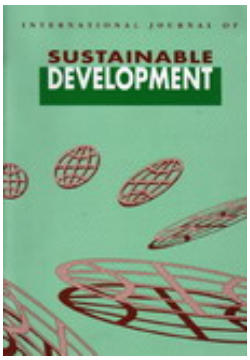


International Journal of Sustainable Development

ISSN online: 1741-5268 - ISSN print: 0960-1406
https://www.inderscience.com/ijsd

Analysis on the impact of river safety regulation projects on the surrounding ecological environment

Ye He

DOI: 10.1504/IJSD.2024.10062174

Article History:

Received:	27 July 2023
Last revised:	26 September 2023
Accepted:	11 December 2023
Published online:	15 July 2024

Analysis on the impact of river safety regulation projects on the surrounding ecological environment

Ye He

School of Civil Engineering,
Hunan City University,
Yiyang, 413000, China
Email: heye19840704@sina.com

Abstract: The river safety improvement project can restore and improve the surrounding ecological environment through measures such as ecological restoration. Based on the grey correlation analysis method, this paper analyses the impact of river safety regulation projects on the surrounding ecological environment. The development stage and existing problems of river safety regulation projects are identified, and the influencing factors are analysed using grey correlation analysis to determine the impact of river safety regulation projects on the surrounding ecological environment. The river safety regulation projects have a positive impact on water quality and terrain, which can stabilise sediment changes in the water area. The experimental results indicate that the river safety improvement project also has a positive impact on the surrounding ecological environment, with the surrounding water pollution index consistently below 0.4 and a relatively small impact on the surrounding terrain loss.

Keywords: river safety regulation projects; surrounding ecological environment; grey correlation analysis method; water quality; influencing factors; stabilise sediment.

Reference to this paper should be made as follows: He, Y. (2024) 'Analysis on the impact of river safety regulation projects on the surrounding ecological environment', *Int. J. Sustainable Development*, Vol. 27, No. 3, pp.262–279.

Biographical notes: Ye He received his Master's degree from Hehai College, Chongqing Jiaotong University. In 2021, he received his Doctor's degree in water Conservancy Engineering from Chongqing Jiaotong University. He is currently a Lecturer in the School of Civil Engineering of Hunan City University. His research interests include mechanical performance analysis of civil and hydraulic engineering materials, safety evaluation of hydraulic structures, etc.

1 Introduction

With the continuous acceleration of social urbanisation, human beings are also constantly improving their living environment in the process of continuous development. In the process of urbanisation, cities continue to expand rapidly, and river channels are also

greatly affected and undergo many negative changes (Shah and Lone, 2022). Under this development trend, rivers are also facing challenges and opportunities. The coordination and balance between urban economic development and river environment is a key link. The level of river safety regulation is closely related to the ecological environment quality of the entire city (Golzari et al., 2022). Therefore, river safety improvement is an important resource and environmental carrier in urban ecological environment improvement, as well as an important way to promote the quality of surrounding ecological environment and harmonious social development. It is also an inseparable and important infrastructure factor in social urban construction (Ahsan et al., 2023). In recent years, China's river training projects have also received great attention, and the impact of the training on the surrounding ecological environment is very significant. The project has a high degree of impact on the surrounding ecological environment. From the perspective of sustainable development, it is very important to strive to continuously improve the safety and ecotype of river regulation. Therefore, analysing the relationship between river regulation work and river protection and ecological environment improvement is the key to reflecting the effectiveness of regulation projects. Therefore, experts in the ecological field have conducted a lot of research on the impact of river safety improvement projects on the surrounding ecological environment, in order to help continuously improve the ecological environment on which humans rely for survival.

Saha et al. (2022) studied and analysed the modelling study of artificial river management on ecological environmental water quality benefits. The study pointed out the need for a better understanding of the impact of manual management on the water quality of sensitive flow channels. The SWAT evaluation tool was used in the study to quantify the potential water quality benefits of artificial irrigation management in river basins through scenario based analysis. A manually redesigned management plan was developed and compared with the baseline 'everything as usual' plan. The impact of fertilisers on the surrounding ecological environment in the river regulation plan was analysed based on crop nutrient requirements through the river regulation scenario. In the study, it was found that the impact of chemical fertilisers on water quality in the ecological environment was effectively controlled in the treatment of artificial river courses, and the significant impact relationship between river course treatment and the surrounding ecological environment was clarified. The analysis mainly analysed the impact of fertilisers in the soil, but more factor analysis is still needed to support the construction of this model. Yao et al. (2021) proposed a modelling study on the environmental impact of river restoration using life cycle assessment and water quality analysis. In this study, the polluted rivers along the Yangtze River were taken as the research object, and it was analysed that bioremediation was a green technology used to treat the polluted water of lakes along the Yangtze River. Use life cycle assessment and comprehensive water quality index to evaluate the potential environmental impacts of artificial wetlands, ecological floating beds, and combined ecological floating beds. The results indicate that the raw material procurement, construction, and operation of CWs, EFB, and CEFB account for 24.1%, 35.3%, and 40.6% of the total environmental impact, respectively. The purchase of raw materials for the construction of the bioremediation system accounted for 51.6% of the total environmental impact. Among the nine impact categories considered, the system has the highest global warming potential. Among the three stages of the project (raw material acquisition, construction, and operation), construction has the greatest impact on eutrophication (with the greatest potential for eutrophication during the construction phase). Rauch et al. (2022) proposed the study of

