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A SEEC Model Based on the DPSIR Framework Approach for Watershed Ecological Security Risk Assessment: A Case Study in Northwest China

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Abstract: The DPSIR model is a conceptual model established by the European Environment Agency to solve environmental problems. It provides an overall framework for analysis of environmental problems from five aspects: driving force (D), pressure (P), state (S), impact (I), and response (R). Through use of the DPSIR model framework, this paper presents the SEEC model approach for evaluating watershed ecological security. The SEEC model considers four aspects: socioeconomic impact (S), ecological health (E), ecosystem services function (E), and control management (C). Through screening, 38 evaluation indicators of the SEEC model were determined. The evaluation results showed that the ecological security index of the study area was >80, indicating a generally safe level. The lowest score was mainly attributable to the low rate of treatment of rural domestic sewage. The water quality status was used to evaluate the applicability of the SEEC model, and the calculation results indicated that the higher the score of the ecological security evaluation results, the better the water quality status. The findings show that the SEEC model demonstrates satisfactory applicability to evaluation of watershed ecological security.

Keywords: watershed ecological security assessment; DPSIR model framework; environmental management

1. Introduction

The footprints of human activities have covered the world [1]. In the process of rapid development of both industry and agriculture, the ecological environment has suffered unprecedented damage [2,3]. Globally, the soil [4,5], water [6,7], air [8,9], and other environmental media in areas with frequent human activity are in a state of continuous deterioration [10,11]. Ecosystem degradation and environmental pollution are gradually threatening and destroying human socioeconomic progress, survival, and development [12,13]. In recent years, researchers have attempted to evaluate the consequences and degree of risk associated with current changes of the ecological environment but without reaching consensus [14,15].

China remains in the process of rapid economic growth and urbanization. However, various ecological and environmental problems continue to emerge, threatening to destroy China's sustainable development and affecting the living conditions of the population [16]. China has experienced ecological and environmental crises in the past and it now faces many new challenges regarding environmental protection. Therefore, President Xi proposed the idea of an ecological civilization, which means that China's model of development has changed from that of "grow first, clean up later" to one of sustainable development [17,18]. At the policy level and in everyday life, the expectation is for a safer and cleaner living environment. In the past, researchers often used the concept of environmental risk to assess whether the environment of a region might pose a threat to human health. Specifically, such assessments can be used to evaluate whether the current ecological situation of an area in which humans survive continues to be safe and whether it can ensure the environmental needs of human life and development. Therefore, evaluation of ecological safety is vital.

The main objective of ecological security assessment is to determine the ecological status and ecological pressure faced by a region under normal human activities [19]. It was formally proposed by the International Institute for Applied Systems Analysis in 1989 [20]. Evaluation results can be expressed using the ecological security index (ESI). A high ESI value indicates that the ecological state of the evaluation receptor is able to not only ensure the needs of human survival and development but also resist the pressures brought by human development. Therefore, through scientific evaluation of the factors on which the ESI is based, policies can be formulated to improve the situation. This approach also makes the work of ecological protection more refined and targeted, which is of great importance considering China's current state of development and environmental protection [21,22].

In accordance with different evaluation objects, ecological security can be divided into water ecological security [23], land ecological security [24], coastal ecological security [25], and urban ecological security [26], and all these aspects of ecological security assessment have been widely studied and applied. Broadly, ecological security includes natural ecological security, economic ecological security, and social ecological security, which mainly refers to a state in which human life, health, and resources are not threatened in terms of the above aspects. In this study, we were interested in the ecological security of a watershed, which refers to the ecological state of the lakes, rivers, and other areas within a catchment, and its ability to resist the ecological pressure brought by human activities.

Currently, model evaluation methods are used in ecological security assessment, and the most commonly used evaluation models include the PSR model, DSR model, and DPSIR model [27]. In 1979, Rapport and Friend proposed a model framework for analyzing and describing the interaction between socioeconomic development and the ecological environment, which was further improved by the Organization for Economic Co-operation and Development and United Nations Environment Programme, forming the PSR model framework [28]. The basic connotation of the PSR model is that human activities exert pressure on the environment and its natural resources (P-pressure), which changes the state of both the environment and the quality of the natural resources (S-state), forcing human society to respond to these state changes through adoption of policies, decisions, or management measures that affect the environment, economy, and land (R-response) [29]. The PSR model is suitable for ecological security evaluation on a small spatial scale and with few influencing factors. However, because it simplifies the causal relationship between indicators, it ignores the complexity of the system, especially the driving force factors of ecological security [30]. To overcome this weakness, the United Nations Conference on Sustainable Development established the DSR framework in 1996, in which the driving force factors (D) refer to the regional socioeconomic objectives which represent the fundamental environmental pressure. The DSR model can better characterize the impact of the driving force factors on ecosystem evolution, but the definitions of the driving force factors and the response factors in the model were vague. Therefore, to improve the applicability of the DSR model, in 1999, the European Environment Agency officially adopted the DPSIR model (driving force–pressure–state–influence–response), in which influence refers to the impact of changes in environmental status on environmental receptors [31]. The model combines the characteristics of the PSR and DSR frameworks. It has the advantages of comprehensiveness, systematicness, and flexibility, and covers five assessment factors and constructs a causal network between them to reflect the impact of socioeconomic development and human activities on the system state and the human response to adverse impacts [32].

In the DPSIR model framework suitable for watershed ecological security assessment, factor D generally includes population, socioeconomic, and other indicators; factor P generally includes pollutant discharge and other indicators; factor S generally includes water quality status, sediment status, and other indicators; factor I generally includes water service function and other indicators; and factor R generally includes river protection policy, ecological restoration, and other indicators. Generally, the DPSIR model framework is a circular system, i.e., the driving force leads to pressure, then the pressure changes the state, and the change of state has a consequential impact, which promotes a response that leads to adjustment of the driving force [33]. In recent years, the DPSIR model has been widely accepted and used in the process of ecological security research because it can reveal causal relationships between ecology and human activities [33–40]. It provides a conceptual model for a research scheme for evaluation of human activities, resources, the ecology, and sustainable development [41,42] and is also applied to interdisciplinary research [36,43]. Through application of the DPSIR model framework, many studies have performed ecological security evaluation of lakes, rivers, land, and oceans, thereby providing a scientific basis for further expansion of the connotation and application of the DPSIR model framework [44,45].

Although the DPSIR model has been used widely in many fields, applicability of the evaluation method has been limited owing to inconsistent selection of indicators, poor analysis of the reasons for the selection of indicators, and unclear determination of the process of index weighting [27,46–48]. Additionally, in previous watershed ecological security assessments, factors D and P were usually evaluated using socioeconomic and other related indicators, and ecological indicators were ignored, which resulted in overestimation of the impact of policy and economic development and underestimation of the ability of the ecosystem to deal with the pressure (factor P). Furthermore, the existing evaluation method lacks verification of the evaluation results, thereby diminishing the reliability and guidance of the evaluation results [49,50]. To resolve the problems of poor applicability of the DPSIR model to watershed ecological security evaluation and lack of a verification method, this study adopted the following research methods. By identifying the key factors affecting the ecological security of a watershed, and through analyzing the DPSIR model framework, the SEEC model including the process of indicator selection and the determination of weights was established. A study area was selected for application of the new model, and a method of water quality evaluation and analysis was innovatively used to evaluate the applicability of the SEEC model. The study area, located in an arid area in Northwest China, comprised a watershed that represents an important water supply source for a large city. However, owing to the specific geographical location and the harsh natural environment of the watershed, research data were scant, and therefore a watershed ecological security assessment was not undertaken. The ESI of the study area was obtained, and the reasons for low ESI values were analyzed, on the basis of which, suggestions for improvement of the ESI of the watershed were proposed. The results could serve both as a reference for subsequent environmental planning and management and as a scientific basis for comprehensive pollution control and ecological environmental protection of the study area.

2. Materials and Methods

2.1. Construction of the Evaluation Model

2.1.1. Identification of the Model

Currently, methods used for watershed ecological security assessment are not unified. By identifying the connotation of the model, this article established a method suitable for watershed ecological security assessment under the framework of the DPSIR model. However, the DPSIR model only provides an evaluation framework, and it does not offer methods for selecting and evaluating the applicability of indicators. Therefore, using the DPSIR model framework, this study identified the primary indicators of each factor and, in combination with consideration of the key issues of watershed ecological security assessment, the SEEC model was constructed. The essence of the SEEC model is that it is a representation of the DPSIR model framework specifically suited to watershed ecological security assessment. Therefore, in building the SEEC model, the connotation of the DPSIR model should be identified first, and an index system suitable for watershed ecological security assessment should also be established.

