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Evaluation and Analysis of Tourism Ecological Environment Statistical Monitoring Indicator System Based on Intelligent

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ABSTRACT
As the economy develops, the tourism ecological environment (TEE) has been gradually damaged. The ecological environment is the basis of human life, and the sustainable development of the ecological environment is of great importance to promote the stable development of society. China has rich grassland tourism resources. However, as a result of the rapid development of tourism, some scenic spots have been overdeveloped and commercialised, leading to the destruction of natural landscapes, damage to ecosystems and the gradual sanding of large tracts of grassland. The desert grassland used for tourism development is located between the grassland and the desert, and is the barrier that ensures the entire grassland ecosystem. To carry out environmental management of tourism ecology, it is necessary to construct a statistical monitoring index system for tourism ecology. However, traditional ecological environment monitoring is mainly based on manual sampling survey, which is cumbersome. The monitoring data is not accurate enough. In this paper, remote sensing technology (RST) was used to obtain remote sensing images of desert grassland, and intelligent image processing (IIP) technology was used for feature recognition. Compared with the traditional ecological environment statistical monitoring method, it showed that: In desert grassland A, the average monitoring accuracy of the traditional ecological environment statistical monitoring method and the ecological environment statistical monitoring method based on IIP were 90.12% and 94.56% respectively; in desert grassland B, the average monitoring accuracy of the traditional ecological environment statistical monitoring method and the ecological environment statistical monitoring method based on IIP were 88.20% and 92.60% respectively. Therefore, statistical monitoring of TEE based on IIP can improve the monitoring accuracy of ecological environment indicators.

Keywords: Monitoring Indicators, Tourism Ecological Environment, Intelligent Image Processing, Analytic Hierarchy Process

1. Introduction

Tourism can be a great importance in the development of modern society and has a positive impact on regional economic growth, job creation and cultural exchanges. However, the problem of

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ecological environmental protection in tourism has become increasingly prominent. Some tourist attractions have caused ecological damage, resource waste and ecological imbalance due to overdevelopment and mismanagement. China is a large country with grassland resources [1], of which 21.7 per cent of the total area is used for tourism. Grassland resources, as an important terrestrial ecosystem, are important for the development of biodiversity, the maintenance of soil and water balance and the development of animal husbandry. In order to maintain the stability of the tourism ecosystem, it is necessary to monitor it continuously. TEE (tourism ecological environment) monitoring is to provide data and statistics on the changes of the ecological environment and the impact of human beings on the ecological environment. However, in recent years, the desert grassland ecosystem has become very fragile due to the irrational use of tourism ecological resources by human beings and the deterioration of the environment as a result of climate warming. It is very important to statistically monitor the environmental indicators in desert grassland areas. Remote sensing and other technologies are used to obtain environmental images of desert grassland areas used for tourism development. Through IIP (intelligent image processing) technology, the image is analyzed and accurate ecological environment information (EEI) is obtained, which is conducive to analyzing the ecological environment and promoting the harmonious development of human and nature. Therefore, this paper had research significance.

Tourism ecology refers to the natural environment involved in tourism activities, including tourist attractions, nature reserves and wildlife habitats. It is a system of mutual circulation and interaction. The spatial correlation of tourism ecological efficiency in China presents a complex network structure, which is manifested in the close connection between hot tourist areas and surrounding areas, forming a radiation effect. There are significant differences between the eastern coast and the western region, and the network centrality is obvious. Interconnection promotes the overall efficiency [2]. Many people analyze the status of the ecological environment through the statistical monitoring indicators of the ecological environment. Among them, Shcherbak V G used key indicators to monitor the environment and economic development in rural areas of Ukraine, and ensured sustainable economic growth by monitoring natural environmental indicators such as soil and vegetation [3]. Gibb Rory used passive acoustic sensors to provide efficient, non-invasive and widely classified means for studying wildlife populations and communities and monitoring their response to environmental changes [4]. Helander Hanna said through research that circular economy was related to the exploitation of environmental resources and the discharge of waste. Through indicator monitoring of the ecological environment, the overall environmental sustainability was improved, thereby reducing the environmental pressure caused by economic activities [5]. Linke Simon used freshwater ecological acoustics as a tool for continuous ecosystem monitoring, which could monitor the ecological environment of water area. According to the sound frequency of aquatic organisms, the species and activity range of aquatic organisms were judged [6]. Based on the above research, it is not difficult to find that the construction of TEE statistical monitoring index system can analyse the TEE data, which is of great significance to maintain the balance of the ecosystem. However, the TEE monitoring method lacks the analysis from the perspective of image processing. Although previous studies have effectively monitored the ecological environment through key indicators and acoustic sensors, most of them focus on physical and biological indicators, ignoring the potential of image processing in ecological monitoring. Image processing can provide more intuitive and comprehensive analysis of ecological data, especially in detail identification and long-term monitoring in complex environment.