using soil and aquatic biotechnology technology to regulate river training projects and improve the quality of the surrounding ecological environment. The study pointed out that a major challenge faced by modern river and coastal management is to adopt a holistic design approach that combines flood control and erosion protection with ecological restoration. Many EU regulations require natural engineering solutions, such as soil and aquatic biotechnology. Compared to traditional 'hard' civil engineering structures, the SWBE structural concept is to use biological components in engineering structures, considering not only technical functions but also ecological and aesthetic values. Although SWBE technology has been applied worldwide and developed well as an engineering discipline, there is a high demand for further development, especially in the field of ecology. The use of plants in river engineering projects requires the correct selection of species based on the technology and environmental conditions used. In addition, the correct harvesting, storage, and implementation of plants are crucial. Their use also requires quantifying the hydraulic and sedimentological impacts of riverine vegetation on one hand, and understanding the impact of SWBE structures on aquatic and terrestrial habitats on the other. Different ecological, vegetation, and plant sociological standards are available and discussed in the evaluation of SWBE structure. All of these standards help to develop a framework that supports stakeholders in defining goals, designing, implementing work, and evaluating the post construction life stages most relevant to SWBE structures. Therefore, using local and historical plant sociological types to define the references to be implemented may become increasingly misleading. By analysing the ecological value of SWBE structure, another aspect must be considered from an ecological perspective. It should be considered that SWBE measures during construction may have negative impacts on the ecosystem.

Due to difficulties in data acquisition and integration, impact identification and evaluation, spatial and temporal scale limitations, uncertainty and risk assessment, as well as consultation and cooperation with stakeholders, the analysis of the impact of river safety improvement projects on the surrounding ecological environment faces many challenges. On the basis of the above research, in order to clarify the relationship between river regulation and the ecological environment, based on the grey correlation analysis method, this paper analyses the impact of river safety regulation projects on the surrounding ecological environment. The technical route studied in this paper is as follows:

1 Analyse the three different stages of the development of river safety regulation engineering, including the stage of river utilisation, flood control and dam construction, and the stage of emphasising the sustainable development and economic value of river channels. Based on these three stages, analyse the problems existing in river safety regulation engineering, including severe straightness of river channel trend, damage to river section, serious trend of river hardening development, and severe deterioration of water quality in river channels,

2 Determine the relevant influencing factors such as engineering benefits, ecological benefits, economic benefits, and social benefits based on the existing problems of the project. Based on the identified influencing factors, grey correlation analysis is conducted to determine the impact of river safety improvement projects on the surrounding ecological environment.

3 The application effect of this method has been thoroughly tested through practical applications.

2 Analysis the impact of river safety regulation projects on the surrounding ecological environment

2.1 Development stage and existing problems of river safety regulation engineering

The river safety regulation project is a key way that is conducive to the development of the entire social economy and the maintenance of ecological balance. Over time, river safety improvement projects have become a topic of concern for the entire society (Zhang et al., 2021a). In the design of this project, it is necessary to follow the development laws and terrain of the river channel, and adopt certain scientific methods to stabilise and improve the development trend of the river channel, in order to achieve the governance of the ecological environment (Huang et al., 2021). At present, the development of river channels in China is generally divided into three stages, mainly including the following stages:

Stage 1: The stage of river utilisation aimed at development, construction of reservoirs, and irrigation, mainly between the 1950s and 1970s in the world.

Stage 2: The main purpose is to prevent floods and build embankments as auxiliary measures. This stage was between the 1980s and 1990s in the world.

Stage 3: Drawing on foreign experience, emphasising the sustainable development and economic value of rivers, gradually beginning to rise to the goal of regulating and protecting rivers, which has continued to this day. In this stage of river safety regulation, measures such as water purification and replenishment, landscape improvement, and maintenance of water culture have achieved initial results (Chen et al., 2021).

In the analysis of the development stage of river safety regulation projects mentioned above, it can be seen that the concept of river safety regulation emerged relatively late. Therefore, traditional treatment methods still exist in the process of river safety regulation in China, which leads to certain problems in river safety regulation projects. The specific problems are as follows:

1 *The trend of the river is severely linearised*

In long-term governance, due to the influence of various factors such as flood and transportation, the natural hydrological laws of the river have been disrupted, and the natural riverbed has been damaged. Through manual regulation, the river has been continuously straightened, resulting in the destruction of the channel channels. Therefore, there has been a rapid flow velocity and an increase in sediment in the river, resulting in a decrease in flood discharge capacity during the rainy season, the disappearance of some shoals and sandbars, and the disappearance of ecological diversity.

2 *The river section has been damaged*

The existence of natural cross sections in river channels helps to maintain the ecological environment of river channels, but due to the lack of scientific attention in the process of river correction and governance, the complex cross sections are damaged, resulting in the destruction of the trapezoidal cross sections that were originally well transported, changing the structure and function of the river ecosystem, and causing continuous degradation of river functions (Liang et al., 2021).