The essence of the DPSIR model is to identify the main factors affecting ecological security under the influence of human activities. It needs to determine the ecological state under the action of these factors, identify the impact, select relevant indicators of the response, evaluate the state of ecological security in terms of the five aspects, and obtain the ESI. Therefore, the key to using the DPSIR model to evaluate watershed ecological security is to accurately identify representative indicators that can characterize watershed ecological security.

The driving force factors (D) in the DPSIR model mainly represent social development and economic growth, reflecting the trends of population change, socioeconomic activity, and industrial economic development. These factors represent potential causes of environmental change, and they are also the most primitive and important indicators of change of the water environment security system.

Pressure factors (P) refer to the pressure applied directly to the water ecosystem through the driving force (D). Similar to D, P is an external force that affects the development and change of water ecosystem security. In previous research on urban ecological security, D and P were regarded as two separate factors, because the driving force and pressure can directly affect urban ecological security [51]. However, it is difficult to observe and calculate the impact of driving forces on watershed ecological security, mainly because most areas of many watersheds are not located in urban built-up areas and there are few human activities around. In this case, it needs to redefine the meaning of P used for watershed ecological security assessment under the DPSIR framework. Therefore, P mainly reflects the pollution load in this article.

State factors (S) refer to the state of the water ecosystem under the influence of both D and P. Thus, S can be illustrated directly through the characteristics of environmental media such as water quality and sediment, which are indicators of ecological health.

Impact factors (I) refer to the impact of the state of the water environment ecosystem on the economy and the livelihood and health of the population, which is the inevitable result of the interaction of the first three factors (D, P, and S). The ecological state changes caused by the above factors are mainly reflected in changes of the watershed ecological service functions. Therefore, the impact factors mainly include watershed ecological service functions such as water resources supply and the cultural landscape.

Response factors (R) refer to the countermeasures taken by humans to improve or adapt to the ecological state, which reflect the process of human regulation and management. Therefore, R mainly includes supervision of the ecological environment, pollution control, and industrial adjustment.

Because the DPSIR model overestimates nonecological factors such as the economy and population change, it is considered that the nature of the ecosystem itself is a more direct factor of ecological security, and thus it should receive greater attention. Moreover, with improvement of the level of ecological management, government departments also consider ecological factors when determining economic and population objectives, resulting in gradual closing of the relationship between the driving force (D) and pressure (P) factors. Considering D and P as a comprehensive factor (i.e., S—socioeconomic impact) allows more detailed analysis of the impact of human social activities on ecology. At the same time, by choosing ecological health (E) as the characterizing factor of S, ecosystem services function (E) as the characterizing factor of I, and control management (C) as the characterizing factor of R, the SEEC model can be established. The framework of the SEEC model is shown in Figure 1.

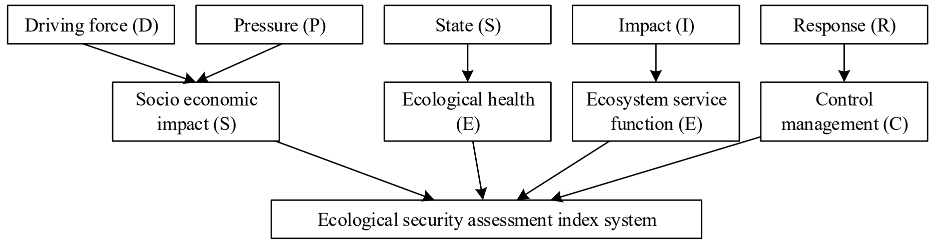

Figure 1. Framework of the SEEC model.

2.1.2. Construction of the System of Indicators

After determining the four factors of the SEEC model, the representative indicators must be screened to obtain the evaluation results of the SEEC model.

(1) Socioeconomic impact

As mentioned in the introduction, the factors D and P in the original DPSIR model were generally related to the socioeconomic factors in the conventional sense [52,53]. However, when assessing the ecological security of the watershed, the particularity of this assessment objective needs to be considered, that is, for the ecological security of the watershed, the driving force and pressure are not very intuitive in the general sense. This paper needs to consider the driving force and pressure indicators that have a more significant impact on the ecological security of the watershed. Moreover, in the assessment of watershed ecological security, the applicability of each assessment factor should be considered in a balanced manner, and the original DPSIR model cannot be relied on completely, which will over amplify the impact of D and P. Therefore, socioeconomic impact factors mainly include the socioeconomic development and pollution load attributable to human activities in this article. Socioeconomic development mainly includes population, economic, and social indicators. Population indicators include the quantity, density, and natural growth rate of the population. Economic indicators are mainly used to determine the level of economic development and the intensity of economic activities. Therefore, economic indicators that can fully represent the structure and scale of the economy should be selected, e.g., GDP, per capita GDP, and total industrial and agricultural output value. Social indicators are relatively comprehensive and can be expressed by the urbanization rate.

Watershed pollution load is the primary way in which human activities affect water ecology. Generally, point source or nonpoint source discharge of pollutants can have serious impact on a watershed.

(2) Ecological health

Ecological health is reflected by the water quality and water ecology. In the process of watershed monitoring, water quality is commonly assessed using dissolved oxygen, total nitrogen, total phosphorus, the permanganate index, ammonia nitrogen, transparency, suspended solids, chlorophyll a, and heavy metal indicators.

In addition to the above indexes, water ecological indicators also include zooplankton, phytoplankton, and the benthic biomass. However, because it is very difficult to monitor the above indicators within many watersheds, the quality of sediment is often used to characterize the ecological status of water.

(3) Ecosystem services

The ecological services function of a watershed is mainly reflected in purifying the water quality, providing aquatic products, and providing cultural tourism services. Considering that aquaculture and fishing are no longer allowed in many watersheds, inclusion of this indicator was dependent on the specific situation of the watershed. The water purification function of a watershed is generally realized through natural shoreline filtration on both banks of the river. Cultural tourism services are also related to the geographical location of the watershed.

(4) Control management

Control management is mainly reflected in policies related to the economy, ecology, and environment, including ecological protection capital investment, industrial structure adjustment, and ecological supervision capacity building.

Through analysis of the connotation, scientificity, representativeness, and applicability of each indicator and following literature-based research, 34 evaluation indicators were determined. See Table A1 for the definition, reasons for selection, and calculation or acquisition method of each indicator.

2.1.3. Data Processing

(1) Data standardization

All indicators must be standardized to facilitate ecological security assessment. The concept of a reference standard should be introduced, meaning the value of each evaluation index in the ideal state (conducive to ecological security) or at the average level in a large-scale region [54].

The process of standardization of the indicators is conducted as follows:

$$\text{Positive indicator: } R_{ij} = X_{ij}/S_{ij}, \quad (1)$$

$$\text{Negative indicator: } R_{ij} = S_{ij}/X_{ij}, \quad (2)$$

where positive indicator means that the larger the value of the indicator, the more favorable it is to ecological security; negative indicator means that the larger the value of the indicator, the more unfavorable it is to ecological security; X_{ij} is the measured value of indicator i at sampling point j; S_{ij} is the reference standard of indicator i; and R_{ij} is the dimensionless value of the evaluation indicator, where $0 < R_{ij} < 1$; when $R_{ij} > 1$, we take $R_{ij} = 1$.

(2) Weight calculation

The main methods used to determine the weights are the subjective weight method and the objective weight method. The most common subjective weighting method is the Delphi method, also known as the expert scoring method [55]. Its advantages are its clear concept, simplicity, and ease of operation, which can grasp the main factors of ecological security assessment, but it needs a certain number of experts with experience to produce the scores. The objective weighting method determines the index weights using a judgment matrix composed of evaluation index values. The most commonly used objective weighting method is the entropy method, which uses the utility values of the index information in the calculation; the higher the utility value, the more important it is to the evaluation. The SEEC model involves four factors, each of which contains information with differing complexity. Thus, the objective weighting method will lead to some factors with less impact on ecological security obtaining higher weighting, making it difficult to truly reflect the importance of the factors. Therefore, the weights of the four factors were determined using the expert scoring method. The full score was set at 10 and the higher the score, the more important the factor. Using a judgment matrix after sorting the consultation results, the weighting coefficient of the index was calculated, and the entropy method was used to determine the weights of the 34 indicators.