IIP is the use of intelligent technology to automatically process a variety of complex images, with the function of intelligent monitoring. Relevant researchers have applied IIP to the statistical monitoring of ecological environment. Among them, Tyagi Deepika monitored the indicators of toxic chemicals, gases, microorganisms and radiation in the ecological environment through two-dimensional material sensors, and protected the ecological environment by controlling the indicators with high degree of environmental pollution [7]. Hill Andrew P developed a small size and low energy acoustic detector to monitor biodiversity and environmental quality, and ensured the ecological environment balance of the tropical rainforest through continuous monitoring of biodiversity in the tropical rainforest [8]. By using satellite to obtain the surface desert image of Naiman Banner area, Guo Bing determined the optimal monitoring model that fully considered the nonlinear relationship between multiple feature spaces and surface parameters, and analyzed the vegetation coverage and other indicators in the desert to provide decision support for the ecological restoration of Naiman Banner area [9]. The use of IIP technology could intelligently analyze the characteristic information in the ecological environment image, which was conducive to the indicator monitoring of the ecological environment, but the analysis of the ecological environment indicators was not comprehensive.

The TEE is deteriorating and the pressure on human survival is increasing. The development of tourism grassland resources can promote local economic development and employment increase, but it also brings certain environmental pressure and ecological problems. The desert grassland in the tourist grassland itself has weak ecological stability, but it does protect the natural barrier of animal husbandry. The purpose of this study is to improve the ability to accurately monitor the dynamic changes of natural ecosystems by constructing and optimizing the monitoring index system of ecological environment. By introducing advanced technical means such as image processing, the problem of insufficient data analysis in existing monitoring methods can be solved, the monitoring efficiency and accuracy can be further improved, scientific basis can be provided for ecological protection and sustainable development, and more effective environmental management and protection strategies can be formulated to ensure the long-term stability and healthy development of the ecosystem. In this paper, RST was used to obtain the geographical image of China's desert grassland, and intelligent image technology was used to analyze the characteristics. The results show that the statistical monitoring method of TEE based on IIP can improve the timeliness of monitoring ecological environment indicators. The innovation of this study lies in the introduction of image processing technology for ecological environment monitoring for the first time, which breaks through the limitations of traditional statistical indicators, improves the accuracy and real-time performance of ecological monitoring through visual data analysis, and is helpful to dynamically evaluate the state of ecosystem.

2. Statistical Monitoring Methods of Ecological Environment

Ecological environment refers to water resources, air resources, biological resources and other resources in the natural environment that affect human survival and development. The state of ecological environment directly affects the form of social development and the speed of economic development [10-11]. The ecological environment is closely related to human survival.

The model mainly combines remote sensing data with ground monitoring data, and uses statistics and machine learning algorithms to establish dynamic monitoring and analysis of ecosystems. The model adopts multi-source data fusion technology, including satellite images, climate data and geographic information, and extracts key ecological parameters, such as vegetation index, soil moisture and surface temperature, through multi-spectral and high-resolution images. Then, the model predicts the trend of ecological change through regression analysis or deep learning, and evaluates the health status of the ecosystem to support decision-making.

As a country with rapid economic development, China's rapid economic development has had a huge impact on the tourism ecosystem. The desert grasslands used for tourism in northern China are an important barrier to China's ecological security. However, due to the continuous deterioration of the environment, the desert grassland ecosystem has become very fragile. Therefore, it is necessary to monitor the ecological environment of China's desert grassland. Through the statistics of the ecological environment index, the state of the desert grassland ecosystem can be accurately assessed, which is helpful for the timely restoration of ecosystem balance. However, the traditional desert grassland ecological monitoring is mainly manual monitoring. It is necessary to send specialists to the designated area to collect ecological samples, including soil moisture, climate conditions, environmental images and other data. It usually takes a lot of manpower and material resources. However, due to the cumbersome process of ecological environment data collection and the long time of data analysis, the effect of monitoring the ecological environment is often poor.

When implementing IIP and RST, data collection and analysis are needed first. This process includes real-time monitoring of environmental variables, equipment status and user requirements using sensor networks. Through big data analysis technology, these data are integrated and processed to identify patterns and trends and ensure the adaptability and reliability of the system. Machine learning algorithm is used to predict and analyze, so as to optimize resource allocation and service response.

2.1.RST

Satellite remote sensing uses satellite sensors to scan the ground information and compress the height feature information in the continuous three-dimensional information on the ground to form a two-dimensional remote sensing digital image [12]. Objects have spectral characteristics, and the spectral performance of remote sensing imaging for different objects is different, so RST can also be used to monitor water quality, soil, biological and other information [13]. RST can be well applied to the statistical monitoring of ecological environment, and various resources in the ecological environment can be collected through remote sensing images.