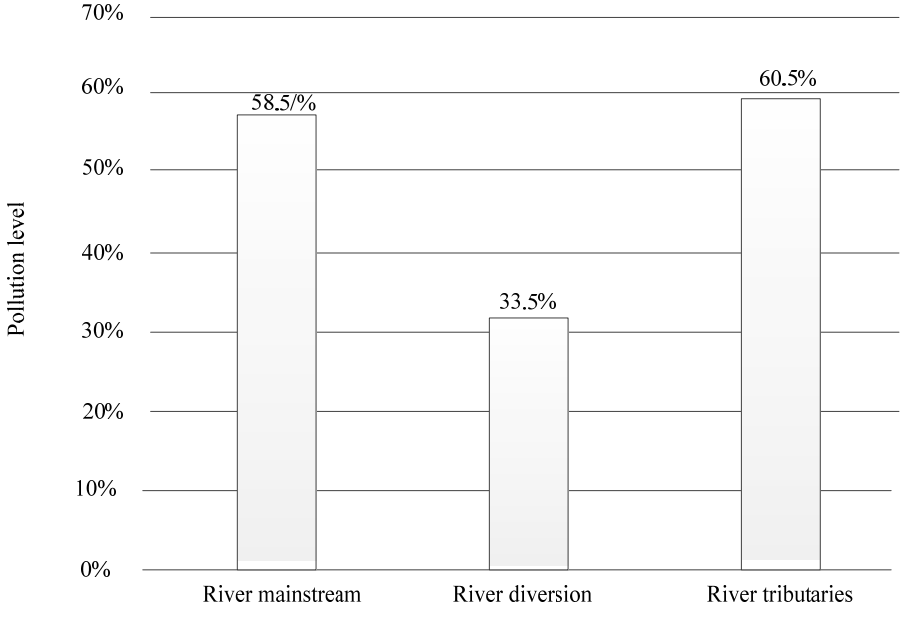
3 *The development trend of river hardening is severe*

Under the effect of long-term dredging works and embankment works, the river bed and embankment formed freely in the river channel are built into hard river channels such as concrete, which leads to the failure of the development of aquatic plant roots in the river channel, the failure of the survival of microorganisms in the river channel, the fragmentation of the soil and water exchanges, the loss of mutual contact, and the serious development trend of river channel hardening (Golzari et al., 2022).

4 *The water quality in the river is severely degraded*

In the process of river engineering construction, no attention was paid to the protection of water quality and aquatic plants, which led to lower and lower water quality compliance rate of rivers, resulting in water pollution. At present, the proportion of river water quality degradation is shown in Figure 1.

Figure 1 Schematic diagram of the proportion of river water quality deterioration



Clarify the three stages and different purposes of the development of river safety improvement projects, analyse the problems of straightness, cross-sectional issues, severe hardening development trends, and pollution in the process of river safety improvement,

and lay the foundation for the subsequent analysis of the impact of river safety improvement projects on the surrounding ecological environment.

2.2 Factors influencing the surrounding ecological environment of river safety improvement projects based on grey correlation analysis

This paper mainly starts from the indicators of the benefits of river safety regulation projects, ecological benefits, economic benefits, and social benefits, and analyses the influencing factors of river safety regulation projects on the surrounding ecological environment. The specific selected indicators are shown in Table 1.

Table 1 Factors affecting the surrounding ecological environment of river safety improvement projects

Major factor	*Secondary factors*
Engineering benefits	Flood control benefits
	Improvement effect of riverbed water volume
	Greening benefits
Ecological benefit	Improvement effect of river water quality
	Improvement effects on riverbed depth, length, etc.
	Restoration of mudflat, etc.
Economic benefits	River utilisation value
	Value added in surrounding areas
Social benefit	Social satisfaction
	Efforts in promoting river culture

The factors affecting the surrounding ecological environment caused by the aforementioned river safety improvement project cannot be directly applied in practice. Therefore, further quantitative research is needed on these indicators to ensure data consistency and operability.

The quantification of flood control benefits is studied through the quantification of the compliance rate of flood control embankments. The main purpose is to calculate the ratio of the length of flood control standards required by the planning to the total length of embankments built on existing river channels, expressed as:

$$L_i = \frac{l_b}{l_{all}} \times 100\% \tag{1}$$

In the formula, L_i represents the compliance rate of flood control embankments in river safety regulation projects, l_b represents the standard embankment length, and l_{all} represents the total length of embankments constructed in actual river regulation projects.

In the quantification of the influencing factor of water quantity improvement, the satisfaction rate of ecological base flow in the river channel is calculated. This indicator refers to the ratio of the time that the annual daily average flow of the main river flow in the river channel meets the ecological needs of the surrounding area. The calculation formula is:

$$D_i = \frac{d_b}{d_{all}} \times 100\% \tag{2}$$

In the formula, D_i represents the ecological base flow satisfaction rate, d_b represents the time when the annual daily flow of the river meets the surrounding ecological needs, and d_{all} represents the total number of days of demand.

In the quantitative study of ecological benefits, the ratio of the actual greening area to the total area occupied by the area is quantified, and the results obtained are:

$$Z_g = \frac{Z_i}{Z_{all}} \times 100\% \tag{3}$$

In the formula, Z_g represents the total proportion of green area, Z_i represents the area of green ecological plants, and Z_{all} represents the total area of river management.

The quantification of water quality improvement is generally based on the ratio of the river length in the water quality standard to the total evaluated river length, and the results are:

$$\mu = \frac{u_i}{u_j} \times 100\% \tag{4}$$

In the formula, μ represents the good state of water quality, u_i represents the total length of water quality rivers, and u_j represents the total length of evaluated rivers.

Based on the above analysis, the impact of the river safety improvement project on the surrounding ecological environment is determined as follows:

Establish a comparison matrix of the impact factors of the river safety regulation project on the surrounding ecological environment. With the help of transfer experience, judge the criticality of each layer's indicators and adjacent indicators in the above hierarchical structure to determine the importance of the assessment indicators. The constructed comparison matrix is shown as follows:

$$G = \begin{bmatrix} g_{11}, g_{12}, \cdots g_{1n} \\ g_{21}, g_{22}, \cdots g_{2n} \\ \cdots \\ g_{n1}, g_{n2}, \cdots g_{nm} \end{bmatrix} \tag{5}$$

In the formula, G represents the comparison matrix, and g_{nm} represents the impact factors of n river safety improvement projects on the surrounding ecological environment.