The process of application of the entropy method is as follows[56]:

a) Construct the judgment matrix Z for n samples and m evaluation indicators:

$$Z=\begin{bmatrix} X_{11} & X_{12} & \ldots\ldots & X_{1m} \\ X_{21} & X_{22} & \ldots\ldots & X_{2m} \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \\ X_{n1} & X_{n2} & \ldots\ldots & X_{nm} \end{bmatrix} \tag{3}$$

b) The dimensionless data are used to obtain a new judgment matrix, in which the expression of the element is:

$$R=(r_{ij}\, n\times m) \tag{4}$$

c) According to the definition of entropy, for n samples and m evaluation indicators, the entropy of the evaluation indicators can be determined as follows:

$$H_i=-\frac{1}{\ln(n)}\left[\sum_{i=1}^{n} f_{ij}\ \ln f_{ij}\right] \tag{5}$$

$$f_{ij}=\frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}} \tag{6}$$

where $0 \le H_i \le 1$.

To make $\ln f_{ij}$ meaningful, it is assumed that $f_{ij}=0$, $f_{ij}\ln f_{ij}=0$, $i=1,2,\ldots,m$, and $j=1,2,\ldots,n$.

d) Calculate the entropy weight (W_i) of the evaluation indicators:

$$W_i=\frac{1-H_i}{m-\Sigma H_i} \tag{7}$$

where W_i is the weighting coefficients of the evaluation indicators that meet the following requirement:

$$\Sigma W_i=1 \tag{8}$$

(3) Expression of the evaluation results

The evaluation results are expressed using the ESI; the higher the ESI value, the safer the ecological status. On the basis of the general expression of river and lake ecosystem assessment results in China, the ESI is divided into five levels from 0–100, as shown in Table 1.

Table 1. Classification standard of the ESI.

Classification	Ecological Security Index (ESI)	Safety Status
I	80 ≤ ESI ≤100	Safe
II	60≤ ESI <80	Relatively safe
III	40≤ ESI <60	Generally safe
IV	20≤ ESI <40	Relatively unsafe
V	ESI <20	Unsafe

2.2. Study Area

The study area is located in Northwest China. The watershed is 214 km long and 25–50 km wide from east to west. The drainage area is 4684 km² and the annual runoff is 237 million m³. The average elevation is 2545.63 m (Figure 2).

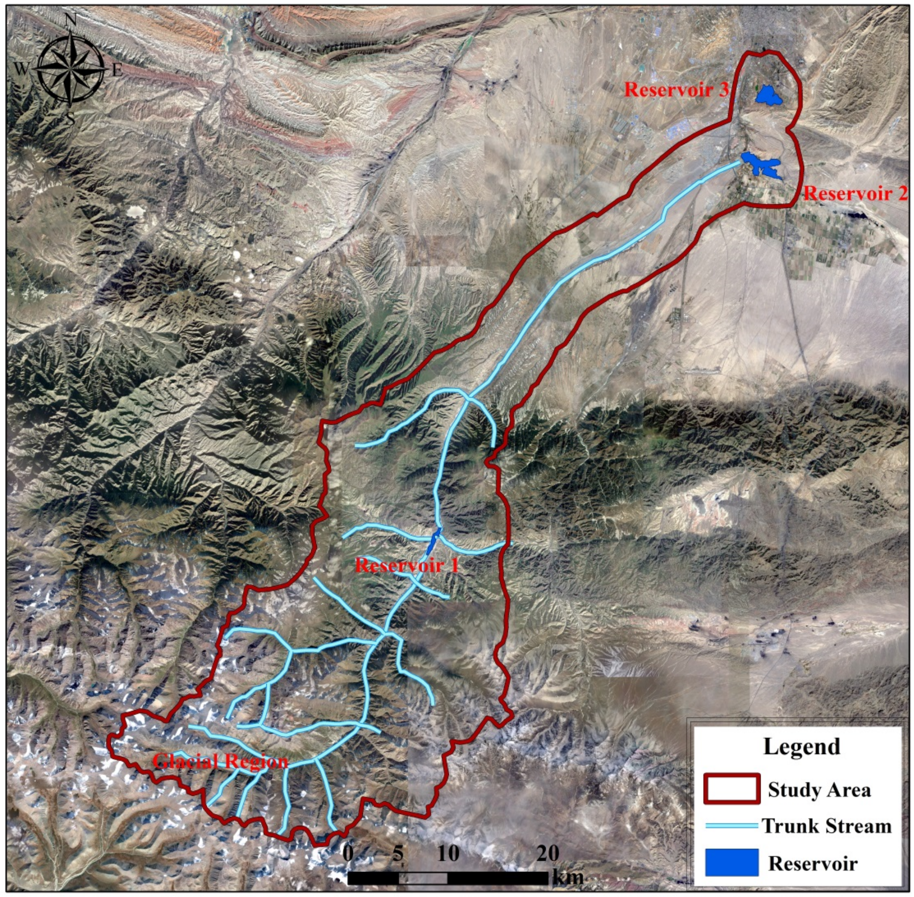

Figure 2. Overview of the study area.

The study area is affected mainly by the mid-latitude near-surface atmospheric circulation. The annual average temperature of the watershed is 3.5 °C. The temporal distribution of precipitation is uneven, falling mainly in June–August. The annual average precipitation of the watershed is approximately 420 mm, and its spatial distribution is very uneven. Solid precipitation accounts for approximately 54.2% of the annual total precipitation. According to the results of the "Water Resources Bulletin," the average annual precipitation in the study area was 1.28 billion m³ during 2006–2013, with no obvious trend of increase or decrease. In 2015, the amount of surface water resources within the study area was 1.160 billion m³, and the amount of groundwater resources was 574 million m³. The total amount of the water supply was maintained at more than 1.1 billion m³, and more than half of the water supply was derived from surface water.

The soil distribution in the upper reaches of the study area has vertical zonation. In addition to ice and snow cover, at elevations above 3600 m, exposed rocks and stone mounds are widely distributed, although some areas have poorly developed soil. The soil in the elevation range of 3100–3400 m is mainly alpine meadow soil; 2000–3100 m is mainly subalpine meadow soil; 1700–2000 m is mountain chernozem; 1200–1700 m is mountain chestnut soil; and 800–1200 m is brown calcareous soil. The soil at 1700–2900 m has mosaic distribution characteristics. Taupe forest soil is mainly found on shady slopes at elevation of 1700–2900 m, and it is distributed in a compound area with chernozem and subalpine meadow soil. The climate and terrain in the watershed vary markedly, and the corresponding vegetation types are relatively complete with obvious regularity in terms of geographical distribution. The main vegetation types are coniferous forest, broadleaved forest, shrub, grassland, meadow, and desert grassland. We used ArcGIS 10.3 to interpret the land use of the study area in 2014, and the results showed that grassland was the main vegetation cover type, followed by woodland and cultivated land (Figure 3).