Remote sensing monitors the change of grassland vegetation coverage in real time through high-resolution satellite images, and obtains vegetation index by using multi-spectral imaging technology to quantitatively evaluate the growth of grassland. At the same time, combined with geographic information system, remote sensing can accurately locate grassland degradation areas, and analyze ecological parameters such as soil moisture and surface temperature, effectively improving monitoring efficiency and accuracy.

When the RST is used for statistical monitoring of the ecological environment, the remote sensing satellite would collect the electromagnetic spectrum signals of all objects in the monitoring area. However, the electromagnetic spectrum expression information of different types of objects is different. In order to analyze a large number of remote sensing data, it is necessary to build a classification tree to classify the acquired remote sensing information level by level, which is helpful to analyze the ecological environment index information.

The advantages of using RST to classify the ecological environment data are as follows: The hierarchical remote sensing image analysis method can help people to analyze the environmental indicators and effectively avoid the logical errors in human analysis. For example, it can avoid artificially analyzing soil data information into biological data information; simplification of complex environmental indicator data can effectively enhance the ability to extract and analyze environmental indicator data.

According to the environmental characteristics of desert grassland in China, the surface characteristics of ecological environment can be divided into atmospheric environment, water environment, vegetation environment and soil environment. RST is mainly used to collect data on the shape and density of the atmospheric environment, the surface waters of the water environment, the characteristics of plants and dominant plants, and the composition of soil and mineral data.

The ecological environment image obtained by RST also needs to be combined with geographic information system. Geographic information system is a combination of geographical knowledge and RST, which can analyze and process spatial data information. The combination of RST and geographic information system to monitor the ecological environment can match the obtained environmental data indicators with the real geographical location and geographical environment, and ensure the accuracy of remote sensing data in the statistical monitoring of the ecological environment.

2.2. IIP

IIP refers to a kind of computer-based image processing and analysis technology that is adaptive to various applications. It is an independent theoretical and technical field, which is also a very important technical support in machine vision [14]. A large amount of EEI can be collected by using RST. However, due to the large amount of information, it is difficult to carry out accurate analysis by traditional manual analysis. The IIP technology can be applied to the ecological environment image analysis to accurately analyze the environmental monitoring index data. The application process of IIP in ecological environment image is displayed in Figure 1.

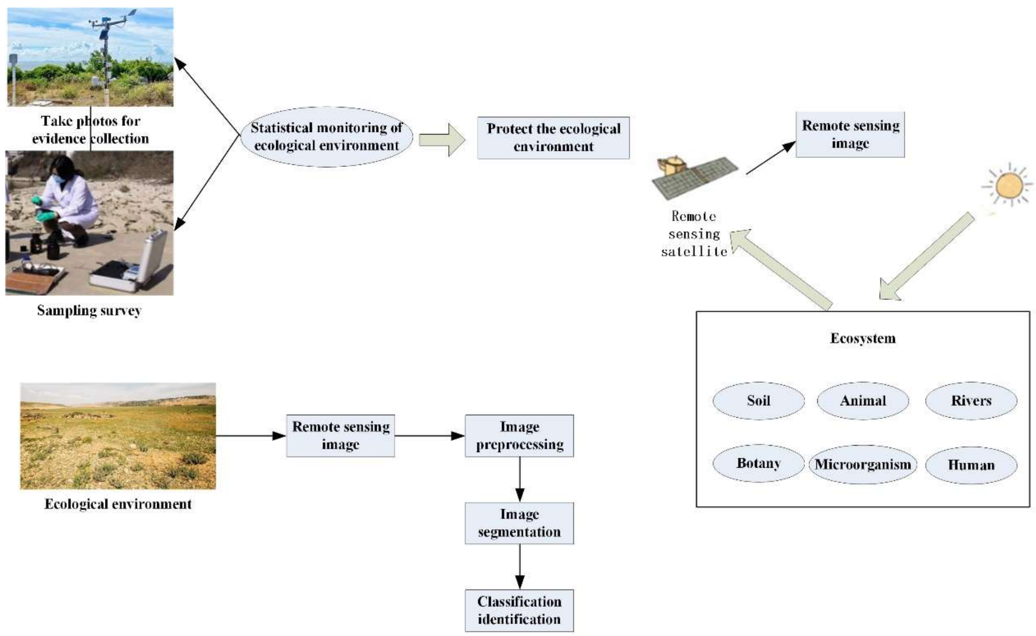


Fig. 1. Application process of IIP in ecological environment image

In Figure 1, first, the ecological environment image is obtained using RST, and the characteristics of the ecological environment image can be analyzed after preprocessing, image segmentation, classification and recognition.

When using remote sensing satellites to collect ecological environment images, due to the influence of equipment and environmental factors, they are often subject to different degrees of interference. Therefore, the collected ecological environment image needs to be preprocessed. Generally, the image needs to be converted to gray image for analysis. The conversion formula of gray image is as follows:

$$K(x,y) = 0.587 \times G(x,y) + 0.299 \times R(x,y) + 0.114 \times B(x,y) \tag{1}$$

In Formula 1, $K(x,y)$ represents the gray value of pixel point (x,y).