On this basis, further construct a judgement matrix to obtain:

$$h_{ij} = \frac{h_i - h_j}{h_{max} - h_{min}}(k-1) + 1 \tag{6}$$

In the formula, h_{ij} represents the constructed judgement matrix, h_i and h_j represent the initial and actual weights of the judgement indicators in the model, h_{max} and h_{min} represent the maximum and minimum criticality of the evaluation indicators, and k represents the sum of the matrix judgement factors.

Grey correlation analysis is an analysis method based on grey system theory. It extracts the inherent correlations and coupling relationships between things through qualitative or quantitative analysis of uncertain, incomplete, or uncertain complete problems, thereby studying adaptability issues and evolutionary trends. The main advantages of grey correlation analysis include:

1 Grey correlation analysis can identify and utilise the information of data, especially for situations where sample information is highly uncertain, data is scarce or missing, and noise is high. It can still perform effective analysis and prediction.

2 Grey correlation analysis does not require too many data premise assumptions and statistical assumptions, and has a certain degree of robustness and anti-interference ability.

3 Grey correlation analysis can be adaptive, self-learning, and has a certain exploratory ability, suitable for exploring new fields and providing assistance for long-term strategic planning.

The application of grey correlation analysis in the decision-making process of the impact of river safety improvement projects on the surrounding ecological environment has the following novelty:

1 *Multi indicator comprehensive evaluation*: Grey correlation analysis can consider multiple evaluation indicators simultaneously, and quantify the impact of different factors on the ecological environment by calculating the degree of correlation between each indicator. This enables decision-makers to comprehensively consider various influencing factors, in order to more comprehensively evaluate the impact of river training projects on the surrounding ecological environment.

2 *Grey information processing*: In grey correlation analysis, some data may be missing or not completely reliable, and grey theory provides an effective method to handle these uncertain information. By filling in missing values or establishing and predicting grey models, the relationship between various influencing factors can be more accurately analysed.

3 *Real time and dynamism*: Grey correlation analysis is suitable for problems with strong real-time and dynamism. In river safety improvement projects, changes in the ecological environment may be closely related to time and require timely decision-making adjustments. The characteristics of grey correlation analysis enable it to analyse and predict in a relatively short period of time, providing real-time reference for decision-makers.

4 *Statistical analysis and visualisation*: Grey correlation analysis can be used for data processing based on statistical methods, providing a means of quantitative analysis. In addition, through visualisation methods, decision-makers can intuitively understand the correlation between different factors and better grasp the impact of river safety improvement projects on the surrounding ecological environment.

In summary, applying grey correlation analysis to the decision-making process of the impact of river safety improvement projects on the surrounding ecological environment can provide a novel method for evaluating and decision-making the impact of river safety improvement projects on the surrounding ecological environment through multiple

indicator comprehensive evaluation, grey information processing, real-time and dynamic characteristics, as well as statistical analysis and visualisation.

Based on the constructed judgement matrix, the optimal transfer matrix is obtained, and the grey correlation degree of the impact of river safety improvement projects on the surrounding ecological environment is determined based on the optimal transfer matrix, which is:

$$C_{ij} = lgh_{ij} \left(i, j = 1, 2...n\right) \tag{7}$$

In the formula, C_{ij} represents the correlation between the impact of river safety improvement projects on the surrounding ecological environment, and lg represents the optimal transmission and treatment process.

Based on the optimal transfer matrix and grey correlation analysis method, a model for analysing the impact of river safety improvement projects on the surrounding ecological environment is established. The model is:

$$\omega_i = \prod_{i=1}^{n} C_{ij} \sum_{i,j=1}^{n} h_{ij} \tag{8}$$

The input of the analysis model of the impact of the river safety regulation project on the surrounding ecological environment is the influencing factors, including flood control benefits, river bed water volume improvement effect, greening benefits, river water quality improvement effect, river bed depth, length and other improvement effects, mudflat and other restoration effects, river use value, value-added value of surrounding areas, social satisfaction, river culture publicity, etc., the output is the degree of impact of river safety improvement projects on the surrounding ecological environment. This model mainly determines the influencing factors of river safety regulation projects on the surrounding ecological environment, constructs a hierarchical structure of the model, quantifies the influencing factors, and obtains the optimal transfer matrix through the constructed judgement matrix. Based on the optimal transfer matrix and grey correlation analysis method, a model for analysing the impact of river safety regulation projects on the surrounding ecological environment is constructed to achieve the analysis of the impact of river safety regulation projects on the surrounding ecological environment.

