Retraction

Retracted: Analysis and Evaluation of Ecological Environment Monitoring Based on PIE Remote Sensing Image Processing Software

Journal of Robotics

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] X. Wang and Z. Wang, "Analysis and Evaluation of Ecological Environment Monitoring Based on PIE Remote Sensing Image Processing Software," *Journal of Robotics*, vol. 2022, Article ID 1716756, 12 pages, 2022.

Hindawi

Research Article

Analysis and Evaluation of Ecological Environment Monitoring Based on PIE Remote Sensing Image Processing Software

Xiaofeng Wang ⬤ **and Zhengran Wang**

School of Water Conservancy and Electric Power of Heilongjiang University, Harbin, Heilongjiang 150080, China

Correspondence should be addressed to Xiaofeng Wang; 1990033@hlju.edu.cn

With the continuous improvement of people's demand for ecological environment quality, the research on ecological environment monitoring, analysis and evaluation had been paid more and more attention by relevant departments and personnel. Because the images collected by remote sensing technology were many and multi-source, the features extracted from remote sensing images using traditional methods had been difficult to meet the needs of related industry applications. Therefore, this paper made use of the advantages of PIE remote sensing image processing software in data analysis and processing, and put forward the research on ecological environment monitoring, analysis and evaluation methods. Firstly, on the basis of summarizing the concepts and related problems of ecological environment, this paper analyzed the processing methods of remote sensing data sources of ecological environment, and explained the evaluation standards and common methods of ecological environment. Secondly, the composition of PIE remote sensing image processing technology system and its application advantages were described, the common indicators and analysis methods of ecological environment monitoring were given, and the index system and model of ecological environment comprehensive evaluation were established. Finally, through the analysis of experimental cases, the results showed that the ecological environment monitoring analysis and evaluation method proposed in this paper was feasible. Compared with the traditional methods, the method proposed in this paper could objectively evaluate the ecological environment. This paper can not only provide support for the analysis and processing of remote sensing image data, but also provide an important reference for the application of remote sensing technology in the field of ecological environment.

1. Introduction

With the continuous development of economy and society, the quality of ecological environment has been widely concerned by people and all sectors of society. The advantages and disadvantages of ecological environment refer to the environmental suitability that affects the sustainable development of human and society from the perspective of ecosystem within a certain time and space [1]. The quality of ecological environment is mainly based on the monitoring results of ecological environment to evaluate the ecological attributes and their changes. The monitoring of the ecological environment is generally to collect the ecological environment parameters in a certain area in real time through relevant equipment. In order to truly reflect the

change law of the ecological environment, the data collection process is not only real-time, but also requires long-term and periodic, and the accuracy of the data needs to meet certain requirements.

In terms of ecological environment monitoring, people often integrate remote sensing technology (RS), global position system (GPS) and geographic information system (GIS) and apply them to the collection and processing of ecological environment parameters [2, 3]. Among them, RS technology can observe real-time data in a wide range of areas all day, and the data acquisition accuracy is high. In recent years, the resolution of remote sensing images obtained by RS in space, time and spectrum has been greatly improved, which makes it widely used in the monitoring of ecological environment. The system integrating spatial

positioning, remote sensing and geographic information technology can collect, analyze and process the target data in real time. Through the intelligent analysis and processing of data, it can provide some support for the application fields of resources, environment and management [4]. With the rapid development of electronic communication, Internet of things, big data and space technology, 3S technology is more and more widely used in ecological environment monitoring, resource exploration and development and natural disaster prevention and control.

There are many ground data sources and a large amount of data collected by remote sensing technology. For example, the sensors of different monitoring equipment may obtain data with different resolutions in the same area, and the same equipment may also obtain data with different spatial and spectral resolutions in the same area [5]. It is known from the existing research that using the data collected by different devices and sensors to study the changes of the ecological environment is no longer a static mode, but a dynamic real-time monitoring mode, which will lead to the existing system unable to meet the effective integration of multi-source data. Therefore, this paper proposes to use PIE remote sensing image processing software to monitor and evaluate the ecological environment, so as to provide technical support for remote sensing technology and its application in the field of ecological environment monitoring.

2. Related Works

According to the existing research, due to different perspectives, the understanding of the ecological environment is not consistent. Early people believed that the ecological environment refers to the life system composed of different types of organisms except human beings. This view focuses on the perspective of ecosystem. Later, some people believed that ecological environment refers to a natural system composed of relevant natural elements, which has certain environmental and resource characteristics [6, 7]. From a narrow environmental perspective, some people believe that ecological environment refers to habitat, that is, the external environmental conditions related to organisms, such as geographical location, terrain, landform, temperature and so on. In a broad sense, people believe that ecological environment refers to the nature related to human production and life. Research shows that, as a necessary external condition for human survival and development, the ecological environment is an organic whole composed of life and environment. Among them, the environmental system includes natural factors related to organisms such as geology, soil, hydrology, climate, etc., and life includes not only human beings, but also all biological worlds [8]. The main research objects of ecological environment include biodiversity, the relationship between biology and environment, etc. With the progress of society and human civilization, the ecological environment has gradually turned into the ecosystem research with human as the main body. Therefore, the research on the ecological environment has important historical and practical significance in the long run.

Ecological environment monitoring mainly uses various equipment to obtain data information such as ground ecological attributes and environmental characteristics. With the rapid development of remote sensing technology, the use of satellites can achieve three-dimensional, multi angle, all-round and all-weather monitoring of ground targets. Because the satellite remote sensing monitoring target has certain advantages such as high spatial resolution, high spectral resolution, high temporal resolution and high radiation resolution, the satellite remote sensing technology can provide rich data sources for ecological environment monitoring. At present, in the aspect of ecological environment monitoring, people mainly use the method of human-computer interactive interpretation and classification to extract various monitoring data on the basis of processing the obtained remote sensing images. In recent years, some scholars have made more research achievements in the automatic extraction of remote sensing image data, and have made great progress in data extraction methods and accuracy [9, 10]. However, most of these methods are limited to the data extraction of small areas and specific areas, which are not suitable for the ecological environment monitoring of large coverage areas, and the effect of data extraction for complex ground objects is not ideal.

The quality of ecological environment mainly reflects the attributes of ecological environment and its changing state. Qualitative or quantitative methods can be used to describe the environmental attributes and their changing process. In order to evaluate the quality of ecological environment, we need to use the obtained ecological environment monitoring data to extract the characteristics that can reflect the attributes of ecosystem and the changes of ecological environment [11]. In the comprehensive evaluation of the ecological environment, we need to use the obtained ecological environment monitoring information, select relevant evaluation indicators and formulate the ecological environment evaluation system, and then use certain evaluation methods and models to evaluate the ecological attributes and environmental characteristics of a region. Using the comprehensive evaluation results of the ecological environment, we can analyze the spatio-temporal changes of the ecological environment in the region, and explore various factors that cause the changes of the ecological environment, so as to provide decision-making basis for scientifically improving the regional ecological environment and formulating environmental protection plans.