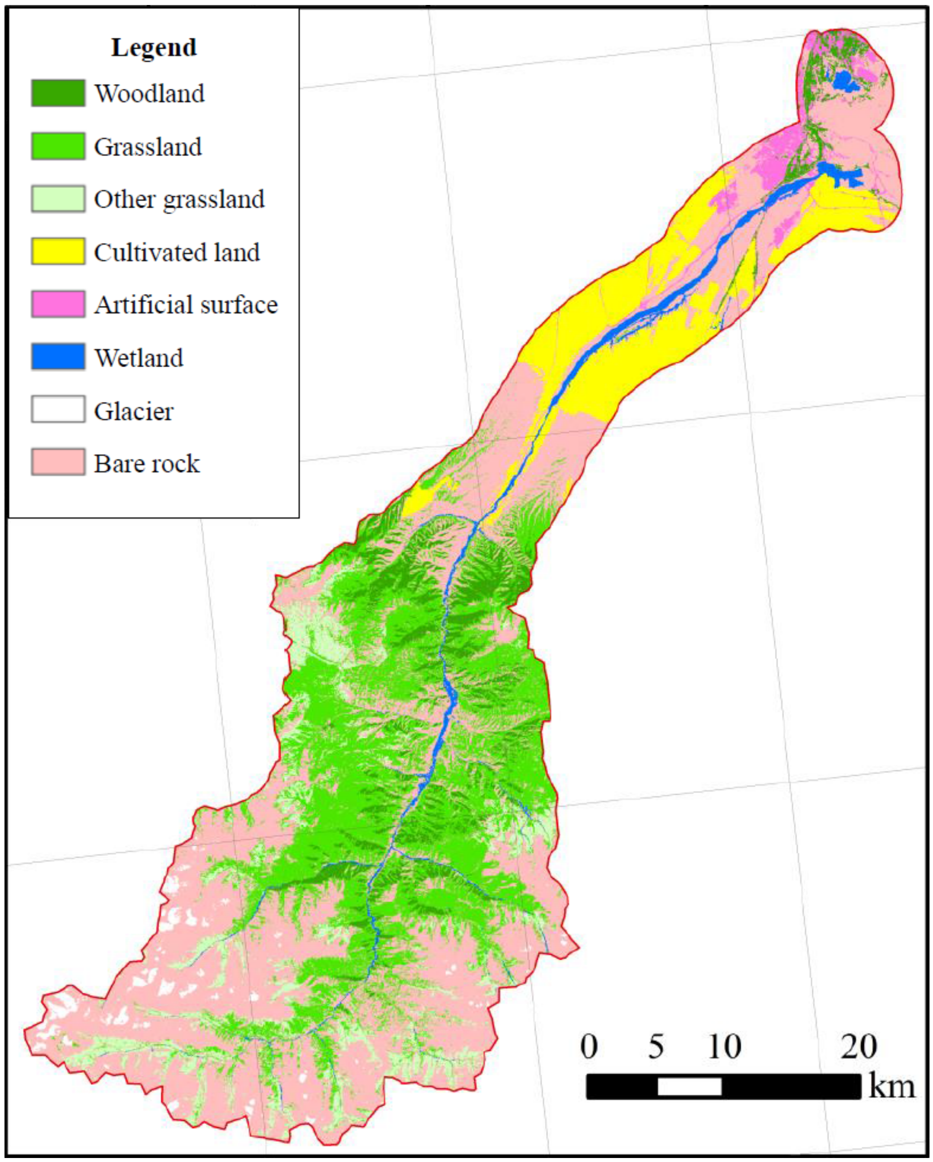

Figure 3. Land use types within the study area (2014).

In addition to the main stream, the study area includes one main glacier and three reservoirs (Figure 2). The main glacier, which is the source of the river, presently covers an area of 1.62 km^2. Taking this glacier as the center, 109 large and small modern glaciers are developed within an area of 300 km^2, comprising a total glacier area of 38.3 km^2. Among them, 22 glaciers are distributed within the study area, covering a total area of 9.7 km^2. The annual runoff of glacier meltwater into the trunk stream is 17.69 million m^3. Therefore, glaciers are not only an important water source in the study area but they also represent a "solid reservoir" regulating runoff. Reservoir 1 (Figure 2) is located in the upper reaches of the study area. It is a water conservancy project that has flood control and irrigation as its primary and secondary purposes. Its operation is mainly divided into reservoir closure, dam flood control, and sluice water storage. The dam crest elevation is 2189.2 m, and the total storage capacity is 69.9 million m^3. The highest dam height is 98 m. Reservoir 1 can exploit its flood-retention capability to cut the peak flood and regulate and store the flood during the flood season. Reservoir 2 (Figure 2) is located in a mountain depression of the middle reaches of the study area. It is a series regulating reservoir upstream of the urban area. It undertakes the three tasks of flood control, drought relief, and urban water supply for the city. The catchment area above the section of Reservoir 1 is 2596 km^2, including 1070 km^2 in the mountainous area of the main stream, 950 km^2 in the piedmont plain area, and 576 km^2 in the mountainous area of tributary gullies. Reservoir 3 (Figure 2) is located 6 km downstream of Reservoir 2. It is a through-injection reservoir built using natural depressions. The current water surface area is 4.5 km^2 and the maximum storage capacity is 53 million m^3. It is a large reservoir for comprehensive flood discharge irrigation, power generation, fish aquaculture, and urban water supply.

To obtain accurate data, a number of investigations were conducted in the study watershed during 2016–2017. These investigations included discussion with local research departments, data acquisition through visits to local government departments, collection of water and sediment samples, and investigation of pollution sources. Thus, data regarding the 34 evaluation indicators were obtained. Details were given in Table A2, which described the source of original data. Table A3 and Table A4, respectively, introduced the weights and reference standards of each indicator.

3. Results and Discussion

3.1. Results of the Ecological Security Assessment

Through evaluation of the SEEC model, it was determined that the ESI value of the study area is 80.9–94.2. In accordance with the geographical characteristics, the watershed was divided into three sections:

- Upstream area: the section from Glacier No. 1 to the region downstream of Reservoir 1 (hereafter, the upstream area);
- Midstream area: downstream of Reservoir 1 to the region upstream of Reservoir 2 (hereafter, the midstream area);
- Downstream area: the section from the region upstream of Reservoir 2 to Reservoir 3 (hereafter, the downstream area).

The assessment results indicate that the status of the entire watershed was in the “safe” state, as defined in Table 1, indicating that the ecological security level was high. The ESI values of the entire study area are shown in Figure 4. It can be seen that the highest ESI values in the entire watershed are in the upstream area, and that the lowest ESI values are near Reservoir 2 in the downstream area. The ESI values of the midstream area are at an intermediate level. To identify the causes of the low ESI scores, we examined the scores for the four evaluation factors in the SEEC model using radar charts, as shown in Figure 5. It can be seen that the scores for the four evaluation factors are uneven. The lowest score is for C, indicating deficiencies in watershed regulation and management, and the second lowest value is for E (ecological health), indicating the need for attention to improve the state of ecological health. The scores for S and E (ecological services function) are high, indicating that the current socioeconomic factors have not impacted negatively on the ecological security of the watershed. Although the score for ecological health is low, it might not have affected the ecological services function of the watershed. Nevertheless, to improve the ESI score of the watershed, factors C and E (ecological health) need to be the focus of attention.

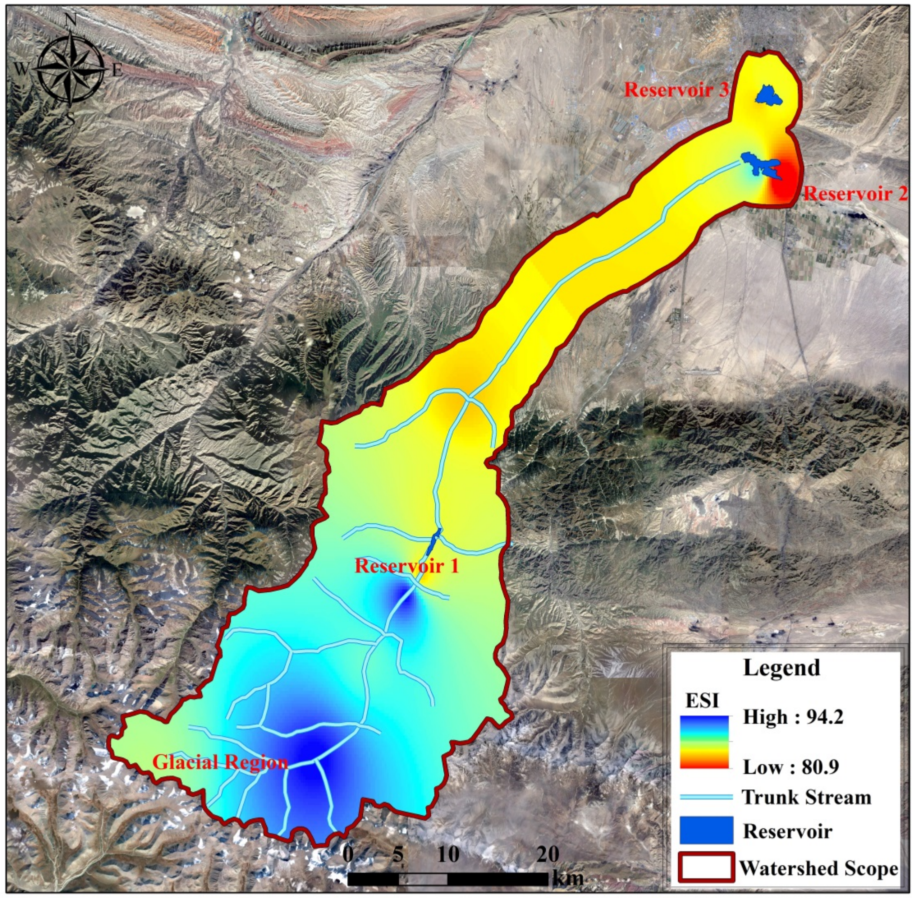

Figure 4. Ecological security index (ESI) values throughout the entire study area.