2.3 Analysis results of the impact of river safety improvement projects on the surrounding ecological environment

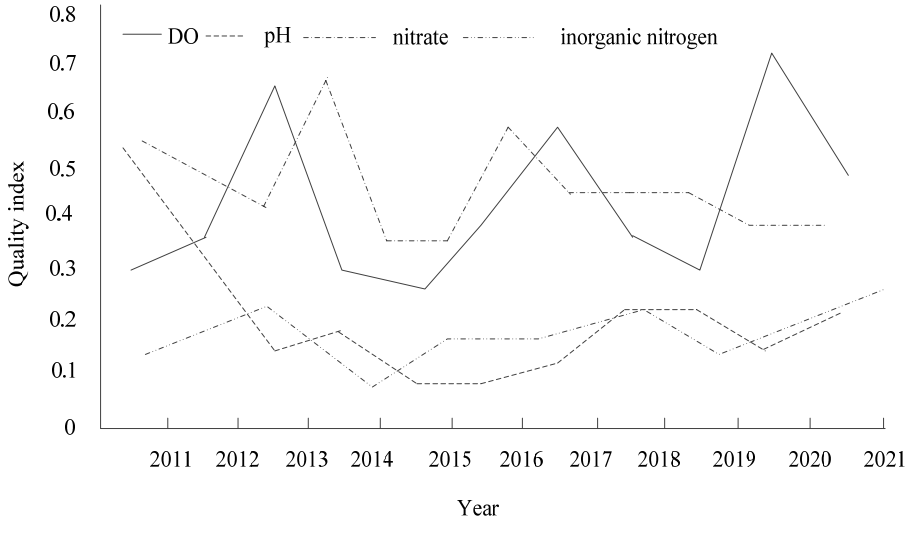
Based on the analysis model of the impact of river safety improvement projects on the surrounding ecological environment, further analyse the results of the impact of river safety improvement projects on the surrounding ecological environment, in order to provide important support for subsequent research.

2.3.1 The impact of river safety improvement projects on water quality in the surrounding ecological environment

The impact of river safety improvement projects on the water quality in the surrounding ecological environment is crucial. In the process of river management, the management of dumped substances in the river is crucial, which will affect the water quality in the river (Svensson et al., 2022). In order to better understand the impact of river dumping

material treatment on river water quality, this study compiled the water quality results of river dumping areas in the past 10 years and compared them comprehensively with the quality index, as shown in Figure 2.

Figure 2 Schematic diagram of changes in water quality coefficients in river dumping areas in the past 10 years



From Figure 2, it can be seen that the water quality in the river dumping area has fluctuated significantly in the past 10 years, with small changes in the content of DO, pH, and other pollutants in the water. However, the heavy metal changes in the later stage are more significant, showing a fluctuating state. It can be inferred that there is a positive correlation between the content of heavy metals and the changes in water quality in river dumping areas. Therefore, by calculating the water pollution index and other factors in the region, it is determined that the river safety improvement project has a positive correlation with the water quality in the surrounding ecological environment (Zhang et al., 2021b). The expression for calculating the pollution index of river water quality is expressed as:

$$E_i = \frac{a_i}{b_i} \tag{9}$$

In the formula, E_i represents the pollution index of the first item in the river water quality, a_i represents the measured concentration of pollution, and b_i represents the pollution evaluation standard.

Dissolved oxygen in river water quality is also a key indicator of water pollution index, and its expression is:

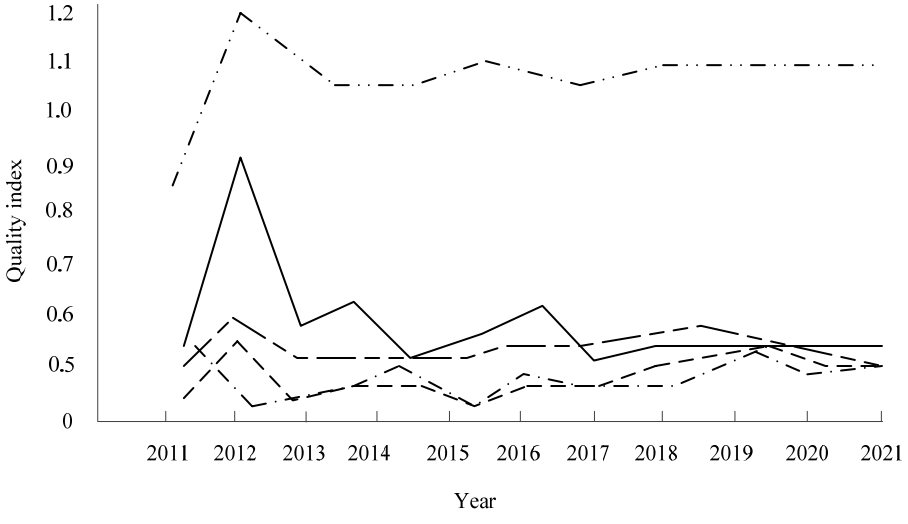
$$Q_i = (C - a_i) / (C - C') \tag{10}$$

In the formula, Q_i represents the dissolved oxygen pollution index, C represents the actual content of dissolved oxygen, and C' represents the predicted content.

2.3.2 The impact of river safety regulation projects on sediments in surrounding ecological environment waters

The management and dredging of sediment in river channels during river safety regulation directly reflect the quality of the surrounding ecological environment by examining the impact of sediment dredging on water sediment in the ecological environment (Rui et al., 2021). Therefore, in this study, data from the past 10 years were collected on the impact of sediment in river channels, reflecting the direct correlation between river safety improvement projects and the surrounding ecological environment. The results obtained through comprehensive comparison with the quality index are shown in Figure 3.

Figure 3 Schematic diagram of changes in dredging quality coefficient of river sediment in the past 10 years



From Figure 3, it can be seen that in the dredging and treatment of river sediment, the sediment quality standards after treatment meet the requirements, and the sediment quality is good. The annual changes in sediment indicators tend to be stable at other times except for the peak period in the initial stage, indicating that the dredging and treatment effect is good and has a significant impact on the surrounding ecological environment.