3. Theory and Method of Ecological Environment Research

3.1. Overview of Ecological Environment and Its Problems. Since the 1980s, with the continuous development of economy and society and the increase of population, the global climate has been continuously warming and the trend of drought has been expanding, resulting in the shortage of water resources, the changes of river systems, the increase of land desertification area, serious vegetation degradation and other problems affecting the ecological balance [12]. For example, due to the reduction of vegetation coverage, the

change of rivers and the contraction of wetland area, the water conservation capacity is weakened, the ecological environment is seriously damaged, and the regulation and restoration functions of the ecosystem are degraded. Regional ecological environment and ecological security issues have been highly valued by relevant government departments.

From the perspective of water resources and water system changes, due to climate warming, glaciers and frozen soils deposited for many years in some areas continue to melt and shrink, seasonal climate disorders, and snow reduction. The depletion of water resources in some regions has affected the surrounding ecological environment, making ecological functions continue to deteriorate, and may lead to the consequences of ecological imbalance [13]. Due to serious water and soil loss, the area of land desertification in some regions is expanding, and soil wind erosion leads to the destruction of vegetation. In addition, due to the large fluctuation of climatic conditions, the restoration ability of vegetation and soil has been seriously reduced, coupled with man-made damage to the natural environment, such as overgrazing or unreasonable reclamation of land resources, the problem of desertification has become increasingly prominent.

From the perspective of wetland change and geological movement, due to the continuous reduction of wetland area, the water supply of some rivers has decreased, resulting in climate changes in some regions. In terms of wetland distribution, wetlands account for a large proportion in some inland areas, and are mainly distributed in some ecologically sensitive areas such as rivers or oases. Affected by global climate and human behavior factors, the overall area of wetlands has shrunk, resulting in the imbalance of river water levels and serious grassland degradation. In addition, some areas are greatly affected by terrain and slope, and geological disasters such as debris flow, landslide and water and soil loss occur all year round, resulting in serious threats to the local and surrounding ecological environment and people's lives.

From the perspective of the impact of population and economic development on the ecological environment, the rapid and uneven growth of population size and economic development has led to the decline of the carrying capacity of natural resources and ecological environment in some regions, resulting in great changes in the attributes of the ecological environment. Affected by global economic development and climate change, human production and life are increasingly interfering with the ecological environment, coupled with the sharp rise in the number of people, making it difficult for limited ecological resources to meet the needs of economic and social development and human production and life [14]. Therefore, in view of the problems existing in the process of ecological environment change, remote sensing technology and geographic information methods can be used to monitor and analyze various factors affecting the ecological environment, and effectively evaluate the changes of ecological factors, so as to provide support for the rational development, protection and utilization of various natural ecological resources.

3.2. Remote Sensing Data Source of Ecological Environment and Its Processing Method.

Remote sensing (RS) technology mainly refers to the method of using remote sensing devices to detect the information of ground objects in the air. It generally uses remote sensing devices on spacecraft, satellites and other equipment to collect data information of ground objects, detect object attribute information by monitoring the mechanism of the response of the target to the spectrum, and identify the target object by analyzing and processing the obtained data. After decades of development, remote sensing technology has been widely used in agriculture, forestry, geology, environmental protection and other fields [15]. With the rapid development of space technology, geographic information system and global positioning technology, the monitoring effect and quality of remote sensing images in spatial resolution, spectral resolution and temporal resolution have been greatly improved. Compared with other monitoring methods, remote sensing technology can effectively provide a large number of real-time collected data for ecological environment monitoring, and can track and monitor the dynamic targets in a large area. Therefore, remote sensing technology provides a certain guarantee for ecological environment monitoring and data collection. As shown in Figure 1, it is a schematic diagram of the acquisition and processing of remote sensing image information.

In order to extract effective information from remote sensing image data, when processing multi-spectral image data, it is necessary to extract image information by calculating the standard deviation and mean vector of image data. Generally, the standard deviation of image data can directly reflect the amount of information of the image, while the brightness difference can reflect the contrast of the image.

If the image is represented by $p_{ij} (i = 1, 2, \ldots, M; j = 1, 2, \ldots, N)$, its matrix size is $H * L$, and the average gray value of the image is represented by p_0, the standard deviation of the image can be expressed as follows [16]:

$$d_S = \frac{\sqrt{\sum_{i=1}^{M} \sum_{j=1}^{N} \left(p_{ij} - p_0 \right)^2}}{H \cdot L}. \tag{1}$$

Since the gray value of the image can be reflected by the brightness difference, the gray value of the image can be expressed by subtracting the minimum brightness value from the maximum brightness value of the image, as shown below:

$$G_r(i, j) = G_{\text{MAX}}(i, j) - G_{\text{MIN}}(i, j). \tag{2}$$

The mean vector of the image mainly describes the average reflection intensity of the target in the image, which can be expressed as follows:

$$G = \frac{\sum_{i=1}^{M-1} \sum_{j=1}^{N-1} G(i, j)}{H \cdot L}. \tag{3}$$

According to the above method, the correlation values of all bands on the remote sensing image are calculated, and then the band with the largest amount of information is extracted by comparison.
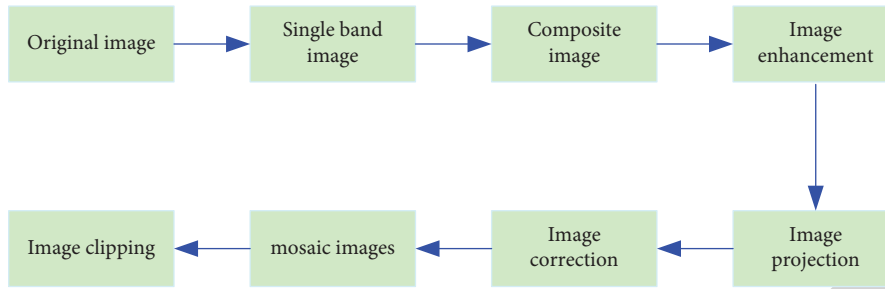
Figure 1: Schematic diagram of remote sensing image processing process.

There are many redundant observation information in the multi-spectral images collected by remote sensing technology. In order to avoid the information interference between different bands in the image, the quality of image synthesis can be improved by reducing data redundancy. The standard deviation of image data is directly proportional to its amount of information, while the correlation between image bands is inversely proportional to its independence, that is, the smaller the correlation, the more obvious the independence of different bands, and the less redundant information. The correlation between bands can be expressed by correlation coefficient, that is, the greater the correlation coefficient, the greater the correlation between different bands.

