the destruction of the walls helps sediments to settle. In types A and E, due to the presence of dense pastures, the depth of root penetration, resistant formations, and the type of clay soil and relatively high adhesion, the river banks erode slowly. The degree of sensitivity to turbulence, sediment nutrition, bank erosion potential, and control of vegetation cover are in a suitable state. The findings of this study hold significant implications for river management and restoration. Identifying river types and the factors influencing bank stability provides essential insights for designing engineering interventions that are compatible with the river's natural characteristics. Areas characterized by high sediment deposition or pronounced cross-sectional changes may require bank stabilization measures, sediment control, and vegetation rehabilitation. Moreover, understanding the distribution of suspended and bed sediments allows for better prediction of flood impacts and the design of optimized hydro-morphological structures. Considering pressures from human activities and climate change, applying these results can support the development of sustainable river restoration strategies, reduce flood risks, and protect aquatic biodiversity. Consequently, water resource managers and urban planners can implement evidence-based management practices aligned with the river's inherent natural dynamics.

Table 4. Management interpretation of river types in the Rasgen model (based on Rosgen model, 1994).

Flow pattern	Control effect of vegetation cover	Edge erosion potential	Sedimentary nutrition	Revitalization potential	Degree of sensitivity to disturbance
A	Good	Weak	Very low	Very good	Low
B	Weak	High	High	Low	Very high
C	Weak	High	High	Good	High
D	Weak	High	Very High	Good	Very high
E	Very good	High	High	Good	Very low
G	Moderate	High	High	Good	Moderate

Then, to investigate the type of river sediments, 5 sediment samples were taken from the riverbed at different intervals and sediment granulometry was performed in the laboratory (Table 5). Based on the results obtained, the proportion of sand was 18.2 percent higher than other sediments, and for this reason it was also used as an evaluation criterion (Fig. 3).

Fig. 3. Sediment sampling to determine the size of the Kal-e Shur riverbed sediments in Sabzevar.

Table 5. Grain size distribution of the Kal-e Shur riverbed sediments in Sabzevar.

Type of sediments	Particle size (mm)	Type of sediments
Clay	0.0521	11.4
Sand	0.198	18.2
Silt	0.0326	10.2
Sand	11	11.5
Cobble	52	8.5
Medium sand	11.5	4.6
Coarse sand	17.6	2.3
Fine sand	0.197	9.4
Very fine sand	2.12	11.1
Coarse sand	0.467	3.1
Very fine sand	0.101	9.7

As can be seen in Table 4, the degree of sensitivity to turbulence refers to increased flows and increased sedimentation, which is observed in the middle parts of the basin, where the river is of type D, C, and B. This part of the river is prone to high sedimentation due to the type of vegetation cover and the type of soil sediment texture and lithology. Suspended sediment riverbed load, and riverbank erosion are high in this part, and it is prone to erosion. According to Fig. 4, management interpretation with the Rasgen model shows that the restoration potential in parts of the river that are of type A, G, and D is in relatively good restoration conditions due to the implementation of watershed management plans. However, in other parts of the river, the restoration potential is poor. The most appropriate watershed management and management plan for river restoration strengthens and maintains the vegetation cover near the riverbed and reduces sediment removal to some extent. Many parts of the river are sensitive to sediment load feeding, and increased sediments cause instability of the river pattern and changes in its morphology. In rivers of type B and D, discharge changes occur continuously, and due to the sediment texture and vegetation cover, which is thin and insignificant, management and watershed management plans should be adopted in this section. Due to the slope of this section of the river, during rain and snowmelt in the highlands of the basin, and due to the type of river pattern, surface flows increase rapidly, causing the creation of a floodplain. In this section, by strengthening the river wall by planting productive plants, the increase in sediments and flow turbulence can be prevented to some extent. Vegetation control in river types A, G, and E is greater than in river types C, B, and D. If vegetation cover is maintained and sediments are not removed, the potential for river wall erosion can be reduced, which reduces sediment feeding and floodplain flooding. Sedimentation in the C-type river is high, and riverbank erosion is also high. Due to the type of river pattern, which is a single branch, there is a possibility of flooding the floodplain, and the suspended load has increased, which increases sedimentation. Management measures in this section include the construction of gabions, maintaining vegetation cover, and preventing the extraction of river materials. Because the extraction of sand and gravel to meet the needs of farmers changes the river bed and morphology. Changes in river discharge, changes in land use, and the construction of river structures are among the most important factors in changing the stability of the river in this section.

Unprincipled changes in land use without regard to the type of soil texture cause an increase in flows and sediment transport. Instability in river discharge is more often seen in areas where vegetation cover is small and insignificant. Of course, it should be taken into account that the difference in the values and types of parameters is due to the specific conditions of each region and may differ from one region to another. According to Ward (2008), some channels may not match the Rasgen classification data.