From the process of gray image conversion, it can be found that the green attribute of the image has the greatest impact on the gray image conversion, while the blue attribute has the smallest impact on the gray image conversion, so the green attribute conversion of the image can be approximately regarded as a gray image.

$$K(x,y) \approx 0.587 \times G(x,y) \tag{2}$$

After the collected ecological environment image is processed in grayscale, the grayscale image needs to be de-noised. The purpose of image noise reduction processing is to eliminate noise data caused by equipment and environmental factors [15]. Too much noise data would interfere with the analysis of the ecological environment image, which is not conducive to the accurate indicator monitoring of the ecological environment. Generally, noise data is eliminated through smoothing. It is assumed that the values of the four adjacent pixel points in the collected ecological environment image are respectively $g(x-1,y-1)$, $g(x,y-1)$, $g(x-1,y)$ and $g(x,y)$. The process of smoothing is as follows:

$$P(x,y)=\left[g(x-1,y-1)+g(x,y-1)+g(x-1,y)+g(x,y)\right]/4 \tag{3}$$

The purpose of image segmentation is to make the image features obvious, which is conducive to the subsequent extraction and analysis of image features. It is assumed that the ecological environment gray image is $K(x,y)$, and the gray subset of image segmentation is set to h. The process of image segmentation is as follows:

$$K(x,y)=\begin{cases} u & K(x,y)\in h \\ v & other \end{cases} \tag{4}$$

In Formula 4, u indicates the value of the ecological environment image within the image segmentation, and v indicates the value of the ecological environment image outside the image segmentation.

Image classification is based on the characteristic information of the image. For example, in the ecological environment image, different plant types in the image can be classified. Support vector machine is an effective binary classification method, which can accurately classify nonlinear structural data. The core of feature classification of ecological environment image using support vector machine is to construct classification hyperplane. The classification hyperplane is represented as follows:

$$R^T X + t = 0 \tag{5}$$

In Formula 5, R represents the normal vector of the hyperplane and t represents the intercept of the hyperplane.

2.3. Analytical Hierarchy Process

Analytic hierarchy process is a qualitative and quantitative analysis method that can objectively describe people's subjective feelings. It decomposes complex logic problems, and finally solves problems in the form of analysis indicators [16-17]. The key to the application of analytic hierarchy process is to decompose the problem well, and compare the determined indicators with each other, so as to rank the indicators according to their weights. There are many factors affecting the ecological environment, and the analytic hierarchy process can well build the ecological environment statistical monitoring index system.

The analytic hierarchy process has a three-level structure, from top to bottom: target level, criterion level and index level. Among them, the target layer is the problem studied; the criterion layer is the preliminary refinement of the target; the indicator layer is the detailed refinement of the target [18]. In the ecological environment statistical monitoring indicator system, the target layer is the ecological environment statistical monitoring effect, and there are many criteria layers, such as soil, vegetation, meteorology, etc.

Analytic hierarchy process is used to analyze the influence of each indicator on the ecological environment monitoring effect. It is assumed that the indicator affecting the ecological environment monitoring effect is $X=\{x_1,x_2,x_3,\cdots,x_n\}$. The influence of any two indicators is compared as follows:

$$x_{ij} = x_i / x_j \tag{6}$$

In Formula 6, x_{ij} represents the influence comparison between the ith indicator and the jth indicator.

By comparing the influence of all indicators, $n \times n$ comparison results can be obtained. By constructing the influence comparison results into a matrix, a matrix of $n \times n$ size can be obtained, which is recorded as matrix N. The data in the i-th column of the matrix represents the relative weight of the i-th index, which is expressed as follows:

$$w_i = \left(x_{i1} + x_{i2} + \cdots + x_{in}\right) / n \tag{7}$$

In Formula 7, w_i represents the weight of the ith indicator.

However, before using the judgment matrix N for index weight analysis, the consistency proportion analysis of the judgment matrix is required.

Among them, the consistency indicator is expressed as follows:

$$CI = \left(r - n\right) / \left(n - 1\right) \tag{8}$$

In Formula 8, r represents the maximum eigenvalue of matrix N.

The consistency ratio is expressed as follows:

$$CR = CI / RI \tag{9}$$

In Formula 9, RI represents the random consistency index, and the value of RI is related to the size of matrix N. When $CR < 0.1$, the representative matrix N passes the consistency test and can be used to calculate the weight of indicators.