It may be assumed that p_{ij} and q_{ij} represent two remote sensing images with the size of $H * L$, and p_0 and q_0 denote the gray mean value of these two images respectively, so the correlation coefficient between different bands on the remote sensing image can be expressed as [17]:

$$r = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} (p_{ij} - p_0)(q_{ij} - q_0)}{\sqrt{\sum_{i=1}^{M} \sum_{j=1}^{N} (p_{ij} - p_0)^2 (q_{ij} - q_0)^2}}. \tag{4}$$

In order to comprehensively monitor the ecological environment, it is usually necessary to obtain more information of ground targets with the help of geographic information system (GIS) and global positioning system (GPS). Through the integration of RS, GIS and GPS technology, we can accurately obtain the target attribute information and location information of the ground ecological area, and establish a spatial information database based on the superposition processing and statistical analysis of the spatial data, so as to effectively manage and query the spatial data [18].

Due to the multi-source nature of the collected data, not only there are many kinds of data, but also the data has its own characteristics in format, space-time scale and so on. Therefore, it is necessary to effectively integrate and fuse all kinds of data when processing data. As shown in Figure 2, the process of organic fusion of the collected remote sensing data is described.

3.3. Ecological Environment Assessment Standards and Common Methods

3.3.1. Selection of Evaluation Criteria. Remote sensing images not only provide data basis for the analysis of

ecological environment changes and their influencing factors, but also provide basis for the evaluation of ecological environment quality. In order to objectively evaluate the obtained ecological environment monitoring results, it is necessary to refer to certain industry standards. The selection of ecological environment quality evaluation standards should not only fully reflect the changes of ecological environment attributes and their advantages and disadvantages, but also reflect the areas and conditions of ecological environment changes. Since most of the ecological environment evaluation indicators are obtained through remote sensing and other technologies, their evaluation standards need to be determined according to the specific actual situation.

At present, the standards adopted generally come from some standards issued by the state, industry and local governments for ecological environment protection and quality requirements. For example, the protection requirements of important ecological function areas, water and soil conservation requirements, river system protection requirements, etc. In addition, the original ecosystem can also be used as the standard, such as the standard requirements for soil biochemistry, the standard requirements for vegetation coverage and biodiversity, and the standard requirements for water and soil holding capacity. As the existing evaluation standards may change with natural conditions and policies, these standards can still be used as a basis to measure the quality of the ecological environment for the ecological environment monitoring data at a certain stage.

3.3.2. Standardization of Evaluation Indicators. Considering the multi-source nature of remote sensing image information, in order to avoid the differences between the original index parameters, the data must be standardized to achieve the standardization of indicators and make different index parameters comparable. When evaluating the ecological environment, if the larger the index parameter value is, the better the evaluation result is, it is called a positive index; if the smaller the index value is, the better the evaluation result is, it is called a negative index; if the index value is closer to a certain value, the better the evaluation result is, it is called a medium index. In order to facilitate the comprehensive evaluation of the ecological environment, different types of indicators need to be treated with the same trend. Therefore, the positive method of indicators can be
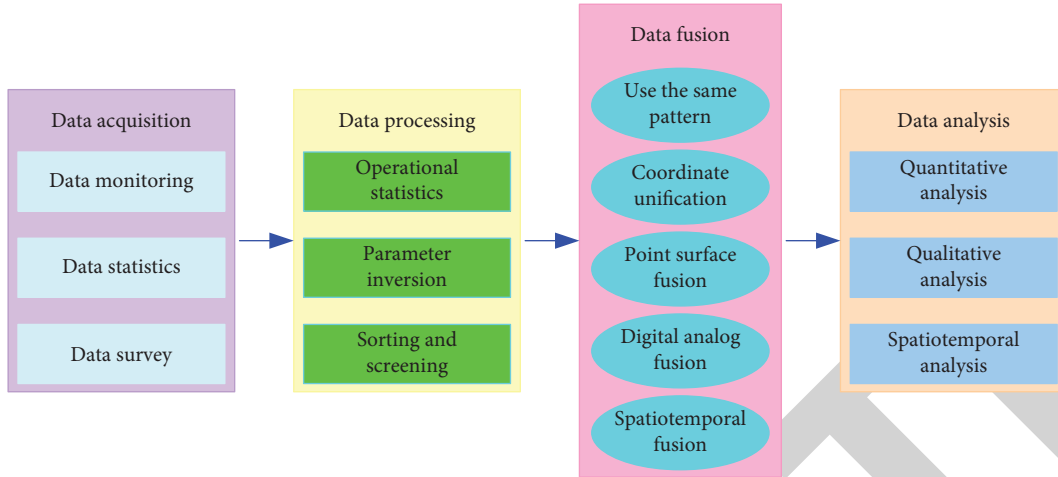
Figure 2: Schematic diagram of multi-source data fusion technology architecture.

adopted to convert negative indicators and neutral indicators into positive indicators.

If D_1 is a positive indicator and D_2 is a negative indicator, they can be expressed as follows in turn:

$$D_1 = \frac{D - D_{\text{MIN}}}{D_{\text{MAX}} - D_{\text{MIN}}} \times 100,$$

$$D_2 = \frac{D_{\text{MAX}} - D}{D_{\text{MAX}} - D_{\text{MIN}}} \times 100, \tag{5}$$

where D_{MIN} represents the minimum value of the index parameter and D_{MAX} indicates the maximum value of the index parameter. The range of index parameter values after standardization is between 0 and 100, and the distribution of index parameter values after standardization is the same as the original index values.

As shown in Figure 3, the geometric method is used to represent the process of index normalization.

Considering the dimensions and unit differences of different evaluation indicators, in order to make the evaluation indicators not affected by this, it is necessary to standardize the relevant evaluation indicators. Common data standardization processing methods are as follows:

$$S_{ij} = \frac{\text{obs}_{ij} - \overline{\text{obs}_i}}{ds_i}, \quad j = 1, 2, \ldots, n, \tag{6}$$

where obs_{ij} shows the observed value, $\overline{\text{obs}_i}$ represents the average value, and ds_i indicates the standard deviation. S_{ij} refers to the evaluation index after standardization. The mean value of all n individuals is 0 and the variance is 1.

As shown in Figure 4, the data standardization process represented by geometric method is described.

