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Article

Analysis of landscape vegetation ecology and cellular structure in nature reserves based on an improved analytic hierarchy process

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Abstract: With the increasing severity of global environmental issues, natural reserves have become crucial areas for maintaining biodiversity and protecting natural ecosystems. The ecological status of landscape vegetation and the characteristics of cellular structures within these reserves have become focal points of research. However, traditional evaluation methods have limitations when dealing with the complex ecosystems of natural reserves, making it difficult to assess the relationship comprehensively and accurately between vegetation ecology and cellular structures. Therefore, this paper proposes an analysis of landscape vegetation ecology and cellular structure in natural reserves based on an improved Analytic Hierarchy Process (AHP). By incorporating fuzzy set theory and expert scoring mechanisms, the evaluation process is enhanced in terms of objectivity and precision. An evaluation index system for landscape vegetation ecology and cellular structure in natural reserves is constructed, covering aspects such as vegetation species richness, community structural complexity, and ecological functional stability. This systematic approach reflects the ecological status of vegetation and cellular structure characteristics, providing scientific support for targeted protection and management measures.

Keywords: improved analytic hierarchy process; nature reserve; landscape vegetation ecology; cellular structure analysis

1. Introduction

Through innovatively designing an analytical framework for evaluation issues and constructing a value system, a method for optimal ranking of alternatives based on Variable Weight AHP (VWAHP) was proposed. The variable weighting mechanism of VWAHP and its advantages over traditional AHP were extensively analyzed theoretically [1]. A series of evaluation criteria, including order preservation, consistency, scale uniformity, memorability, perceptibility, and weight fitting, were introduced to comprehensively assess the performance of different scales used in AHP [2]. In the context of performance evaluations for head nurses, the application of weighted comprehensive assessment effectively promoted the alignment of departmental and hospital nursing goals, achieving continuous optimization of nursing quality and improvement in management levels [3]. For risk assessment in Fujian agriculture, an integrated risk indicator system covering hazard vulnerability, disaster-prone body fragility, and disaster prevention capacity was developed using a hybrid AHP-EWM method [4]. An integrated evaluation index system combining entropy weight coefficients was constructed for assessing corporate operational performance, enhancing the scientific rigor and objectivity of the evaluation [5]. Using AHP, a credit evaluation index system for small and medium enterprises (SMEs) operating in an internet finance environment was established and validated with actual brand online direct sales data [6]. By combining AHP with cluster analysis, weights were assigned to corporate credit indicators, allowing for the calculation of corporate credit scores and providing quantitative basis for credit management [7]. The basic principles of AHP and the application scenarios of its weight calculation methods were described [8]. A fuzzy evaluation matrix construction method based on single-index relative membership degrees was proposed to simplify and optimize the judgment matrix construction process, improving the rationality of weight determination [9]. In ecological research, detailed investigations and analyses of phytoplankton within a biocontrol enclosure in Lake Tai's Zhushan Lake revealed community structure, dominant species, and diversity characteristics, providing important bases for ecological management [10]. An ontological classification method in landscape ecology offered new perspectives for landscape classification studies [11]. Its characteristics and existing issues were outlined, and protective strategies were proposed from multiple dimensions [12]. In the field of ecosystem classification, an innovative framework centered on ecosystem service functions and human activity intensity was designed [13]. An improved AHP method based on three-scale modification was proposed, which effectively reduced subjectivity in judgment matrix construction. Through mathematical transformations, it achieved optimal consistency matrices, simplifying the consistency check step in traditional AHP [14]. The weight determination processes of traditional AHP and the improved method were compared, and a comprehensive discussion of the advantages and disadvantages of the improved method was provided through case study analysis [15].

To overcome the shortcomings of traditional AHP methods, this paper proposes a landscape vegetation ecological and cellular structure analysis method for nature reserves based on the Improved Analytic Hierarchy Process (IAHP). While retaining the original advantages of AHP, the concept of fuzzy complementary matrices is introduced, making the analysis process more flexible and capable of handling fuzzy information, thus enhancing the accuracy and reliability of the analysis. With the FAHP method, we can systematically evaluate the ecological, environmental, cultural, and development values of landscape vegetation in nature reserves and explore the characteristics and functions of their cellular structures, providing strong support for the scientific management and protection of these areas.