3. Experiment of TEE Statistical Monitoring

3.1. Construction of TEE Statistical Monitoring Indicator System

Desert grassland is between desert and grassland, and has less species richness, but it plays a great role in maintaining ecological stability [19]. The desert grassland in China is mainly concentrated in the area west of the second line of Beijing in Inner Mongolia. In this paper, the vegetation of the desert grassland in Xilingol League of Inner Mongolia Autonomous Region was monitored. The geographical area of this study is located in the desert grassland area of Xilin Gol League, Inner Mongolia Autonomous Region, which is between the typical grassland and the desert area and has a unique ecological environment. Its landform is mainly arid and semi-arid desert grassland, with open terrain, harsh climatic conditions, limited annual precipitation and large evaporation. The vegetation in this area is mainly drought-tolerant herbs with relatively low species richness, but it plays a key role in maintaining regional ecological stability and preventing land desertification, so it is an important ecological monitoring object. The common vegetation of the desert grassland was shown in Table 1.

Table 1. Common vegetation in desert grassland

Serial number	Vegetation	Percentage
1	**Sand holly**	**28%**
2	**Camel thorn**	**26%**
3	**White thorn**	**24%**
4	**Haloxylon ammodendron**	**22%**

Using high-resolution satellite images and vegetation index, different vegetation types are classified and identified, and their spatial distribution ratio in the study area is calculated. In Table 1, the common vegetation in desert grassland was described. There were four kinds of common vegetation, including sand holly, camel thorn, white thorn and Haloxylon ammodendron. Among them, the proportion of sand holly was the highest at 28%, and that of Haloxylon ammodendron was the lowest at 22%.

The study area is shown in Figure 2.

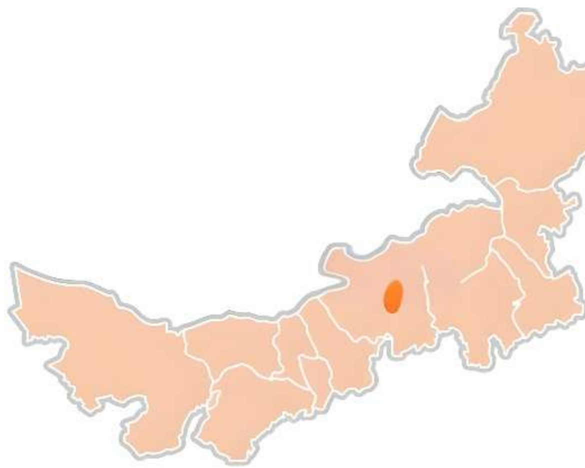


Fig. 2. Study area

The ecological environment of the desert grassland is very unstable. It is necessary to analyze the ecological environment through artificial statistical monitoring of the ecological environment indicators of the desert grassland. In order to effectively monitor the desert grassland ecosystem, this paper, based on the ecological structure of the desert grassland, used the analytic hierarchy process to build the TEE statistical monitoring indicator system [20-21]. This mainly monitored the indicators of soil, meteorology, vegetation and animals. The statistical monitoring indicator system of ecological environment was shown in Table 2.

Table 2. Statistical monitoring indicator system of TEE

Target layer	Criterion layer	Indicator layer	Weight
Statistical monitoring of TEE	Soil	Soil moisture content	0.15
		Soil compactness	0.11
	Meteorological	Evaporation capacity	0.12
		Temperature	0.12
	Vegetation	Vegetation coverage	0.17
		Height of dominant species	0.11
	Animal	Number of species	0.13
		Range of animal activities	0.09

In Table 2, the TEE statistical monitoring indicator system was described. A total of 8 indicators were counted. Among them, the highest weight of vegetation coverage was 0.17, and the weight of soil water content was 0.15. The minimum weight of the range of animal activity was 0.09.

3.2. Experimental Design of TEE Statistical Monitoring

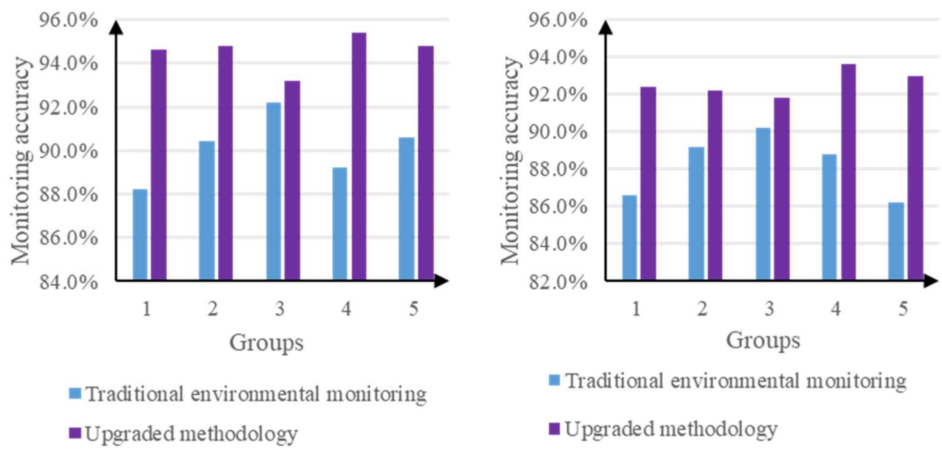
Tourism development has led to an increase in desertification of the desert steppe, so it is important to statistically monitor the ecological environment of the desert steppe. In this paper, RST was used to obtain the ecological environment image, and IIP technology was used to analyze the environmental characteristics of the image. In order to highlight the effect of ecological environment statistical monitoring based on IIP, this paper would compare with traditional ecological environment statistical monitoring methods.