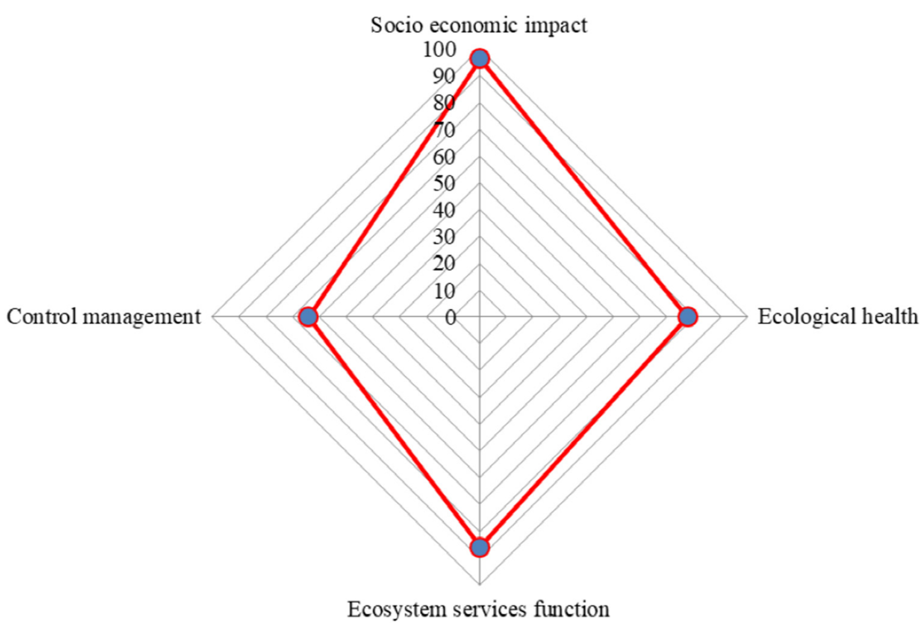

Figure 5. Radar diagram for the four factors in the SEEC model.

3.2. Score for Each Evaluation Factor

(a) Assessment Results of Socioeconomic Impact (S)

The score for S is approximately 96, indicating the positive role it plays in ensuring ecological security. The score distribution of the 10 indicators is shown in Figure 6a. Among the 10 indicators, those with relatively low scores are population growth rate and per capita GDP. The lowest values of both are in the upstream and midstream areas, which are regions with poor natural conditions, sparse population, and low per capita GDP. In the past, it was often believed that if the population growth rate and per capita GDP were low, the pressure on ecology would be small and ecological security would not be threatened. The assessment reveals that levels of population growth rate and per capita GDP that are too low are not conducive to ecological security and thus they should be maintained at reasonable levels.

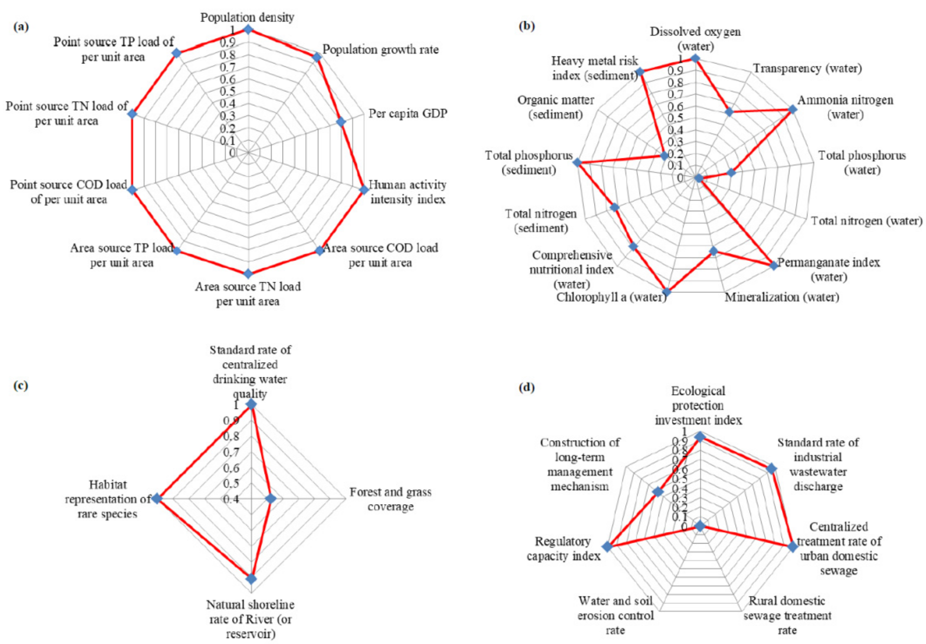

Figure 6. Radar diagrams for the four factors in the SEEC model: (**a**) socioeconomic impact assessment results, (**b**) ecological health assessment results, (**c**) ecological services function assessment results, and (**d**) control management assessment results.

(b) Assessment Results of Ecological Health (E)

The score for E (ecological health) is about 78, indicating the negative role it has in ecological security. The score distribution of the 13 indicators is shown in Figure 6b. Among the 13 indicators, the value for the total nitrogen in the water is too high, followed by the comprehensive nutritional index, organic matter, and heavy metal risk index. In terms of the spatial distribution, the comprehensive nutritional index in the upstream area is relatively low, but it increases gradually from the midstream area to the downstream area, reaching its highest value near Reservoir 3, which mainly reflects the intensity of human activity and tourism development [57]. The heavy metal risk index in the upstream and midstream areas is low, while the highest value is near Reservoir 2. The evaluation results of the comprehensive nutritional index and heavy metal risk index are shown in Figure 7.

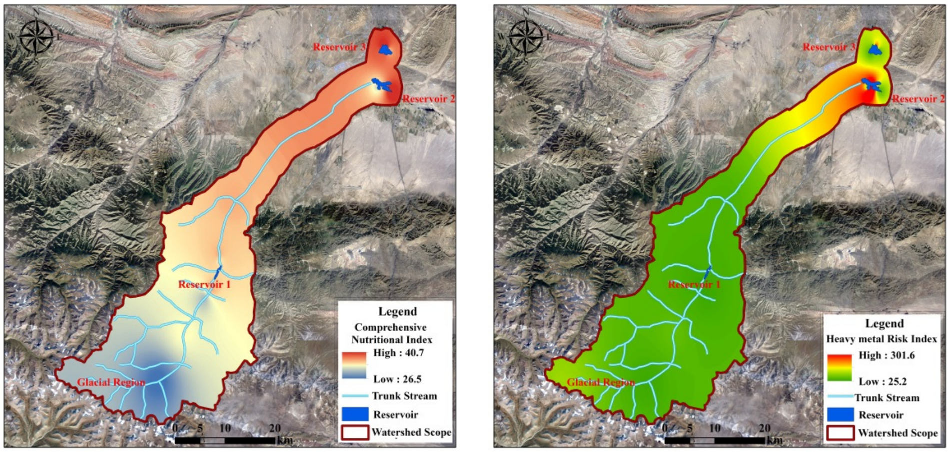

Figure 7. Scoring results for the comprehensive nutritional index (**left**) and potential heavy metals ecological risk index (**right**).

(c) Assessment Results of Ecosystem Services Function (E)

The calculation result of E (ecosystem services function) is approximately 86, indicating its negative role in ecological security. The score distribution for the four indicators is shown in Figure 6c. The main reason for the low score for E is the low coverage of forest and grass, especially in the upstream and midstream areas, which mainly reflects the relatively intense water and soil erosion in these areas in recent years. Moreover, human activities such as livestock grazing and free-range poultry breeding have aggravated grassland degradation [58]. Additionally, the natural shoreline rate of the river is also low, which is mainly attributable to the construction of embankments, diversion channels, and other human projects in the downstream area [59].

(d) Assessment Results of Control Management (C)

The score for C is approximately 64, indicating its negative role in ecological security. The score distribution for the seven indicators is shown in Figure 6d. The low rate of treatment of rural domestic sewage is the main problem in relation to the low C score. The population of the watershed is sparse and scattered, meaning that the high cost of construction of environmental infrastructure make it difficult to collect and treat domestic sewage. The score for the soil and water erosion control rate is the second biggest problem in relation to the low C score. Water and soil erosion in the upstream and midstream areas is serious, and the grassland is deteriorating steadily. The effect of implemented mitigation measures has been limited because the dry climate and steep terrain in the upstream and midstream areas are not conducive to the control of water and soil erosion.