3.3.3. Commonly Used Comprehensive Evaluation Methods of Ecological Environment.
With the rapid development of economy and society, the monitoring and quality evaluation of ecological environment has attracted extensive attention of governments and relevant personnel. In the process of monitoring, analyzing and evaluating the ecological environment, the evaluation standard and evaluation model are
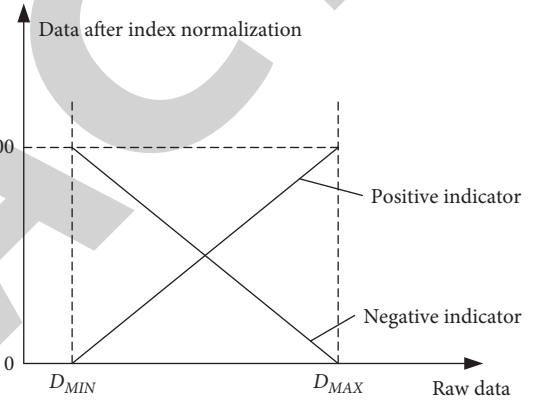

Figure 3: Schematic diagram of geometric representation results of index normalization.
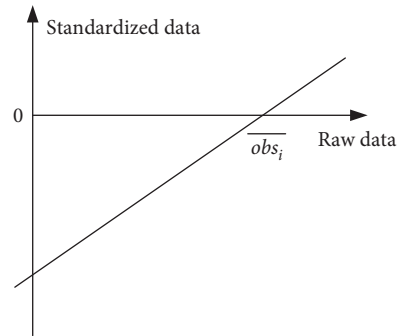

Figure 4: Schematic diagram of geometric representation results of index standardization.

the key to the comprehensive evaluation results. The traditional evaluation method generally takes single factor or natural environment system as the standard, and uses the static method to evaluate. This method is simple, but the evaluation result is quite different from the actual situation. In order to accurately reflect the development of the ecological environment, the current evaluation methods are mainly based on multi factor indicators, and use a dynamic way to evaluate. Common comprehensive evaluation methods include comprehensive index method, fuzzy

evaluation method, artificial neural network analysis method, gray correlation analysis method and principal component analysis method [19].

The index evaluation method is mainly used to compare the original data obtained from environmental monitoring with the evaluation standards. This method is suitable for the index evaluation of single factor environmental impact, but it can not be applied to the synergy evaluation of multiple impact factors. Fuzzy evaluation method mainly uses fuzzy mathematics to quantify some factors that are not easy to define, and applies them to comprehensive evaluation. This method adopts fuzzy evaluation matrix to determine some uncertain factors that need to be considered in ecological environment assessment. Because this method needs to use membership degree to describe the quality of ecological environment, the determination of index weight and membership function is the key of this method. It is known from the existing research that the artificial neural network analysis method can train the environmental monitoring samples through the neural network model, and obtain certain knowledge rules from the training results. Then, the network model can be used to accurately identify and evaluate the monitoring information. For example, when using B-P neural network model to comprehensively evaluate the quality of ecological environment, it is not necessary to deal with the evaluation indicators, and the evaluation results obtained by using this model are relatively objective. In addition, using B-P neural network model, multiple evaluation indexes can be selected to establish a comprehensive evaluation system of ecological environment quality, but there are problems such as parameter convergence and optimization in the application of B-P neural network algorithm [20].

4. Analysis and Evaluation of Ecological Environment Monitoring Based on PIE Remote Sensing Image Processing Technology

4.1. Overview of PIE Remote Sensing Image Processing Technology. Remote sensing image processing software is mainly a tool software that provides technical support for the application of remote sensing monitoring data to different industries. Since 2008, China has developed the first generation of remote sensing image processing software, namely pixel information expert (PIE) [21, 22]. PIE is mainly used to analyze and process remote sensing monitoring data and apply it to different industries to provide technical support. The software can effectively analyze the monitoring information from land, meteorology, ocean and other fields, and provide accurate and efficient processing results according to the characteristics of various parameters collected by domestic satellites. The software can support local coordinate system, has friendly user interface and interaction mode, can support the secondary development of different languages, and can provide solutions for applications in different industries. Through nearly a decade of application, the development progress of PIE has been improved from version 1.0 to version 6.0, as shown in Figure 5.
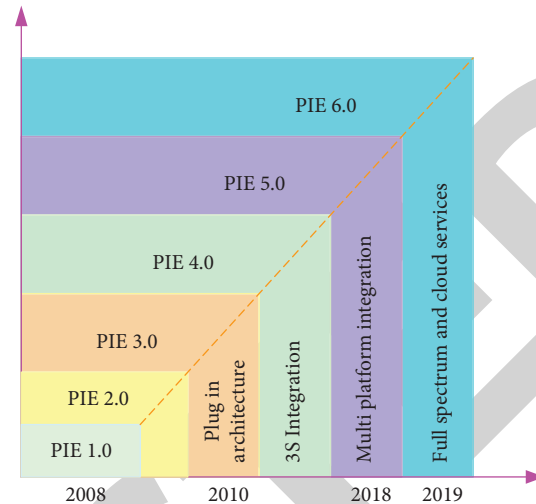

Figure 5: Schematic diagram of PIE development process.

The latest generation of remote sensing image processing software PIE 6.0 integrates cloud computing and terminal technology, adopts a multi-layer structure design method, and provides secondary development interfaces and a series of toolkits. The professional toolkit provided by the software not only involves PIE-Basic remote sensing image basic function, PIE-Ortho satellite image mapping function, PIE-SAR radar image processing function, PIE-Hyp hyperspectral image processing function, PIE-UAV image processing function, but also includes PIE-SIAS image analysis software, PIE-AI image intelligent processing software and PIE-Map geographic information system software. In addition, the software can integrate standardized data in relevant service fields through PIE-Cloud platform, so as to establish a remote sensing technology support system integrating cloud and terminal [23]. As shown in Figure 6, the functional composition of PIE 6.0 remote sensing technology support system is described.

According to the needs of different industries, PIE-Cloud platform adopts key technologies such as spatiotemporal big data analysis and storage, intelligent data analysis and mining, cloud computing, etc. to solve the problems of remote sensing image data analysis and processing, data mining and decision-making. The system can integrate the processing, detection, feature extraction and application of multi-source remote sensing data according to the various needs of users, so as to effectively complete the monitoring and evaluation function of remote sensing data.