The results of this study indicate that river classification using Rasgen levels 1 to 3 can reliably and efficiently identify river types in the arid region of Birjand. This finding aligns with the work of Roostaei et al. (2013), who similarly concluded that in semi-arid rivers of Iran, the primary Rasgen levels, particularly level 2 effectively captures channel geometry variations and morphological heterogeneity, whereas level 4, due to its reliance on long-term sediment and hydrological data, is less applicable in such regions. Likewise, the results correspond with the findings of Roy and Sahu (2016), who reported that in dry rivers of India, high hydrological variability and seasonal floods substantially reduce the accuracy of level 4 classification, making analyses at levels 1 to 3 more practical for management decisions.

A novel aspect of the present study is the systematic assessment of land use and vegetation cover as factors influencing channel variability and their relationship with classification accuracy, an element largely overlooked in prior research. Overall, the findings not only corroborate Roostaei and Roy regarding the limitations of the Rasgen method in arid environments but also demonstrate that, despite data challenges at level 4, lower levels (1 to 3) remain valuable tools for geomorphological analysis and water resource management. In doing so, this study not only confirms the method’s applicability under Iran’s specific climatic conditions but also advances previous research by highlighting the critical role of land use in shaping river classification outcomes.

According to the studies conducted, most of the channels match the Rasgen classification. Due to land use changes in recent years, agricultural and irrigated lands have expanded in the basin, and construction near rivers has caused river instability, which is a serious threat to residents and farmers. The results obtained are consistent with the results of studies by Panahi et al. (2022), Kheirizadeh Arough et al. (2018), Rezaei moghadam et al. (2017), Ismaili and Hosseinzadeh (2015), Roostaei et al. (2013), Daja et al. (2018), Banerji and Patel (2018), and Haron et al. (2022).

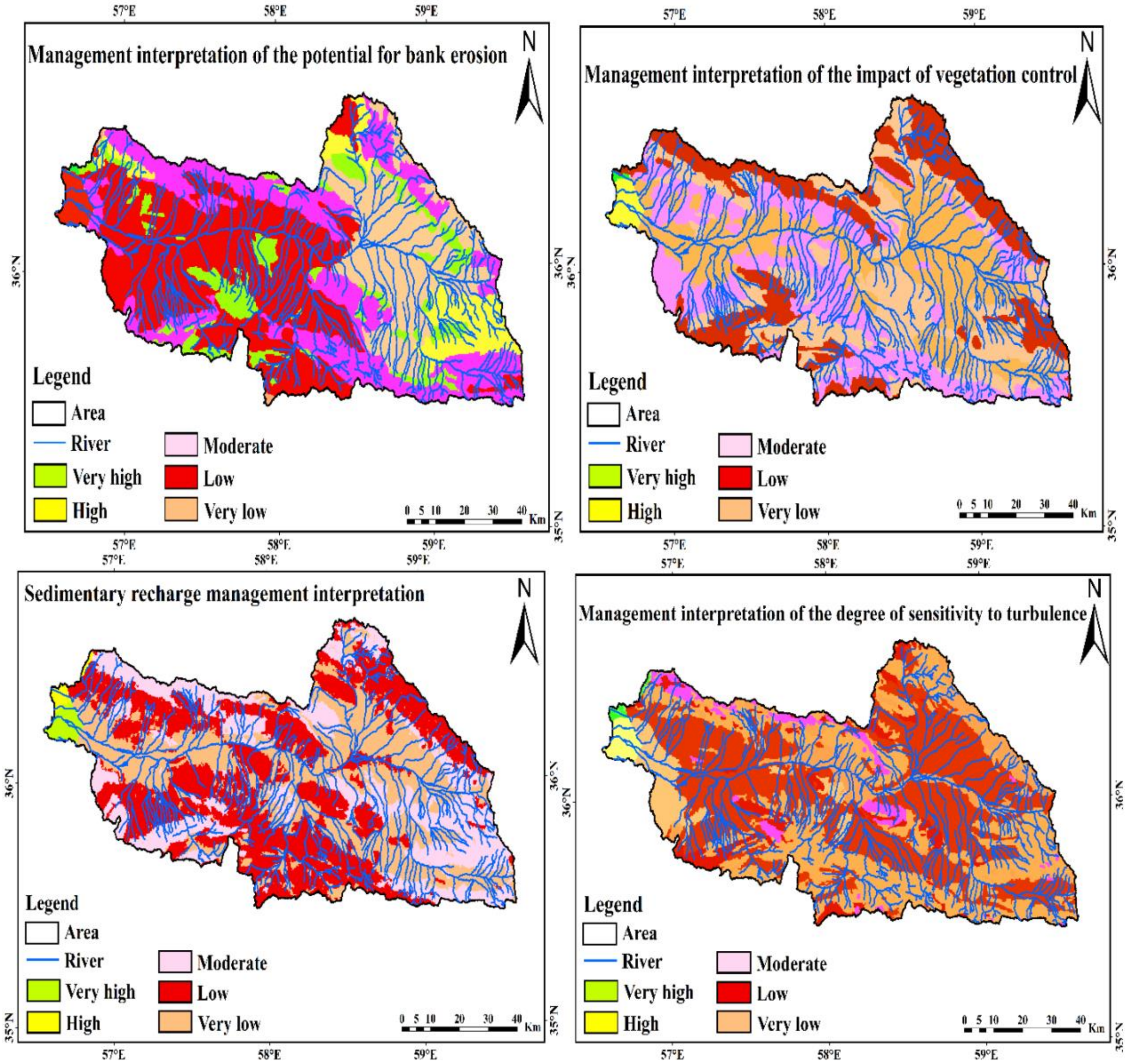

Fig. 4. Rasgen management interpretations in the Kal-e Shur River of Sabzevar.