3.3. Applicability Evaluation of the SEEC Model

To evaluate the applicability of the SEEC model, factors that could characterize the level of watershed ecological security were selected. If the assessment results of the SEEC model indicated that these factors were relevant, then the evaluation method could be considered to have satisfactory applicability. In assessment of watershed ecology, water quality status is often used as an important comprehensive assessment factor with which to characterize whether the current ecology is threatened, i.e., whether the ecological status is safe. Therefore, the water quality of the study watershed was selected as the assessment factor for evaluation of the applicability of the SEEC method. To keep the assessment independent, we gave priority to the correlation analysis between the selected water quality indicators for evaluation (hereafter, the water evaluation indicators) and the water quality indicators participating in the evaluation of the SEEC model (hereafter, the water model indicators). The water evaluation indicators comprised pH, conductivity, biochemical oxygen demand, petroleum, volatile phenol, mercury, lead, copper, zinc, fluoride, selenium, arsenic, cadmium, hexavalent chromium, cyanide, anionic surfactant, sulfide, fecal Escherichia coli, sulfate, chloride, nitrate, and suspended solids. The water model indicators comprised dissolved oxygen, transparency, ammonia nitrogen, total phosphorus, total nitrogen, the permanganate index, mineralization of water, chlorophyll a, and the comprehensive nutritional index. The water quality data of the evaluation indicators were obtained from the local environmental monitoring department.

First, the monitoring data at the same point and for the same period were selected, and IBM SPSS 20.0 software was used to calculate the Pearson correlation coefficient of the two datasets (i.e., water evaluation indicators and water model indicators). Evaluation indicators that showed obvious correlation with the water model indicators were eliminated. Additionally, because the SEEC model included the heavy metal risk index of sediment, the heavy metal indicators were also removed from the water evaluation indicators to avoid affecting the independence of the index. Through the screening process, the evaluation indicators were determined as follows: pH, petroleum, volatile phenol, fluoride, cyanide, anionic surfactant, sulfide, fecal Escherichia coli, sulfate, chloride, and suspended solids. There was no obvious correlation between the final water evaluation indicators and the water model indicators, indicating that the final water evaluation indicators were independent and could be used to evaluate the applicability of the SEEC model.

Second, using the water evaluation indicators, the Nemero index method [60] was used to evaluate water quality, and the evaluation results were expressed in terms of China's surface water environmental quality standard. The evaluation results were characterized as the higher the score, the worse the water quality. Obviously, when the water quality of the watershed is poor, its ecological security level is low. In other words, under natural conditions, the water quality score results should be negatively correlated with the watershed ecological security index. If the evaluation result of this paper also conforms to the above rules, it shows that the evaluation result of this paper is relatively accurate, and the evaluation method has good applicability.

Then, ArcGIS 10.3 was used for spatial interpolation to obtain the spatial distribution characteristics of water quality, as shown in Figure 8. Finally, the Pearson correlation coefficient between the data illustrated in Figure 8 and the SEEC evaluation results (Figure 4) was calculated using the ArcGIS 10.3 spatial analysis module. Through calculation, the Pearson correlation coefficient was determined to be approximately −0.4, which was consistent with the rules described above, indicating that the comprehensive evaluation results of water quality were better in areas with high ecological security scores. The evaluation results showed that the SEEC model has satisfactory performance when applied to evaluation of watershed ecological security.

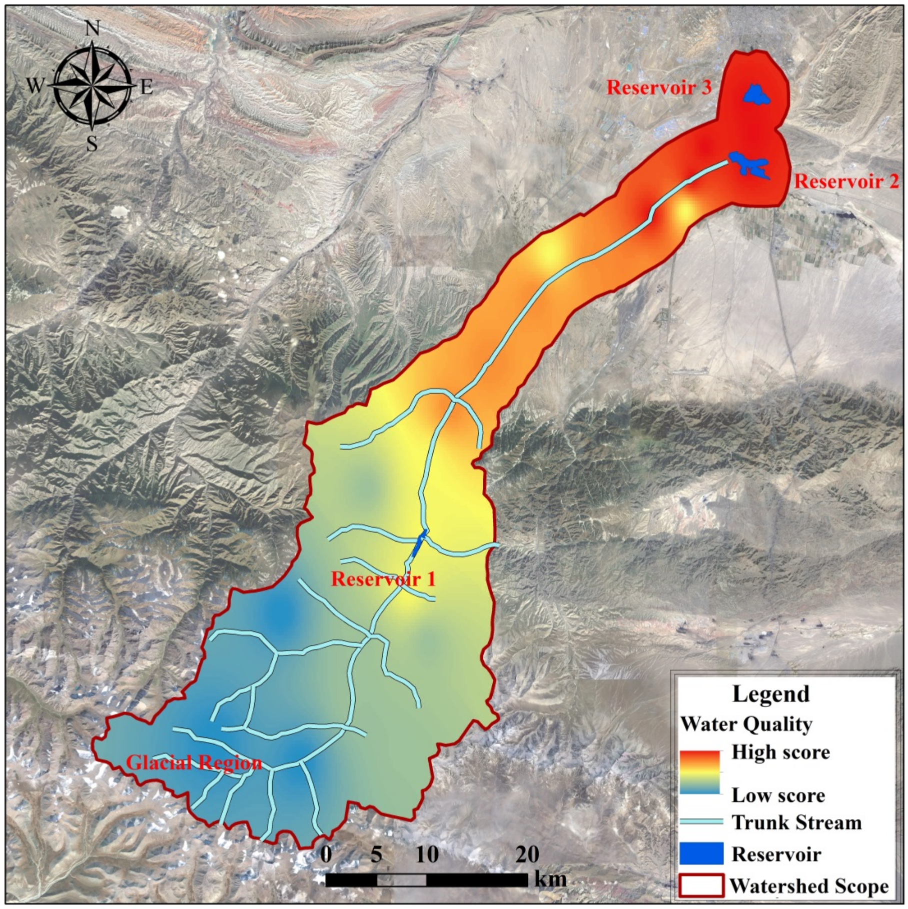

Figure 8. Comprehensive evaluation results of water quality in the study area in 2014 (the lower the score, the better the water quality).

4. Conclusions

Using the framework of the DPSIR model, and considering the connotation of watershed ecological security assessment, this article established the SEEC model that incorporates four factors: socioeconomic impact (S), ecological health (E), ecosystem services function (E), and control management (C). The SEEC model contains 34 evaluation indicators. We selected a watershed in the arid region of Northwest China for application of the research method. Through evaluation, the ESI value of the study area was approximately 81–94. Through analysis of the evaluation results, it was elucidated that the factors leading to the low score were mainly the low rate of treatment of rural domestic sewage and the low rate of mitigation of soil and water erosion. The results of the evaluation of the applicability of the SEEC model showed that the SEEC model has satisfactory performance in evaluation of watershed ecological security.

This article is successful from these aspects: it puts forward the method approach for watershed ecological security assessment and gives the specific evaluation index, index weight, and other key information; through application, it identifies the key factors affecting the ecological security of the study area, which has good guiding significance for local environmental management and can also provide reference for similar studies. However, owing to limited research funds and other reasons, this article fails to verify the SEEC model, such as through comparison of analysis of the ecological security status in different years. Therefore, more in-depth research is needed regarding the applicability and verification of the SEEC model.

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Appendix A

Table A1. Definition, reasons for selection, and calculation or acquisition method of each indicator.

Factors	Involved Aspects	Indicators	Definition and Reasons for Selection	Method of Calculation (Within the Study Area)
Socioeconomic impact	Population	Population density	Population of per unit area. It is an important factor in the impact of social economy on the environment. It affects the allocation of resources and the surplus of environmental capacity.	Total population/area
		Population growth rate	The ratio of population growth to the total population in a given period of time (usually one year). It is an important indicator of population growth.	(Population at the end of the year - population at the beginning of the year)/annual average population × 1000‰
	Economy	Per capita GDP	Regional GDP per capita in the study area. It is the most common indicator to measure the level and pressure of social and economic development. It can not only reflect the development of social economy but also indirectly reflect the pressure of social and economic activities on the environment to a certain extent.	Total GDP/total population
	Social	Human activity intensity index	Proportion of the sum of construction land area and agricultural land area in the total land area, which are the main land types reflecting the intensity of human activities, which can reflect the pressure of social and economic activities on the environment at present and in the next few years.	(Construction land area + agricultural land area)/total area
	Watershed pollution load	Area source chemical oxygen demand (COD) load per unit area	COD load per unit land area, which mainly includes COD emissions from area sources such as livestock and poultry free range breeding, planting, rural residents' life, and so on. It is one of the most important evaluation indexes of environmental pollution. Considering the horizontal comparison between different watersheds and different statistical	(COD emission of livestock and poultry free range breeding + COD emission of planting + COD emission of rural residents' life)/total area