4.2. Ecological Environment Monitoring and Analysis. In ecological environment monitoring, vegetation index is often used for qualitative and quantitative analysis and evaluation of vegetation coverage. In the remote sensing image, the relevant vegetation index can be calculated by combining the visible band and the near-infrared band. In order to facilitate data analysis and evaluation, normalized difference vegetation index can be used to describe vegetation coverage.
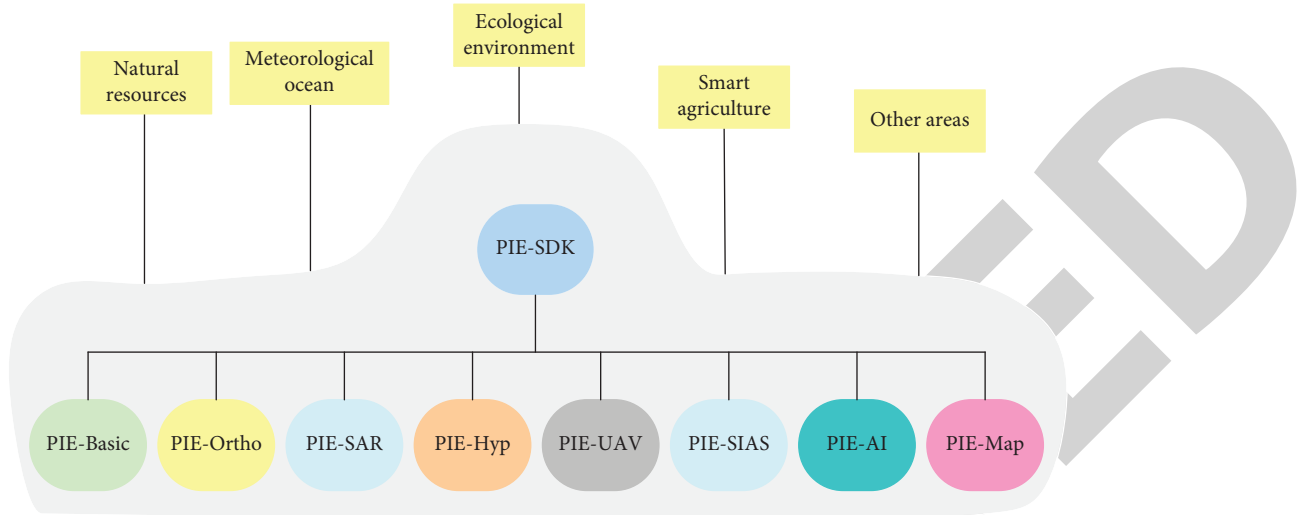
FIGURE 6: PIE 6.0 remote sensing technology and its application system diagram.

The calculation method of vegetation index ND is as follows:

$$ND = \frac{NR - RV}{NR + RV},\qquad(7)$$

where RV refers to the reflectance of visible band, NR indicates the reflectance of near-infrared band, and the value range of vegetation index is (−1, 1).

Fractional vegetation coverage mainly describes the proportion of the vertical projection area of vegetation in the total area of remote sensing area, which is usually used to evaluate plant coverage. Vegetation coverage can be estimated using vegetation index values, as follows:

$$FC = \frac{NR - NR_{MIN}}{NR_{MAX} - NR_{MIN}},\qquad(8)$$

where NR_{MIN} and NR_{MAX} respectively represent the minimum and maximum values of NR within a certain confidence interval, and the value range of FC is (0, 1).

As the ecological environment monitoring indicators contain multiple ecological factors, these ecological factors have a mutually restrictive relationship, and any factor may affect the whole ecological environment. In order to facilitate the analysis of the relationship between ecological environment factors, we can explore the factors that play a leading role in the ecological environment, so as to take corresponding measures to avoid the impact of these factors on the ecological environment. For example, climate change factors can not only affect the regional ecological environment, but also be affected by local climate due to ecological environment changes. The change of ecological environment cannot be separated from the interaction of many factors. Among these factors, climate change and human behavior are the two main factors affecting environmental change. Although climatic factors are the main factors that affect the changes of ecological environment, human behavior factors can further affect the changes of ecological environment caused by climatic factors. Because human behavior is not subject to certain constraints and the excessive exploitation of resources and energy, human behavior factors often become the leading factors affecting local regional ecological environment changes. As shown in Figure 7, the changing relationship between different factors and their impact on the ecological environment is described.

From a large number of studies on the influencing factors of the ecological environment, it is known that the main factors driving the change of the ecological environment are usually natural factors, human behavior and the basis of the ecological environment itself. Considering the regional differences and the different factors that cause the changes of the ecological environment in different regions, the changes of the ecological environment can usually be divided into three categories. The first category is the changes of the ecological environment dominated by natural factors, the second category is the changes of the ecological environment jointly affected by natural factors and human behavior, and the third category is the changes of the ecological environment dominated by human behavior. As shown in Figure 8, it reflects the types of ecological environment changes under the influence of different factors.

4.3. Ecological Environment Quality Evaluation Model. In order to grasp the changes of local ecological environment and comprehensively evaluate the quality of ecological environment in this area, the selection of evaluation indicators is very important. In the existing ecological environment evaluation methods, analytic hierarchy process is often used. This method mainly adopts qualitative and quantitative indicators to divide various factors in the system, and determines the corresponding weight according to the impact of each factor on the evaluation system. Among the various factors that affect the change of ecological environment, natural factors mainly include temperature, biodiversity, soil humidity, precipitation and vegetation coverage, while human behavior mainly includes land use, cultivated land water use, population density and resource exploitation. According
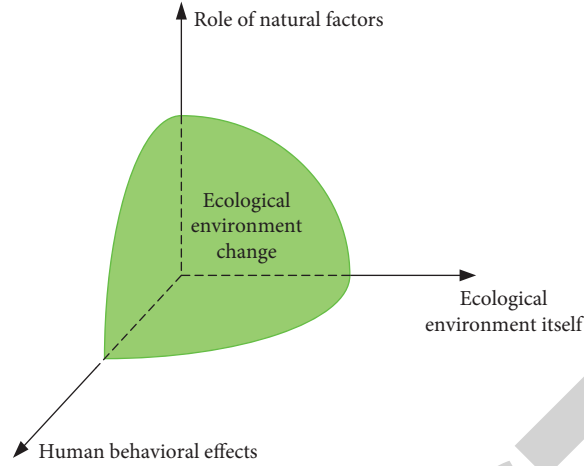
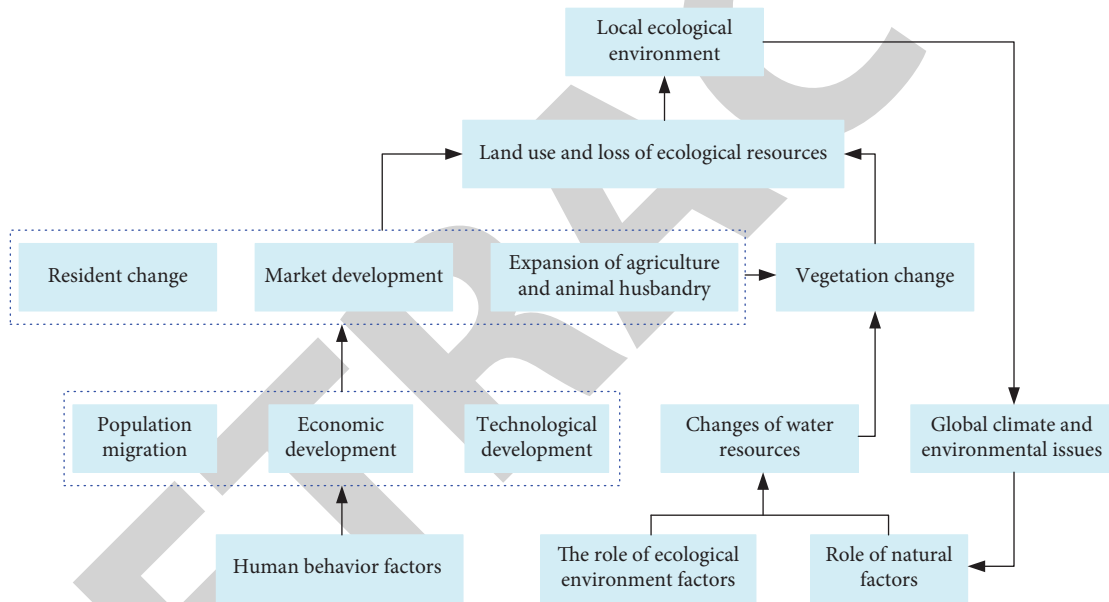FIGURE 7: Structural diagram of ecological environment factors.