This paper aims to construct a scientifically reasonable evaluation index system and use the FAHP method to conduct a comprehensive and in-depth analysis of the landscape vegetation in nature reserves. First, we will establish a comprehensive evaluation index system for the landscape vegetation in nature reserves from the perspectives of ecology and cellular structure; secondly, we will use the FAHP method to quantitatively assess each indicator and determine their relative importance; finally, based on the evaluation results, targeted conservation strategies and management recommendations will be proposed.

2. Theories and concepts related to analytic hierarchy process

The core idea of the Analytic Hierarchy Process (AHP) is to systematize complex decision-making problems by breaking them down into more specific, manageable objectives, criteria, and indicator levels. This process combines qualitative and quantitative methods, using fuzzy quantification techniques to rank the elements within the hierarchy. The aim is to provide a scientific basis for optimizing decisions involving multiple objectives and alternatives.

The key steps in implementing the Analytic Hierarchy Process (AHP) are outlined as follows:

Construct the hierarchical structure framework: First, clarify the decision-making objective and identify the key factors (criteria) influencing the decision as well as the specific alternatives to be evaluated. These elements are then logically organized into three levels: the top level represents the decision goal, the middle level consists of the criteria, and the bottom level includes the alternatives. By drawing a hierarchical structure diagram, the relationships and levels between these elements are visually presented.

Establish pairwise comparison judgment matrices: For elements between adjacent levels, particularly between the criteria and alternative levels, use a relative importance scoring method to compare alternatives pairwise under the same criterion to assess their relative importance. Based on this, judgment matrices are constructed, reflecting the integration of expert judgments and experiential knowledge.

Solve for individual level weights and conduct consistency verification: Employ mathematical methods (such as the eigenvalue method) to solve for the maximum eigenvalue and its corresponding eigenvector of the judgment matrix. After normalization, this yields the weight vector for each element. Following this, consistency checks are performed to ensure logical consistency within the judgment matrices. The consistency ratio (CR) is a critical measure of consistency; when the CR is less than 0.1, it is deemed that the construction of the judgment matrix is reasonable.

Calculate the total weights and verify overall consistency: Using the hierarchical total ranking method, calculate the comprehensive weights of the elements at each level relative to the overall goal, proceeding from top to bottom. In this process, the weights of each level are derived by multiplying the weights of the elements from the upper level with the internal weights of the respective level. Additionally, to ensure the consistency of the entire hierarchical structure, a consistency check must be performed on the weight results at each level, ensuring the logical rigor of the entire decision model and the reliability of the results.

2.1. Establish a hierarchical structure model

When building a hierarchical structure model, the primary task is to clearly define the core issue, which serves as the foundation for the entire model construction. Following this, the key factors that impact the resolution of the issue should be systematically divided into three levels of the hierarchical structure: the top level is the objective level, the middle level is the criteria level, and the bottom level is the alternatives level. Specifically, the objective level directly reflects the core task to be resolved or achieved; the criteria level further elaborates on the key principles, standards, and considerations necessary to achieve this objective, providing a guiding framework for the decision-making process; and the alternatives level focuses on specific implementation paths, listing various solutions or action plans designed for addressing the problem, serving as concrete means to achieve the objective. As displayed in **Figure 1**, this model is presented through an intuitive hierarchical diagram, making it easy to understand and apply.