Factors	Involved Aspects	Indicators	Definition and Reasons for Selection	Method of Calculation (Within the Study Area)
			units, the COD load per unit area is used as the evaluation index.	
		Area source TN load per unit area	TN load per unit land area, which mainly includes TN emissions from area sources such as livestock and poultry free range breeding, planting, rural residents' life, and so on. It is one of the main factors leading to river eutrophication.	(TN emission of livestock and poultry free range breeding + TN emission of planting + TN emission of rural residents' life)/total area
		Area source TP load per unit area	TP load per unit land area, which mainly includes TP emissions from area sources such as livestock and poultry free range breeding, planting, rural residents' life, and so on. It is one of the main factors leading to river eutrophication.	(TP emission of livestock and poultry free range breeding + TP emission of planting + TP emission of rural residents' life)/total area
		Point source COD load of per unit area	Point source COD load of per unit area, which mainly includes urban industrial COD emission and urban living COD emission. The reason for selection is similar to area source but point source and area source characterize different processes of pollution.	(Urban industrial COD emission and urban living COD emission)/total area
		Point source TN load of per unit area	Point source TN load of per unit area, which mainly includes urban industrial TN emission and urban living TN emission. The reason for selection is same as above.	(Urban industrial COD emission and urban living COD emission)/total area
		Point source TP load of per unit area	Point source TP load of per unit area, which mainly includes urban industrial TP emission and urban living TP emission. The reason for selection is same as above.	(Urban industrial COD emission and urban living COD emission)/total area
Ecological health		Dissolved oxygen	Molecular oxygen dissolved in water is an important index to judge water quality and an important item of water quality monitoring. The growth and reproduction of phytoplankton in water and pollutants in water will affect dissolved oxygen. It is an important indicator of water quality.	Field measurement
		Transparency	It reflects the clarification degree of the water body, which is related to the content of suspended solids and colloids in the water. It is an important indicator for evaluating water eutrophication.	Field measurement
		Ammonia nitrogen	Refers to nitrogen in the form of free ammonia (NH_3) and ammonium ion (NH_4^+) in water. It is an important indicator for evaluating water quality.	Testing
	Water quality	Total phosphorus	The total amount of various organic and inorganic phosphorus in water, which is generally expressed by the determination results after various forms of phosphorus are transformed into orthophosphate after digestion. It is the key indicator to evaluate the degree of water eutrophication and water quality.	Testing
		Total nitrogen	The total amount of various forms of inorganic and organic nitrogen in water. The reason for selection is same as above.	Testing
		Permanganate index	It refers to the amount of oxidant consumed when treating water samples with potassium permanganate ($KMnO_4$) as oxidant under certain conditions. It is an important indicator to evaluate water quality.	Testing
		Mineralization of water	It refers to the amount of carbonate, bicarbonate, chloride, sulfate, nitrate, and various sodium salts containing calcium, magnesium, aluminum, manganese, and other metals in water. The reason for selection is same as above.	Testing
	Water eutrophication	Chlorophyll a	It is an important photosynthetic pigment in plant photosynthesis. By measuring chlorophyll a of phytoplankton, it can master the primary productivity of water. At the same time, chlorophyll a content is also one of the indicators of water eutrophication. It is	Testing

Factors	Involved Aspects	Indicators	Definition and Reasons for Selection	Method of Calculation (Within the Study Area)
			an important indicator to reflect eutrophication and algal biomass of water.	
		Comprehensive nutritional index	It is a comprehensive indicator to reflect water eutrophication.	Taking the state index TLI (Chla) of chlorophyll a as the benchmark, the nutritional state indexes of TP, TN, COD, SD, and other parameters close to the benchmark parameters (with small absolute deviation) are selected for weighted synthesis with TLI (Chla). The comprehensive weighted index model is: $TLI(\Sigma)=\sum_{j=1}^{M} W_j \cdot TLI(j)$ where: TLI (å) is the comprehensive weighted nutritional status index; TLI (j) is the nutritional status index of the j-th parameter; W_j is weight of nutritional status index of the j-th parameter. $W_j = \frac{R_{ij}^2}{\sum_{j=1}^{M} R_{ij}^2}$ where: R_{ij} means correlation coefficient between the jth parameter and the benchmark parameter, M is number of main parameters close to the benchmark parameter.
	Sediment	Total nitrogen	Nitrogen content in sediments. It is an important indicator for evaluating sediment quality.	Testing
		Total phosphorus	Phosphorus content in sediments. The reason for selection is same as above.	Testing
		Organic matter	It generally refers to substances derived from life in sediments, including sediment. Microorganisms, benthos, and their secretions, as well as plant residues and plant secretions in soil. The reason for selection is same as above.	Testing
		Heavy metal risk index	It is a relatively fast, simple, and standard method to classify the degree of sediment pollution and its potential ecological risk. The reason for selection is same as above.	The Hakandson risk index method [61] is used for calculation. For detailed method introduction, please refer to the references cited here.
Ecosystem services function	Drinking water service function	Standard rate of centralized drinking water quality	It refers to the inspection frequency of the water quality monitoring of all centralized drinking water sources in the watershed that meets or exceeds the class II water quality standard of the "environmental quality standard for surface water" (GB 3838-2002), accounting for the proportion of the total inspection frequency in the whole year. It is important data of drinking water service function survey.	(Sum of compliance frequency of all monitoring sections/total monitoring frequency of all sections throughout the year) × 100%
	Water conservation function	Forest and grass coverage	It refers to the proportion of the sum of forest and grass vegetation areas such as arbor forest, shrub forest, and grassland in the regional land area. It is an important indicator to reflect the function of water conservation.	(Forest land area + grassland area)/total land area × 100%
	Interception and purification function	Natural shoreline rate of River (reservoir)	The riverbank zone is divided into natural zone (undeveloped or natural shoreline length) and artificial zone. Here, it refers to the proportion of the length of natural riverbank zone in the total length of riverbank shoreline. It is an important indicator	Length of natural zone/(length of natural zone + length of artificial riverside zone) × 100%

Factors	Involved Aspects	Indicators	Definition and Reasons for Selection	Method of Calculation (Within the Study Area)
			reflecting the interception and purification function of the riverbank.	
	Cultural landscape function	Habitat representation of rare species	It mainly refers to whether the habitat reflects the characteristics of rare fish and important cultural landscape within the region, and whether it includes key species, rare and endangered species, and key protected species of natural ecosystem. It is an important indicator to reflect the function of cultural landscape.	Expert opinion method (Delphi method)
	Ecological protection investment	Ecological protection investment index	Proportion of environmental protection investment in regional GDP. According to the experience of developed countries, in the period of rapid economic growth, if a country wants to effectively control pollution, the investment in environmental protection should continuously and stably account for 1.5% of the gross national product within a certain period of time. Only when the investment in environmental protection reaches a certain proportion can it maintain good and stable environmental quality while rapid economic development.	Environmental protection investment/regional GDP × 100%
Control management	Pollution control and environmental protection	Standard rate of industrial wastewater discharge	It refers to the proportion of the total amount of industrial wastewater discharged by key industrial enterprises within the scope of towns and townships through the sewage outlet and stably reaching the pollution discharge standard in the total amount of discharged industrial wastewater. It is an important indicator to reflect pollution control.	(Up to standard discharge of industrial wastewater/discharge of industrial wastewater) × 100%
		Centralized treatment rate of urban domestic sewage	The proportion of domestic sewage treated by the sewage treatment plant and meeting the discharge standard in the total discharge of urban domestic sewage. The reason for selection is same as above.	Treatment capacity of urban sewage treatment plant/total urban sewage generation er) × 100%
		Rural domestic sewage treatment rate	It refers to the proportion of rural domestic sewage treated by sewage treatment facilities and meeting the discharge standards in the total discharge of rural domestic sewage. The reason for selection is same as above.	Rural domestic sewage treatment capacity/total rural domestic sewage discharge × 100%
		Water and soil erosion control rate	Water and soil erosion refers to the migration and deposition process of water and soil caused by flowing water, gravity, or human action. The water and soil erosion control rate refers to the water and soil loss control area divided by the original water and soil loss area within a certain area and a certain period of time. It is an important indicator to reflect environmental protection.	Control area of water and soil erosion in a certain period/original water and soil erosion area × 100%
	Regulatory capacity	Regulatory capacity index	The ability to supervise and manage the ecological environment in the watershed. It is mainly composed of the degree of standardized construction of drinking water sources, environmental monitoring capacity, environmental monitoring standardization construction capacity, scientific and technological support capacity, etc. It is an important index to reflect human protection of the environment through regulation and management.	Expert opinion method (Delphi method)
	Long term mechanism	Construction of long-term management mechanism	An institutional system that can ensure the normal operation of the environmental protection system and play its expected functions for a long time. It is mainly composed of laws, regulations, policies, unified management institutions in the watershed, market-oriented long-term investment, and financing system, etc. The reason for selection is same as above.	Expert opinion method (Delphi method)

Table A2. Data acquisition process.