Also, the results of field observations indicate encroachment and occupation in some parts of the river, such that some gardens and agricultural lands adjacent to the river have been disturbed by the construction of walls and terraces in some parts, causing the natural shape of the riverbed to collapse. In the upstream and downstream of the river, the width of the bed is less than in the middle part. Because in these areas, the river ends at high altitudes, and the width of the valley between the high altitudes decreases. The bed bottom is made of clay and sand, and there is relatively good vegetation cover in the bed.

4. Conclusion

With the increase in population, urbanization, implementation of development projects, and competition in consumption, conflicts and contradictions in the way rivers are exploited have increased. Humans, by indiscriminately extracting sand from the riverbed, constructing in the riverbed, constructing intersection structures, etc., destroy the balanced and stable regime of the river. The present study aims to investigate the morphology of the Kal-e Shur River in Sabzevar using the Rasgen classification model. HEC-RAS software was used to extract the morphological parameters of the basin. Also, 40 intervals and 419 sections were extracted using satellite images. Then, the most important factors affecting the type of river were examined using the IGR index, and the parameters of lithology, drainage density, soil, and land use were identified as the most important factors affecting the type of river in the basin. According to the results obtained, in parts of the river where the river pattern is of type D, the streams flow in a single branch, there is little vegetation, and the soil texture is sandy. In terms of sediment nutrition, erosion, vegetation control, and floodplain formation, the situation is unfavorable, and management plans should be adopted in this part of the riverbed, considering the construction and land affairs in this part of the riverbed. The type C river also has a similar situation, and the river discharge is constantly changing. The floodplain is also widespread in this part. In type E river, the channels are relatively stable, and the vegetation is relatively favorable. Sediment nutrition, erosion, and flooding are less widespread in this part. Type A and G rivers are intermediate due to their clay texture and vegetation control. The sediments in this part prevent erosion and reduce sediment nutrition by strengthening the riverbed wall. Also, the vegetation is relatively favorable and reduces the intensity of current turbulence to some extent, and the riverbank is stable. In general, in river types A, G, and E, the width-to-depth ratio is low, and due to the shape of the river pattern, which is multi-branched, the flow speed is slow and sluggish. According to the sediment samples collected from the study basin, the sandy texture type is dominant in parts of the river, which, along with the role of lithology, which consists of loose and resistant formations (limestone, volcanic, and Quaternary sediments) and due to the difference in the relative resistance of the formations, plays a vital role in the formation of the river type. In general, the channels of the river that have low sinuosity, suitable vegetation, and clay sediments have good morphological conditions, and the channels that have sandy sediments and weak vegetation have inappropriate morphological conditions due to erosion and asymmetrical channel shape. The results of the studies show that a number of channels are consistent with the Rasgen classification, and this model can quantitatively predict the morphology of the Kalshur River in Sabzevar. The results of this study can be helpful in management plans, hydrological plans, preventing land use changes to preserve river banks, preventing sand extraction by humans, preventing unprincipled construction, creating dams and earthen embankments to prevent floods, and restoring rivers. To reduce flood risks in the study periods, measures should be taken, including combating soil erosion adjacent to the riverbed, which is constantly exposed to erosion, organizing and reconstructing communication structures to reduce the effects of floods and sedimentation, directing the flow downstream by limiting the flood flow by constructing gravel and earthen embankments, increasing the river capacity by deepening the riverbed and reducing the hydraulic resistance of the flow. Based on the findings of this study, several practical recommendations can be proposed for river management and restoration. First, in areas experiencing intense bed sedimentation and significant cross-sectional changes, bank stabilization measures using native vegetation or environmentally compatible engineering structures are advised. Second, continuous monitoring of suspended sediment and real-time flow at key sections enables flood forecasting and mitigation of its destructive impacts. Third, in zones sensitive to bank instability, the implementation of flow-guiding structures and controlled channelization can reduce erosion. Fourth, the restoration and protection of aquatic and riparian habitats support biodiversity conservation and enhance ecosystem resilience to climate variability. Ultimately, integrating hydromorphological data with evidence-based management planning provides a robust foundation for sustainable river restoration strategies and the reduction of human-related hazards.

Acknowledgments

The authors confirm that this article was not under any financial support.

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