The traditional ecological environment statistical monitoring method is manual sampling and analysis. In order to compare the effect of the traditional ecological environment statistical monitoring method and the ecological environment statistical monitoring based on IIP, this paper would compare and analyze the accuracy, timeliness and coverage of the ecological environment indicator monitoring. In order to ensure the authenticity of the experiment, the desert grassland in the Sunit Left Banner area of Xilingol League was recorded as desert grassland A; the desert grassland in Sunit Right Banner area was recorded as B desert grassland, and the ecological environment statistics and monitoring were carried out respectively. Finally, according to the results of indicator monitoring and the corresponding indicator weight, the corresponding desert grassland ecological index was calculated, and the ecological index was between 0 and 4.

4. Statistical Monitoring Results of TEE

4.1. Monitoring Accuracy

The analysis of the TEE is mainly through the statistical monitoring of environmental indicators, including soil moisture content, vegetation cover and so on. The accuracy of the monitoring of TEE indicators reflects the effectiveness of the analysis of the ecological environment situation in the monitored area. Inaccurate monitoring can easily lead to deterioration of the ecosystem. This paper compared the monitoring accuracy of traditional ecological environment statistical monitoring and ecological environment statistical monitoring based on IIP. The comparison results were shown in Figure 3.



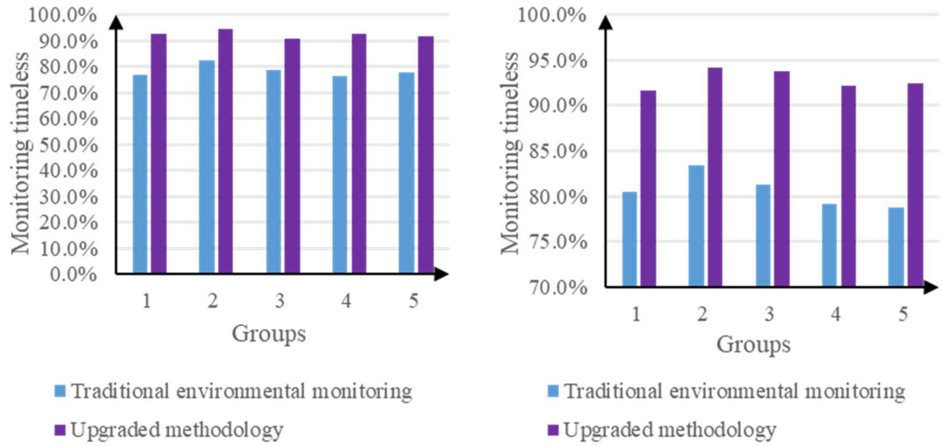
(a) Monitoring accuracy of desert grassland A (b) Monitoring accuracy of desert grassland B

Fig. 3. Results of monitoring accuracy

In Figure 3 (a), the comparison of monitoring accuracy of two ecological environment statistical monitoring methods on desert grassland A was described. Among them, the monitoring accuracy of traditional ecological statistical monitoring methods was the poorest in the first group, 88.2%, and the highest in the third group, 92.2%. In Figure 3 (b), the comparison of monitoring accuracy of two ecological environment statistical monitoring methods on desert grassland B was described. The monitoring accuracy of the traditional ecological environment statistical monitoring method was lower than that of the ecological environment statistical monitoring method based on IIP in five groups of experiments. The monitoring accuracy of the two monitoring methods in desert grassland B was lower than that in desert grassland A. Therefore, the use of IIP technology for monitoring ecological environment indicators could improve the accuracy of monitoring. The advantage of environmental monitoring in this paper lies in the comprehensive monitoring of ecological environment by combining a variety of advanced technologies. Obtaining a wide range of spatial data through remote sensing technology, combined with ecological acoustics to monitor water areas and wildlife activities, can capture the dynamic changes of ecosystems efficiently and non-invasively. In addition, the multi-dimensional statistical monitoring index system is used to accurately analyze natural environmental parameters such as vegetation type and coverage rate. This method not only improves the monitoring accuracy, but also reflects the ecological changes in real time, providing strong support for ecological protection and sustainable development decision-making, especially suitable for ecologically sensitive areas such as desert grassland.

4.2. Monitoring Timeliness

In addition to the accuracy of monitoring, it was also necessary to ensure the timeliness of monitoring to monitor the ecological environment indicators of desert grassland. This paper compared the monitoring timeliness of traditional ecological environment statistical monitoring and ecological environment statistical monitoring based on IIP.