Indicators	Data Sources and Processing	Source of Original Data
Population density	Statistical yearbook 2016 of study area	Data available from government departments.
Population growth rate	Same as above	Same as above.
Per capita GDP	Same as above	Data available from government departments.
Human activity intensity index	Graphic translation of land use types	Purchased satellite images from the satellite remote sensing image Department and used Arc GIS 10.3 for remote sensing interpretation.
Area source COD load of per unit area	Statistical yearbook 2016 of study area, data calculation	We took the data published by government departments as the basis and reference and calculated it by the method in Table A1.
Area source TN load of per unit area	Same as above	Same as above.
Area source TP load of per unit area	Same as above	Same as above.
Point source COD load of per unit area	Same as above	Same as above.
Point source TN load of per unit area	Same as above	Same as above.
Point source TP load of per unit area	Same as above	Same as above.
Dissolved oxygen (water)	Sampling, detection, and analysis	In June 2017, 16 surface water samples were collected on site and tested in field (Hereinafter referred to as "sampling and test in field"). The test method was electrochemical probe method.
Transparency (water)	Same as above	Sampling and test in field, and the test method was Saybolt Disk Method.
Ammonia nitrogen (water)	Same as above	In June 2017, 16 surface water samples were collected on site, which were tested in the Analysis and Testing Center of Beijing Normal University (Hereinafter referred to as "sampling and test in laboratory"), and the test method was salicylic acid spectrophotometry.
Total phosphorus (water)	Same as above	Sampling and test in laboratory. The test method was molybdic acid spectrophotometry.
Total nitrogen (water)	Same as above	Sampling and test in laboratory. The test method was alkaline potassium persulfate digestion UV spectrophotometry.
Permanganate index (water)	Same as above	Sampling and test in laboratory. The test method was acid method.
Mineralization (water)	Same as above	Sampling and test in laboratory. The test method was 180 °C dry gravimetric method.
Chlorophyll a (water)	Same as above	Sampling and test in laboratory. The test methods were acetone extraction and spectrophotometer determination.
Comprehensive nutritional index (water)	Calculated according to the test results	According to the test results of the samples, it was calculated by the method in attached Table A1.
Total nitrogen (sediment)	Sampling, detection, and analysis	Sampling and test in laboratory. The test method was the Kai's Nitrogen Determination Method.

Indicators	Data Sources and Processing	Source of Original Data
Total phosphorus (sediment)	Same as above	Sampling and test in laboratory. The test methods were perchloric acid and sulfuric acid digestion.
Organic matter (sediment)	Same as above	Sampling and test in laboratory. The test method was potassium dichromate method.
Heavy metal risk index (sediment)	Calculated according to the test results	According to the test results of the samples, it was calculated by the method in attached Table A1.
Standard rate of centralized drinking water quality	Local water resources bulletin of study area 2015	Data available from government departments.
Forest and grass coverage	Interpretation of satellite remote sensing images	Purchased satellite images from the satellite remote sensing image Department and used Arc GIS 10.3 for remote sensing interpretation.
Natural shoreline rate of River (or reservoir)	Same as above	Same as above.
Habitat representation of rare species	Research data of the Chinese Academy of Sciences	Data from the Chinese Academy of Sciences.
Ecological protection investment index	Compilation of performance evaluation data of study area eco-environmental protection project in 2015–2016	Data from local environmental protection department and financial department.
Standard rate of industrial wastewater discharge	Calculated according to the environmental system data of study area	Data from local environmental protection department.
Centralized treatment rate of urban domestic sewage	Same as above	Same as above.
Rural domestic sewage treatment rate	Same as above	Same as above.
Water and soil erosion control rate	Local water and soil conservation Bulletin	Data available from government departments.
Regulatory capacity index	Compilation of performance evaluation data of study area eco-environmental protection project in 2015–2016	Data from local environmental protection department.
Construction of long-term management mechanism	Same as above	Same as above.

Table A3. Weight of each factor and indicator.

Factors	Weight	Indicators	Weight
Socioeconomic impact	0.21	Population density	0.020
		Population growth rate	0.020
		Per capita GDP	0.020
		Human activity intensity index	0.027
		Area source COD load of per unit area	0.020
		Area source TN load of per unit area	0.020
		Area source TP load of per unit area	0.020
		Point source COD load of per unit area	0.020
		Point source TN load of per unit area	0.020
		Point source TP load of per unit area	0.020
Water ecological health	0.36	Dissolved oxygen (water)	0.001
		Transparency (water)	0.022
		Ammonia nitrogen (water)	0.026
		Total phosphorus (water)	0.046
		Total nitrogen (water)	0.009
		Permanganate index (water)	0.009

Factors	Weight	Indicators	Weight
		Mineralization (water)	0.025
		Chlorophyll a (water)	0.042
		Comprehensive nutritional index (water)	0.001
		Total nitrogen (sediment)	0.025
		Total phosphorus (sediment)	0.114
		Organic matter (sediment)	0.014
		Heavy metal risk index (sediment)	0.027
		Standard rate of centralized drinking water quality	0.058
Ecological service function	0.23	Forest and grass coverage	0.058
		Natural shoreline rate of River (or reservoir)	0.058
		Habitat representation of rare species	0.058
		Ecological protection investment index	0.029
Regulation and management	0.2	Standard rate of industrial wastewater discharge	0.029
		Centralized treatment rate of urban domestic sewage	0.029
		Rural domestic sewage treatment rate	0.029

Table A4. Reference standard and basis for determination of each indicator.

Indicators	Reference Value	Unit	Determination Basis
Population density	193.5	person/km^2	Statistical bulletin of local national economic and social development in 2016, regional level
Population growth rate	6.08	‰	Same as above
Per capita GDP	69565	￥	Same as above
Human activity intensity index	0.2	Dimensionless	Consulting experts, regional level
Area source COD load of per unit area	20	kg/(hm^2·a)	Lake ecological security strategy
Area source TN load of per unit area	5	kg/(hm^2·a)	Same as above
Area source TP load of per unit area	0.5	kg/(hm^2·a)	Same as above
Point source COD load of per unit area	40	kg/(hm^2·a)	Same as above
Point source TN load of per unit area	1.5	kg/(hm^2·a)	Same as above
Point source TP load of per unit area	0.1	kg/(hm^2·a)	Same as above
Dissolved oxygen (water)	7.5	mg/L	Environmental quality standard for surface water, Class I
Transparency (water)	1	m	Same as above
Ammonia nitrogen (water)	0.15	mg/L	Same as above
Total phosphorus (water)	0.02	mg/L	Same as above
Total nitrogen (water)	0.2	mg/L	Same as above
Permanganate index (water)	2	mg/L	Same as above
Mineralization (water)	1	μg/L	Lake ecological security strategy
Chlorophyll a (water)	300	mg/L	Comprehensive background value, groundwater standards, and drinking water standards
Comprehensive nutritional index (water)	30	Dimensionless	Comprehensive nutritional index classification, take the poor nutrition level
Total nitrogen (sediment)	700	mg/kg	Consulting experts, take a very safe level
Total phosphorus (sediment)	500	mg/kg	Same as above
Organic matter (sediment)	1.69	%	Same as above

Indicators	Reference Value	Unit	Determination Basis
Heavy metal risk index (sediment)	150	Dimensionless	Classification of heavy metal ecological risk index, take the level of slight ecological hazard
Standard rate of centralized drinking water quality	100	%	Consulting experts, take a very safe level
Forest and grass coverage	75	%	Same as above
Natural shoreline rate of River (or reservoir)	100	%	Same as above
Habitat representation of rare species	0.7	Dimensionless	Same as above
Ecological protection investment index	3	%	Environmental and economic benefit analysis data
Standard rate of industrial wastewater discharge	100	%	Consulting experts, take a very safe level
Centralized treatment rate of urban domestic sewage	90	%	The 13th five-year plan for environmental protection
Rural domestic sewage treatment rate	80	%	Same as above
Water and soil erosion control rate	2.45	%	2014 water and soil conservation Bulletin
Regulatory capacity index	5	Dimensionless	Consulting experts, regional level
Construction of long-term management mechanism	5	Dimensionless	Same as above

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