FIGURE 8: Ecological environment change and its influencing factors.

to different index relations, the comprehensive evaluation index system can be divided into three layers, namely, the comprehensive evaluation target layer, the influencing factor layer and the specific observation layer. The comprehensive evaluation target layer includes natural factors and human behavior factors, and the influencing factor layer can be divided into ecological response, ecological vitality and ecological components, which restrict each other.

As shown in Figure 9, the hierarchical relationship between different evaluation indicators in the comprehensive evaluation index system of ecological environment quality is described.

Because each evaluation index has different influence on the quality of ecological environment, the weight value can be used to reflect the importance of the evaluation index in the comprehensive evaluation index system. Therefore, the subjective evaluation method can be used to determine the weight according to the effect of the evaluation index on the

process of ecological environment change. If ω_{jk} represents the weight value of the j-th evaluation index parameter given by the k-th expert, and $\sum_{j=1}^{N} \omega_{jk} = 1$, the weight value of the j-th evaluation index parameter is calculated as follows:

$$
\begin{aligned}
\overline{\omega_j} &= \frac{\sum_{k=1}^{M} \omega_{jk}}{M}, \\
w_j &= \frac{\overline{\omega_j}}{\sum_{j=1}^{N} \overline{\omega_j}}.
\end{aligned}
\tag{9}
$$

In the comprehensive evaluation index system of ecological environment, the indexes at different levels are compared with each other, and the relative importance of each evaluation index is determined. Then, the judgment matrix of each evaluation index is established. After calculating the relative weight values of all evaluation indicators, the weight factor judgment table can be obtained, as shown in Table 1.
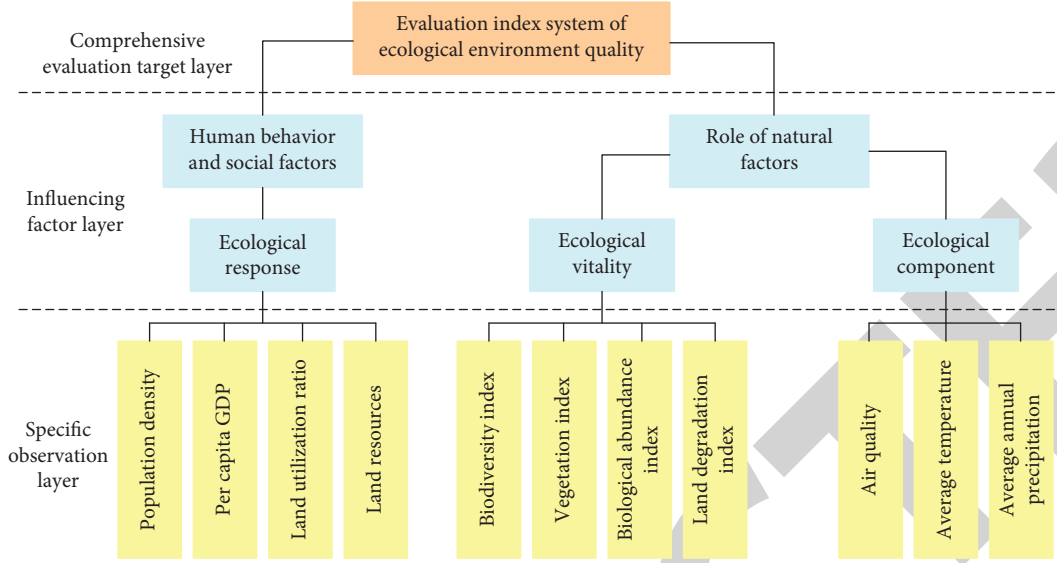
FIGURE 9: Hierarchical structure diagram of comprehensive average index system of ecological environment quality.

TABLE 1: Evaluation index weight factor judgment table.

| Evaluation index | Evaluation index | | | | | |
	1	2	—	k	—	M
1	1	b_{12}	—	b_{1K}	—	b_{1M}
2	b_{21}	1	—	b_{2K}	—	b_{2M}
—	—	—	—	—	—	—
j	b_{j1}	b_{j2}	···	b_{jk}	—	b_{jM}
—	—	—	—	—	—	—
N	b_{N1}	b_{N2}	—	b_{Nk}	—	1

According to Table 1, the judgment matrix of evaluation indicators can be obtained, as shown below:

$$B = \begin{pmatrix} 1 & b_{12} & b_{13} & \cdots & b_{1k} & \cdots & b_{1M} \\ b_{21} & 1 & b_{23} & \cdots & b_{2k} & \cdots & b_{2M} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ b_{j1} & b_{j2} & b_{j3} & \cdots & b_{jk} & \cdots & b_{jM} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ b_{N1} & b_{N2} & b_{N3} & \cdots & b_{Nk} & \cdots & 1 \end{pmatrix}. \quad (10)$$

The judgment matrix can be obtained from the weights given by different experts, and then the average weight can be calculated by hierarchical sorting and consistency testing methods. The weight value of the evaluation index can be obtained after normalization.