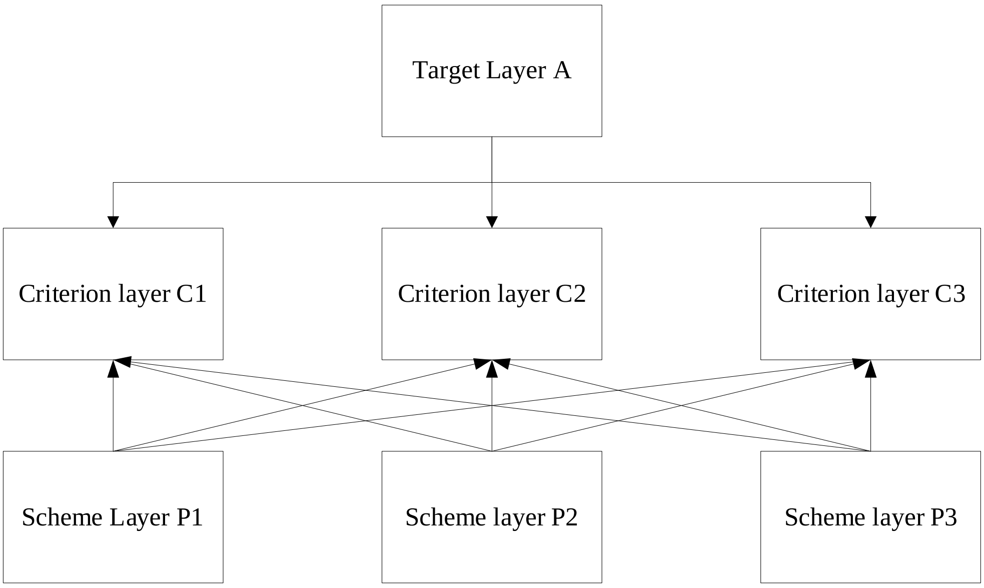

Figure 1. Hierarchical structure model.

2.2. Construct the judgment matrix

In the Analytic Hierarchy Process (AHP), to quantify the relative importance of factors within each level, we need to use an appropriate scaling system for evaluation and organize these quantitative values into a judgment matrix. This process is the cornerstone of implementing AHP and is critical for ensuring the accuracy and effectiveness of subsequent analyses.

First, clarify the objects of comparison: Select the elements to be compared within the same hierarchical structure, such as different criteria within the criteria layer.

Table 1. Meaning of the 1–9 scale.

Scale	Definition of materiality
1	Equally important
3	Slightly important
5	Obviously important
7	Strongly Important
9	Extremely important
2, 4, 6, 8	Intermediate transition values of adjacent judgments

Next, establish the comparison scale: To precisely express the relative importance between elements, we often use the 1–9 scale (or other suitable scaling systems). As presented in **Table 1**, in the 1–9 scale, numbers 1 through 9 represent different levels of importance, where 1 indicates that two elements are equally important. As the numbers increase, they indicate that one element is increasingly more important than another, up to 9, which denotes extreme importance. The reciprocals of these numbers are used to denote the opposite importance relationship. This scaling method provides a clear and operable tool for quantifying the relative importance between elements.

Constructing judgment matrix: Based on the selected comparison elements and the determined comparison scale, a judgment matrix A is constructed. The element a_{ij} in the matrix A represents the degree of importance of element i compared to element j. The judgment matrix A has the following properties:

$$\begin{cases} a_{ij} > 0 \\ a_{ij} = \dfrac{1}{a_{ij}}, (i \neq j) \\ a_{ij} = 1, (i = j) \end{cases} \tag{1}$$

2.3. Consistency check

The consistency requirement of the judgment matrix is that the maximum eigen root of the absolute value of the judgment matrix is not much different from the dimension of the matrix, and the index CI is introduced to express the inconsistency degree of the judgment matrix. Expression of CI [16]:

$$\mathrm{CI} = \frac{\lambda_{\max}}{n-1} \tag{2}$$

where it represents the maximum eigenvalue of the judgment matrix, and n represents the sum of the diagonal elements of the judgment matrix, which is also the sum of the eigen roots of the judgment matrix. Introducing the consistency ratio [17]:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{3}$$

When CR < 0.1, it is considered that the inconsistency degree of the judgment matrix is within the allowable range, and its normalized eigenvector can be used as the weight vector to obtain the weight value of each factor relative to a factor in the upper layer. On the contrary, the judgment matrix needs to be reconstructed. The interval RI value corresponding to the n value is as follows in **Table 2**:

Table 2. RI values corresponding to different values of n.