2.3.3 The impact of river safety improvement projects on the terrain in the surrounding ecological environment

In river safety improvement projects, it is crucial to analyse the impact of changes in terrain and depth of the river after treatment on the surrounding ecological environment. Therefore, this paper further analyses the impact of the implementation of the governance project on the ecological environment of the surrounding river channels (Dominguez and Guimares, 2021). The measurement of terrain in river management is generally reflected through the calculation of tortuosity, which are a relative ratio coefficient and a dimensionless feature. The calculation formula is:

$$H = \frac{AB}{\overline{AB}} \tag{11}$$

In the formula, H represents the tortuosity of the riverway coastline, AB represents the actual length of the riverway from the starting point A to B, and $\overline{AB}$ represents the straight-line distance between two points after the river is regulated.

After determining the tortuosity of the river channel, the affected length of the terrain is determined through the calculation of artificial indices (Kawalko et al., 2021), which is calculated as follows:

$$G = \frac{U}{N+U} \times 100\% \tag{12}$$

In the formula, G represents the artificial degree index of the river, N represents the natural length of the unchanged river, and U represents the change in the length of the river after treatment.

The degree of loss in river safety management engineering refers to the degree to which the natural riverbed is damaged or missing during the management process (Shao et al., 2021), expressed as:

$$R = \frac{r_i}{r_0} \tag{13}$$

In the formula, R represents the loss index in river management, r_0 represents the natural length of the river, r_i represents the length after river management, and if the value is less than 1.0 then loss occurs.

Based on the above riverbed tortuosity, length after treatment, and loss degree, it is clear that the river safety management project has a significant impact on the surrounding ecological environment.

In summary, the river safety improvement project has a positive impact on the water quality and terrain of the surrounding ecological environment, which can stabilise the sediment changes in the water area. Therefore, the river safety improvement project has a positive impact on the surrounding ecological environment.

3 Experimentation

3.1 Experimental scheme

To reflect the impact of river safety improvement projects on the surrounding ecological environment, a field test study was conducted. Select a suburban river channel in a certain city and its surrounding areas as experimental testing objects to analyse the impact of river safety improvement projects on the surrounding ecological environment. When designing the historical data length for experimental analysis of the impact of river safety regulation projects on the surrounding ecological environment, it is necessary to comprehensively consider factors such as data time span, data accuracy and availability, representative sites, relevant variables, and data sampling frequency to ensure the suitability and reliability of the selected historical data. The ecosystem around the river channel in this area was divided into forest ecosystem, grassland ecosystem, agricultural

ecosystem, etc. based on the investigation of animal and plant distribution and biomass. Based on the obtained ecosystem data of this area, the impact of the river channel safety improvement project on it was analysed. The specific ecosystem details are shown in Table 2.

Table 2 Ecological system details of sample river training areas

Ecosystem type	*Forest ecosystem*	*Grassland ecosystem*	*Agroecosystem*	*Village ecosystem*
Area/hm^2	1198	1867	7167	890
Percentage/%	8.1	12.5	24.2	48.9
Raise crops	Italian poplar and dry willow	Reed and Artemisia argyi	Paddy fields, dry land	Amphibians and reptiles

The specific experimental parameters during the validation process are shown in Table 3.

Table 3 Test parameters

Parameter	*Data*
Test system	Windows 10
System running memory/GB	32
Cycle of river safety regulation projects/Day	60
Evaluation indicators/categories	3
Number of evaluation indicators/piece	100
Evaluation error control range/%	<0.5
Data statistics software	SPSS.13.0

In order to highlight the effectiveness of this modelling during the testing, method in this paper, method of Saha et al. (2022) and method of Yao et al. (2021) were compared, and the significance of the positive impact of river safety improvement projects on the surrounding ecological environment, as well as the impact of river safety improvement projects on surrounding water quality, sediment in water bodies, and terrain were compared.

3.2 Verification results

In the test, the significance of the positive impact of the sample area on the surrounding ecological environment in the river safety improvement project was analysed based on the set experimental environment and parameters. Method in this paper, method of Saha et al. (2022) and method of Yao et al. (2021) were used for analysis, and the results are shown in Table 4.

According to the analysis of the test results in Table 4, there is a certain degree of variability in the significance analysis results of the positive impact of the sample area on the surrounding ecological environment in the river safety improvement project using method in this paper, method of Saha et al. (2022) and method of Yao et al. (2021). Among them, the value of 1 in this paper represents very significant and consistent with the true value, while the other two methods represent significant. Compared to this, the

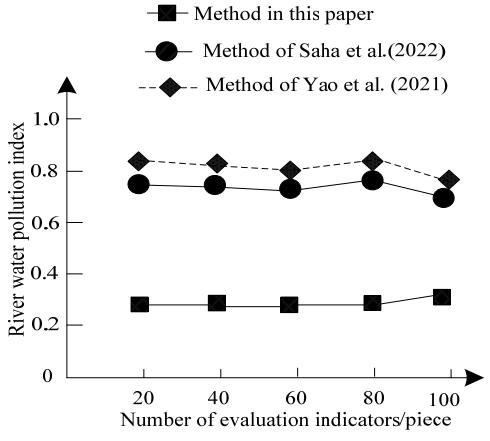
analysis results of this method are more accurate, indicating the positive impact of the river safety regulation project on the surrounding ecological environment, thus verifying the feasibility of the proposed method.