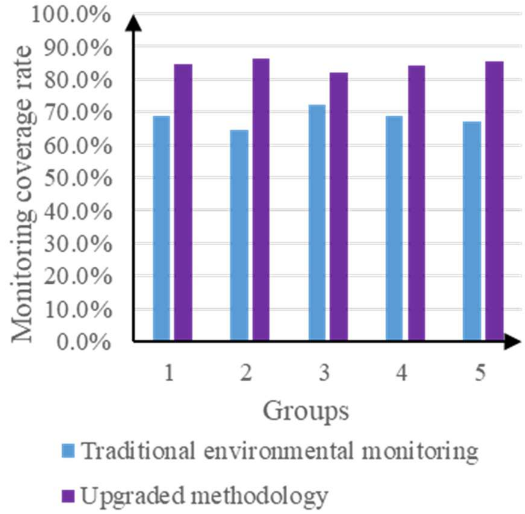
(a) Monitoring timeliness of desert grassland A (b) Timeliness of monitoring on desert grassland B

Fig. 4 Comparison results of monitoring timeliness

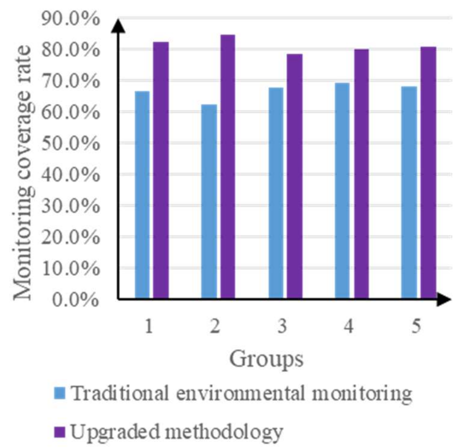
In Figure 4 (a), the comparison of monitoring timeliness of two ecological environment statistical monitoring methods on desert grassland A was described. The monitoring timeliness of traditional ecological environment statistical monitoring methods reached the lowest of 76.2% in the fourth group and the highest of 82.4% in the second group. In Figure 4 (b), the comparison of monitoring timeliness of two ecological environment statistical monitoring methods on desert grassland B was described. It was obvious that the timeliness data of the two kinds of ecological environment monitoring were very different. Therefore, the statistical monitoring of desert grassland ecological image obtained by RST and IIP could effectively improve the timeliness of ecological environment monitoring.

4.3. Monitoring Coverage

In the process of ecological environment monitoring, it was necessary to improve the coverage of ecological environment monitoring as much as possible. The higher the monitoring coverage, the more comprehensive the indicator data would be and the more conducive to the analysis of ecological environment. The monitoring coverage of traditional ecological environment statistical monitoring and ecological environment statistical monitoring based on IIP was compared, and the comparison results were shown in Figure 5.



(a) Monitoring coverage of desert grassland A



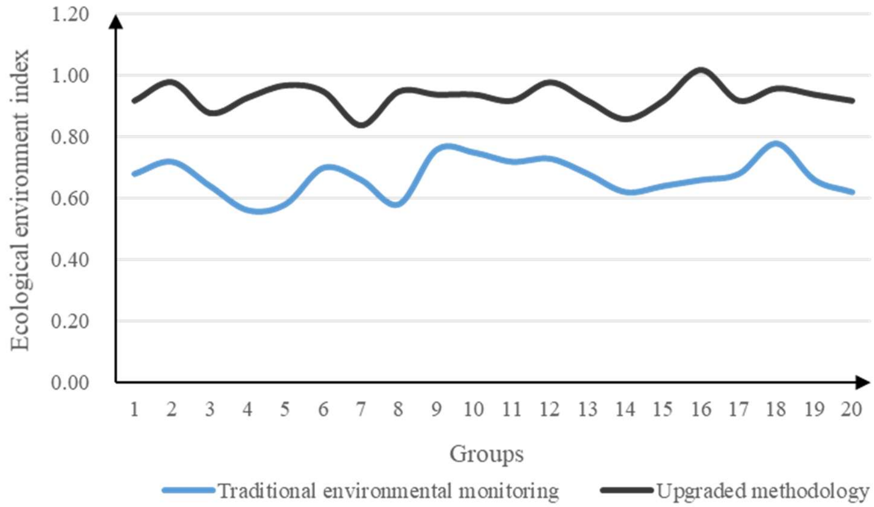
(b) Monitoring coverage of desert grassland B