In order to obtain the comprehensive evaluation results of ecological environment quality, it is necessary to conduct comprehensive treatment according to the monitoring value and weight value of different evaluation indicators. The specific calculation method is as follows:

$$Eq = \sum_{j=1}^{N} v_j w_j, \quad (11)$$

where, v_j represents the value of the j-th evaluation index monitoring data after standardized processing, w_j shows the weight value of the j-th evaluation index, and N is the number of all evaluation indexes.

5. Experiment and Analysis

In order to test the effectiveness of the ecological environment monitoring analysis and evaluation model proposed in this paper, a wetland ecological experimental area in a province in southern China was selected as the object of the experiment. The study area has a typical warm temperate continental climate, hot in summer and cold in winter. The annual average temperature is 12.8°C, and the temperature difference between day and night is large. The highest temperature in the year is from July to August, which is higher than 38°C most of the time. The lowest temperature is in January, which is often lower than −5°C. Precipitation is mostly concentrated in May to July, with an average annual precipitation of 120 mm, and the number of rainfall days throughout the year generally does not exceed 55 days.

The data needed for the experiment comes from the images covered by remote sensing satellites in the wetland ecological experimental area. Due to the obvious spectral characteristics of wetland ecological elements in summer, the images collected by satellite sensors are clearly visible.

TABLE 2: Remote sensing image selection time period and data type.

Year	Image selection time		Remote sensing image data type
2010	July 15th	August 10th	TM
2013	July 20th	August 15th	TM
2015	July 23rd	August 20th	TM
2017	July 7th	August 5th	ETM+
2020	July 13th	August 8th	OLI

(a)   (b)   (c)
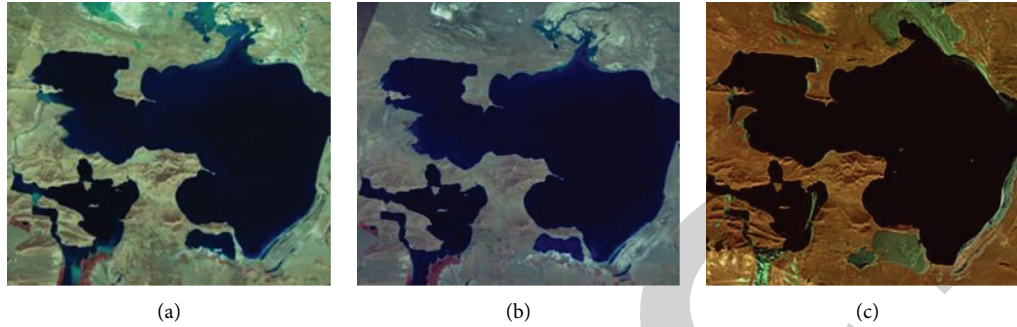
FIGURE 10: Remote sensing images of wetland ecological areas with different data types. (a) TM, (b) ETM + and (c) OLI.

TABLE 3: Evaluation indicators at all levels and their weight values.

Influencing factor index	Specific observation indicators	Weight value	Cumulative value
Role of natural factors	Ecological vitality	0.293	0.638
	Ecological component	0.345	
Human behavior and social factors	Ecological response	0.362	0.362
Cumulative value		1	1

The images of wetland temperature, vegetation coverage, soil humidity and other monitoring indicators are mainly from satellite remote sensing data when the cloud cover is thin from July to August every year. Considering the long experimental period, TM data was selected for the images from 2010 to 2015, ETM + data was selected in 2017, and OLI data was selected in 2020, as shown in Table 2.

In order to comprehensively monitor the ecological changes of wetlands, sampling points were arranged in the relevant experimental areas during the experiment to facilitate the collection of relevant data. The layout of sampling points should not only be as uniform as possible, but also consider the regionality and scope of sampling points. During the experiment, sampling points were arranged at intervals of 5 km along different directions of the wetland according to the concentric circle method, as shown in Figure 10.

The serial numbers of all sampling points, longitude and latitude coordinates, vegetation coverage, surface temperature, soil humidity, air quality and other information are recorded and statistically analyzed through PIE remote sensing image processing software. Then, according to the comprehensive evaluation index system of ecological environment quality proposed in this paper, the weight factors of relevant monitoring indicators are calculated, and finally the weight values of indicators at all levels are obtained, as shown in Table 3.
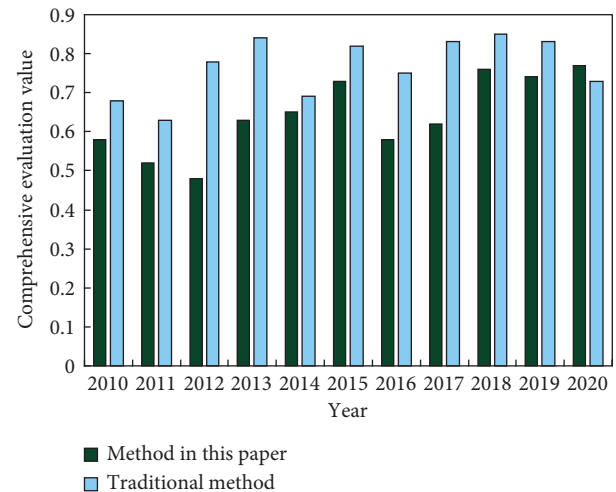

FIGURE 11: Comparison of the results of comprehensive evaluation of ecological environment quality by using this method and traditional method.

During the experiment, the ecological environment monitoring and evaluation method proposed in this paper is compared with the comprehensive evaluation value obtained by the traditional method, as shown in Figure 11.

According to the comprehensive evaluation results of ecological environment quality, the method proposed in this paper can objectively reflect the change law of the ecological

environment and its influencing factors in this area. The ecological environment quality of the wetland area has shown an overall growth trend in the past decade, indicating that the wetland ecological environment has been continuously improved in recent years. Due to the relatively high temperature in this area, the scarcity of biological resources and the less impact of human behavior, the ecological environment is easy to be improved. Although the precipitation factor in this area has a great impact on the ecological environment quality, even if the annual average temperature is high, the precipitation can improve the ecological environment quality of the wetland. In addition, because the surface coverage of this area is mainly the oasis ecotone, the wetland is more sensitive to the changes of the surrounding ecological environment. The evaluation results obtained by using traditional methods are quite different from the actual ecological environment changes, and the results of the evaluation of ecological environment changes by using this method basically conform to the change law of natural environmental conditions. Therefore, this method is more scientific in ecological environment monitoring, analysis and evaluation.