Table 4 Significant results of positive impact on surrounding ecological environment in river safety improvement projects

Method name	*P*
Method in this paper	≤0.01
Method of Saha et al. (2022)	≤0.05
Method of Yao et al. (2021)	≤0.05
True value	≤0.01

In the experiment, the impact of method in this paper, method of Saha et al. (2022) and method of Yao et al. (2021) on the surrounding water quality in the river safety improvement project in the sample area was tested, mainly by analysing the water pollution index. If the index is less than 1, it indicates that the water quality is within the specified standard range, and if it is greater than 1, it indicates that the water quality is poor. The results obtained are shown in Figure 4.

Figure 4 Results of the impact of the river safety improvement project on the surrounding water quality



Analysing the test results in Figure 4, it can be seen that method in this paper, method of Saha et al. (2022) and method of Yao et al. (2021) have a significant impact on the surrounding water quality during the river safety improvement project in the sample area. Among them, the water pollution index of method in this paper is always below 0.4, and the other two methods are also below 1. However, compared to using method in this paper, the water pollution index is lower, verifying that the river safety improvement project has a positive impact on the surrounding water quality.

In the experiment, the impact of method in this paper, method of Saha et al. (2022) and method of Yao et al. (2021) on the analysis of the impact of the sample area on the sediment in the surrounding water area during the river safety regulation project,

the impact of three methods on the sediment in the surrounding water area during the river safety regulation project was analysed based on the standard of no less than 25% of the cross-section value of the river safety regulation project and no less than 15% of the non-numerical measurement inspection cross-section. The results obtained are shown in Table 5.

Table 5 Analysis of the impact of river safety improvement projects on sediments in surrounding waters

Comparison project	*Method in this paper*	*Method of Saha et al. (2022)*	*Method of Yao et al. (2021)*
Engineering section value	30%	27%	26%
Non numerical measurement	24%	18%	20%

From Table 5, it can be seen that method in this paper, method of Saha et al. (2022) and method of Yao et al. (2021) in the impact of the sample area on the sediment in the surrounding water area during the river safety improvement project, the section value of the method in this paper for river safety regulation projects is 30%, and the non-numerical measurement inspection section is based on 24%; method of Saha et al. (2022) and method of Yao et al. (2021) in the impact of the sample area on the sediment in the surrounding water area during the river safety regulation project, the cross-sectional values of the river safety regulation project are 27% and 26%, the non-numerical measurement inspection cross-section is 18% and 20% respectively as the standard. Compared with the benchmark data, method in this paper has a better dredging effect on the impact of sediment in surrounding water bodies in river safety improvement projects, verifying the feasibility of the method proposed in this paper.

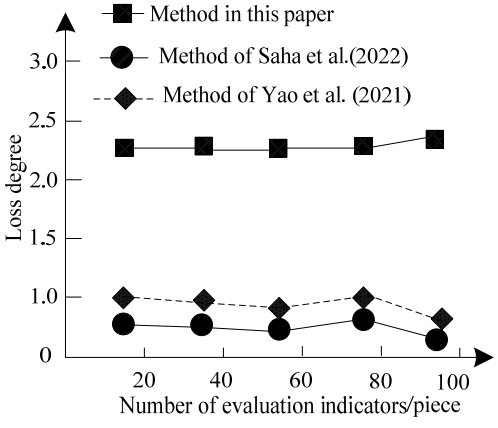
The experiment tested the impact of method in this paper, method of Saha et al. (2022) and method of Yao et al. (2021) in the impact of the sample area on the surrounding terrain in the river safety regulation project is reflected by the degree of terrain loss in the river safety regulation project. Therefore, in the experiment, the loss degree is used to reflect the impact on the surrounding terrain in the river safety regulation project. If the value is less than 1.0, there will be terrain loss. The results obtained are shown in Figure 5.

Analysing Figure 5, it can be seen that there are certain differences in the degree of damage to the surrounding terrain in the sample area during the river safety improvement project between method in this paper, method of Saha et al. (2022), and method of Yao et al. (2021). Among them, the loss degree of method in this paper is greater than 1.0 and around 2.3. The terrain loss degree of method of Saha et al. (2022) and method of Yao et al. (2021) is less than 1.0, indicating that the method in this paper sample area has a relatively small impact on the surrounding terrain in river safety training projects.

In summary, the river safety improvement project has a positive impact on the surrounding ecological environment. The pollution index of the surrounding water quality in the river safety improvement project has always been lower than 0.4, which has improved the surrounding water quality; In the impact of river safety regulation projects on sediment in surrounding waters, the cross-sectional values of river safety regulation projects are 27% and 26%, respectively, which meet the dredging standards; The main reason why the impact of river safety regulation engineering on the surrounding terrain loss is relatively small is that the method in this paper determines the relevant influencing

factors such as engineering benefits, ecological benefits, economic benefits, and social benefits, and conducts grey correlation analysis on the influencing factors to determine the impact of river safety regulation engineering on the surrounding ecological environment, thereby ensuring that the method has high analytical accuracy.

Figure 5 Results of the impact of river safety improvement projects on the loss of surrounding terrain



4 Conclusion

This paper analyses the impact of river safety regulation projects on the surrounding ecological environment, mainly analysing the three different stages of the development of river safety regulation projects, and analysing the problems existing in river safety regulation projects based on these three stages. Based on the problems existing in the project, determine the factors that affect the surrounding ecological environment caused by the river safety renovation project. Conduct grey correlation analysis on the ecological environment and influencing factors to determine the impact of the river safety renovation project on the surrounding ecological environment. Through experimental testing results, the following conclusions are drawn:

1 The significance of the positive impact of river safety improvement projects on the surrounding ecological environment is very significant, $P \leq 0.01$, indicating that river safety improvement projects have a certain positive impact on the surrounding ecological environment.