Fig. 5. Comparison results of monitoring coverage

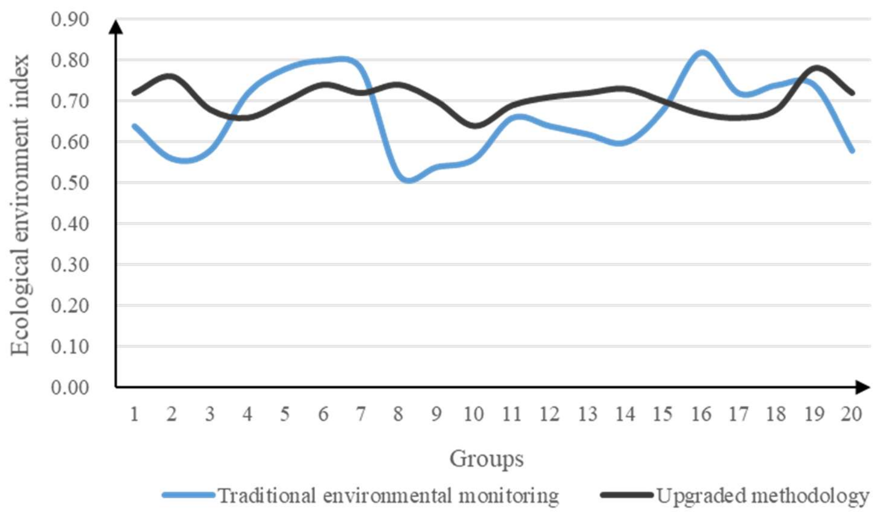
In Figure 5 (a), the comparison of monitoring coverage of two ecological environment statistical monitoring methods on desert grassland A was described. The monitoring coverage of the ecological environment statistical monitoring method based on IIP reached the lowest of 78.4% in the third group and the highest of 84.6% in the second group. The average monitoring coverage rate was 81.24%. Therefore, the ecological environment statistical monitoring based on IIP could effectively improve the monitoring coverage.

4.4. Ecological Environment Index

The ecological environment index is an integrated evaluation of the ecological environment system utilizing ecological environment statistical monitoring methods. The environmental index was obtained by monitoring the data of various indicators in the environment and combining them with the weight of the indicators. The environmental index was within the range of [0,1), [1,2), [2,3), and [3,4), indicating poor, average, good and excellent environmental quality. The traditional ecological environment statistical monitoring and the ecological environment statistical monitoring based on IIP were compared with the ecological environment index, and the comparison results were shown in Figure 6.



(a) Ecological environment index of desert grassland A



(b) Ecological environment index of desert grassland B

Fig. 6. Comparison results of ecological environment index

In Figure 6 (a), the ecological environment index of desert grassland A under the two ecological environment statistical monitoring methods was described. The average ecological environment index was about 0.67. The ecological environment index of the ecological environment statistical monitoring method based on IIP reached the lowest of 0.84 in Group 7 and the highest of 1.02 in Group 16. The average ecological environment index was about 0.93. In Figure 6 (b), the ecological environment index of desert grassland B under the two ecological environment statistical monitoring methods was described. The ecological environment index measured by the traditional ecological environment statistical monitoring method reached the lowest of 0.52 in Group 8 and the highest of 0.82 in Group 16. The average ecological environment index was about 0.66. The ecological environment index of the ecological environment statistical monitoring method based on IIP reached the lowest of 0.64 in Group 10 and the highest of 0.78 in Group 19. The average ecological environment index was about 0.71. There were great differences between the ecological environment of A and B regions, but the traditional ecological environment statistical monitoring methods measured the ecological environment index of different ecological environments very close, which meant that the measurement of the traditional ecological environment statistical monitoring methods was not accurate. When the ecological environment statistical monitoring method based on IIP was used for analysis, the ecological environment index of desert grassland A was higher than that of desert grassland B.

The results of this study provide a more accurate data analysis tool for ecological monitoring, and can effectively identify the dynamics of environmental changes and biodiversity. This will not only help to formulate targeted protection measures, but also promote the implementation of sustainable development policies, provide scientific basis for long-term health management of ecosystems, and further promote the application of ecological monitoring in policy formulation and environmental management.

5. Conclusions

By combining remote sensing technology, eco-acoustic monitoring and multi-dimensional statistical monitoring index system, this paper systematically monitored and analyzed the ecological environment of desert grassland in Xilin Gol League, Inner Mongolia. The results show that vegetation coverage monitoring based on remote sensing can accurately reflect the temporal and spatial changes of grassland, and eco-acoustic monitoring can effectively capture the ecological dynamics of water areas and wildlife, which proves the feasibility and advantages of multi-technology integration in desert grassland ecological monitoring. The contribution of this study lies in the innovative combination of various monitoring methods, the establishment of a statistical monitoring index system suitable for ecologically sensitive areas, and the verification of its effectiveness in this special ecological environment of desert grassland. This system not only improves the accuracy and efficiency of ecological monitoring, but also provides an important reference for grassland ecological protection and sustainable development. However, there are still limitations in the application process, especially in the acquisition and processing of high-resolution remote sensing data, and eco-acoustic monitoring is sensitive to environmental noise. In addition, the research mainly focuses on vegetation coverage and wildlife monitoring, and has not yet involved broader ecological factors such as climate change. In the future research, multi-source data should be further integrated, especially the monitoring of comprehensive factors such as climate and soil, and the spatial and temporal resolution of the model should be improved, and the monitoring index system should be further improved to improve the accuracy and adaptability of the overall ecological monitoring.

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