6. Conclusion

With the continuous development of remote sensing technology and the improvement of people's requirements for ecological environment quality, the research on ecological environment monitoring had been widely concerned. Due to the multi-source nature of ecological environment monitoring data, it was impossible to obtain the observation information required by relevant industry applications by traditional methods. Therefore, starting from the application advantages of PIE remote sensing image processing software, this paper put forward the research on ecological environment monitoring, analysis and evaluation methods. By summarizing the concept of ecological environment and related problems, this paper analyzed the processing methods of ecological environment monitoring data sources, and gave the standardized processing methods of ecological environment evaluation indicators. Based on the analysis of the composition of pie remote sensing image processing technology system and its application advantages, the design and analysis methods of ecological environment monitoring indicators were proposed, and the comprehensive evaluation index system and evaluation model of ecological environment quality were constructed. Through the test of experimental cases, the results showed that the ecological environment monitoring, analysis and evaluation method proposed in this paper not only had certain effectiveness, but also could evaluate the ecological environment more objectively than the traditional methods. This paper will provide some technical support for the analysis and processing of remote sensing image data and the application of remote sensing technology in related fields.

Data Availability

The labeled data set used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

Acknowledgments

References

[1] X. Li, Z. Y. He, L. L. Jiang, and Y. J. Ye, "Research on remote sensing dynamic monitoring of ecological resource environment based on GIS," *Wireless Personal Communications*, vol. 102, no. 4, pp. 2941–2953, 2018.

[2] R. Gibb, E. Browning, P. Glover-Kapfer, and K. E. Jones, "Emerging opportunities and challenges for passive acoustics in ecological assessment and monitoring," *Methods in Ecology and Evolution*, vol. 10, no. 2, pp. 169–185, 2019.

[3] Q. F. Shi, "Research on image detection of ecological environment monitoring based on multiple feature parameters," *Fresenius Environmental Bulletin*, vol. 30, no. 3, pp. 2831–2839, 2021.

[4] C. Chen, X. Y. He, Y. Lu, and Y. L. Chu, "Application of landsat time-series data in island ecological environment monitoring: a case study of zhoushan islands, China," *Journal of Coastal Research*, vol. 108, no. sp1, pp. 193–199, 2020.

[5] R. T. Pennington and T. R. Baker, "Plants, people and long-term ecological monitoring in the tropics," *Plants People Planet*, vol. 3, no. 3, pp. 222–228, 2021.

[6] D. Y. Zhu, T. Chen, N. Zhen, and R. Q. Niu, "Monitoring the effects of open-pit mining on the eco-environment using a moving window-based remote sensing ecological index," *Environmental Science and Pollution Research*, vol. 27, no. 13, pp. 15716–15728, 2020.

[7] H. Liu, Y. Jiang, R. Misa et al., "Ecological environment changes of mining areas around Nansi lake with remote sensing monitoring," *Environmental Science and Pollution Research*, vol. 28, no. 32, pp. 44152–44164, 2021.

[8] H. M. Zhai, W. Q. Xie, S. Q. Li, and Q. Zhang, "Evaluation of urban ecological environment based on remote sensing based ecological index model," *Fresenius Environmental Bulletin*, vol. 30, no. 3, pp. 2527–2535, 2021.

[9] J. Zhao, "Design and implementation of geo-spatial information technology in marine ecological environment monitoring," *Journal of Coastal Research*, vol. 83, no. sp1, pp. 50–56, 2019.

[10] V. S. Negi, R. Pathak, R. S. Rawal, I. D. Bhatt, and S. Sharma, "Long-term ecological monitoring on forest ecosystems in Indian Himalayan Region: criteria and indicator approach," *Ecological Indicators*, vol. 102, pp. 374–381, 2019.

[11] W. P. Lin, "Monitoring and protection of forest ecological tourism resources by dynamic monitoring system," *Ecological Chemistry and Engineering S*, vol. 26, no. 1, pp. 189–197, 2019.

[12] L. Liu and Y. Zou, "Monitoring of marine ecological environmental data security and management system based on internet of things," *Environmental Engineering And Management Journal*, vol. 21, no. 2, pp. 225–236, 2022.

[13] H. Mollenhauer, M. Kasner, P. Haase et al., "Long-term environmental monitoring infrastructures in Europe: observations, measurements, scales, and socio-ecological

representativeness," *Science of the Total Environment*, vol. 624, pp. 968–978, 2018.

[14] S. F. Wei, Y. L. Mo, and P. Wen, "Dynamic monitoring of ecological environment quality of land consolidation based on multi-source remote sensing data and rsei model," *Fresenius Environmental Bulletin*, vol. 30, no. 1, pp. 317–329, 2021.

[15] Y. X. Liu and Y. Wang, "Real-time monitoring system for pollution intensity of carbon emission in ecological environment," *Ekoloji*, vol. 28, no. 107, pp. 3879–3889, 2019.

[16] C. R. Firkowski, A. M. Schwantes, M. J. Fortin, and A. Gonzalez, "Monitoring social-ecological networks for biodiversity and ecosystem services in human-dominated landscapes," *FACETS*, vol. 6, pp. 1670–1692, 2021.

[17] W. Q. Xie, M. M. Yang, X. F. Pan, H. M. Zhai, Q. X. Cheng, and B. Q. Sun, "Study on the change of ecological environment in zhengzhou based on rsei," *Fresenius Environmental Bulletin*, vol. 31, no. 7, pp. 7148–7159, 2022.

[18] S. P. Wu, X. Gao, J. Q. Lei, N. Zhou, Z. K. Guo, and B. J. Shang, "Ecological environment quality evaluation of the Sahel region in Africa based on remote sensing ecological index," *Journal of Arid Land*, vol. 14, no. 1, pp. 14–33, 2022.

[19] Y. Chen, Q. Y. Ma, C. Liu, and Q. Shu, "Research on marine environment monitoring based on Internet of things," *Desalination and Water Treatment*, vol. 219, pp. 71–76, 2021.

[20] W. Q. Deng, X. Zhang, J. C. Luo, and Y. Peng, "South China sea environment monitoring using remote sensing techniques," *Journal of Coastal Research*, vol. 95, no. sp1, pp. 29–33, 2020.

[21] M. S. H. Shuva, M. R. Golder, M. A. Rouf, M. M. Uddin, and J. Bir, "Daytime and nighttime sea surface temperature (SST) along with diurnal variability (D-SST) in the northern bay of bengal: a remote sensing approach," *Thalassas*, vol. 38, no. 1, pp. 697–708, 2022.

[22] J. J. Huo, B. Z. Zhou, Q. Zhao, and I. Mason, "Suppressing reflected guided waves from contaminated borehole radar data," *IEEE Geoscience and Remote Sensing Letters*, vol. 16, no. 5, pp. 736–740, 2019.

[23] D. Benito, A. Ahvo, J. Nuutinen et al., "Influence of season-depending ecological variables on biomarker baseline levels in mussels (*Mytilus trossulus*) from two Baltic Sea subregions," *Science of the Total Environment*, vol. 689, pp. 1087–1103, 2019.