2 The pollution index of surrounding water quality in the river safety improvement project has always been lower than 0.4, which has improved the surrounding water quality.

3 In the impact of river safety regulation projects on sediment in surrounding waters, the cross-sectional values of river safety regulation projects are 27% and 26%, respectively, which meet the dredging standards.

4 The impact of river safety regulation projects on the surrounding terrain loss is relatively small, which verifies the feasibility of the research method based on grey correlation analysis for the impact of river safety regulation projects on the surrounding ecological environment.

The future work on the analysis of the impact of river safety improvement projects on the surrounding ecological environment needs to strengthen research and practice in data collection and monitoring, establishment of comprehensive evaluation indicators, establishment and optimisation of models, uncertainty treatment and risk assessment, ecological restoration and protection strategy research, sustainable development and comprehensive management, etc.

Acknowledgements

This work was supported by Scientific Research Project of Hunan Provincial Department of Education under grant no. 20C0379.

References

Ahsan, A., Das, S.K., Khan, M.H.R.B., Ng, A.W.M., Al-Ansari, N., Ahmed, S., Imteaz, M., Tariq, M.A.U.R. and Shafiquzzaman, Md. (2023) 'Modeling the impacts of best management practices (BMPs) on pollution reduction in the Yarra River catchment, Australia', *Applied Water Science*, Vol. 13, No. 4, pp.98–108.

Chen, S., Chen, L., Gao, Y., Guo, J. and Shen, Z. (2021) 'Larger phosphorus flux triggered by smaller tributary watersheds in a river reservoir system after dam construction', *Journal of Hydrology*, Vol. 601, No. 3, p.126819.

Dominguez, J. and Guimares, J.K. (2021) 'Effects of Holocene climate changes and anthropogenic river regulation in the development of a wave-dominated delta: The So Francisco River (eastern Brazil)', *Marine Geology*, Vol. 435, No. 2006, pp.106456–106478.

Golzari, S., Abyaneh, H.Z., Dinan, N.M., Delavar, M. and Wagner, P.D. (2022) 'Modeling the effects of human influences on water quality and quantity in the Zarrineh River Basin, Iran', *Journal of Hydro-Environment Research*, Vol. 40, No. 1, pp.51–63.

Huang, S., Zhang, X., Chen, N., Li, B. and Ma, H. (2021) 'Drought propagation modification after the construction of the three gorges dam in the Yangtze River Basin', *Journal of Hydrology*, Vol. 603, No. 12, pp.1–17.

Kawalko, D., Jezierski, P. and Kabala, C. (2021) 'Morphology and physicochemical properties of alluvial soils in riparian forests after river regulation', *Forests*, Vol. 12, No. 3, pp.329–377.

Liang, J., Yi, Y., Li, X. and Zhai, Y. (2021) 'Detecting changes in water level caused by climate, land cover and dam construction in interconnected riverlake systems', *Science of the Total Environment*, Vol. 78, No. 8, p.147692.

Rauch, H.P., Thannen, M., Raymond, P., Mira, E. and Evette, A. (2022) 'Ecological challenges* for the use of soil and water bioengineering techniques in river and coastal engineering projects', *Ecological Engineering*, Vol. 176, No. 12, pp.1–9.

Rui, P.R., Feio, M.J., Almeida, S., Vieira, C. and Aguiar, F.C. (2021) 'Multi-biologic group analysis for an ecosystem response to longitudinal river regulation gradients', *Science of the Total Environment*, Vol. 767, No. 6, p.144327.

Saha, A., Saha, G.K., Cibin, R., Spiegal, S., Kleinman, P.J.A., Veith, T.L., Mira, J. and Aguiar, F. (2022) 'Evaluating water quality benefits of manureshed management in the Susquehanna River basin', *Journal of Environmental Quality*, Vol. 52, No. 2, pp.328–340.

Shah, M. and Lone, M.A. (2022) 'Modeling the impact of climate change on the flow regimes of river Sindh of Kashmir valley', *Journal of The Institution of Engineers (India): Series A*, Vol. 103, No. 146, pp.1165–1181.

Shao, Y., Mu, X., He, Y. and Chen, K. (2021) 'Variations in runoff, sediment load, and their relationship for a major sediment source area of the Jialing river basin, southern China', *Hydrological Processes*, Vol. 29, No. 7, pp.1–10.

Svensson, N., Norén, A., Modin, O., Fedje, K.K., Rauch, S., Strmvall, A.M. and Andersson-Skld, Y. (2022) 'Integrated cost and environmental impact assessment of management options for dredged sediment', *Waste Management*, Vol. 138, No. 11, pp.30–40.

Yao, X., Cao, Y., Zheng, G., Devlin, A.T. and Lu, Y. (2021) 'Use of life cycle assessment and water quality analysis to evaluate the environmental impacts of the bioremediation of polluted water', *Science of the Total Environment*, Vol. 761, No. 11, pp.1–13.

Zhang, P., Lu, G., Liu, J., Yan, Z. and Zhou, R. (2021a) 'Biodegradation of 2-ethylhexyl-4-methoxycinnamate in river sediments and its impact on microbial communities', *Journal of Environmental Sciences*, Vol. 104, No. 10, pp.307–316.

Zhang, Y., Meng, X., Bai, Y., Wang, X. and Zhang, H. (2021b) 'Sources and features of particulate organic matter in tropical small mountainous rivers (SW China) under the effects of anthropogenic activities', *Ecological Indicators*, Vol. 125, No. 17, pp.107471–107486.