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The ranking weight process of determining the relative importance of all factors in a certain layer to the total goal is called hierarchical total ranking. Let the hierarchical single ranking consistency index of the secondary evaluation index on the impact factor of the upper layer be C_{ij} and the random consistency index be Rij, and the consistency ratio of the total ranking of the hierarchy is obtained as follows:

$$\mathrm{CR} = \frac{\sum_j^m a_j \cdot CI_j}{\sum_j^m a_j \cdot RI_j} \tag{4}$$

When the Consistency Ratio (CR) is less than 0.1, it is considered that the overall ranking of the hierarchy has passed the consistency test. The eigenvector of the judgment matrix for the total hierarchical sorting is calculated and normalized to obtain the relative weights of each factor in the scheme layer compared to the overall goal.

2.4. Improved analytic hierarchy process (AHP)

Given the complexity of objective phenomena, the diverse characteristics of human cognition, and the inevitable partiality and variability in subjective judgments, the Analytic Hierarchy Process (AHP), during its theoretical and practical applications, often encounters issues where the risk ranking results derived from expert scoring mechanisms for comparing the importance of factors significantly deviate from actual conditions. This deviation often leads to high inconsistency levels in judgment matrices, making it difficult to meet the strict criteria for consistency testing. More importantly, as the number of evaluation indicators included in a particular level increase, such deviations become more pronounced, greatly increasing the difficulty of constructing logical and effective hierarchical structure judgment matrices.

To overcome the limitations of traditional AHP in dealing with vague and uncertain information, some scholars have introduced fuzzy thinking and methods into AHP, proposing the Fuzzy Analytic Hierarchy Process (FAHP).

Features: FAHP introduces fuzzy set theory to handle fuzziness and uncertainty in the decision-making process. It allows decision-makers to use fuzzy language to describe the relative importance of factors and quantifies these descriptions using fuzzy mathematical methods.

Application: FAHP has significant advantages in handling complex, fuzzy multi-objective decision-making problems and has been widely applied in areas such as management decision-making, economic project investment, personnel evaluation, and merit selection.

2.4.1. FAHP

The integration of fuzzy mathematics into the Analytic Hierarchy Process (AHP) leads to Fuzzy AHP (FAHP). Given the complex, changeable, and fuzzy nature of the real world, FAHP has emerged as a solution. Its characteristics include the use of fuzzy judgment matrices and simplified calculations, overcoming the shortcomings of traditional AHP such as complex scaling and difficulty in controlling consistency. FAHP establishes a hierarchical model, constructs priority relation matrices, converts them into fuzzy consistent matrices, and then performs step-by-step evaluation of indicators. Finally, it compares the results to achieve optimal decision-making.

In the FAHP, two factors are compared with each other pairwise. Fuzzy judgment matrix [18]:

$$A = (a_{ij})_{m\times n} \tag{5}$$

Fuzzy properties [19]:

$$a_{ij} = 0.5, i = 1,2,\ldots,n \tag{6}$$

$$a_{ij} + a_{ji} = 1, i = 1,2,\ldots,n \tag{7}$$

Such a matrix is called a fuzzy complementary judgment matrix. The factors need to be compared. Complementary judgment matrix [20]:

$$A=\begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} \quad (8)$$

Complementary judgment matrix weights [21]:

$$W_i=\frac{\sum_{i=1}^{n} a_{ij}+\frac{n}{2}-1}{n(n-1)}, i=1,2,\ldots,n \quad (9)$$

Fuzzy judgment matrix consistency test [22]:

$$I(A,B)=\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}+b_{ij}-1 \quad (10)$$

Matrix A and B compatibility indicators [23]:

$$\sum_{i=1}^{n} W_i=1, W_i>0 \quad (11)$$

Characteristic matrix [24]:

$$W^*=(W_{ij})_{m\times n} \quad (12)$$

When constructing a fuzzy judgment matrix, ensuring its consistency is crucial, as it directly reflects the inherent logical consistency of people's judgments about things. However, given the complexity of the real world and the limitations of human cognition, the matrix built may initially lack consistency. Therefore, an adjustment process is essential, aimed at optimizing the matrix to meet consistency standards, ensuring the accuracy and reliability of the analysis results.

2.4.2. Improving the establishment of the FAHP

Although FAHP addresses some of the shortcomings of the traditional AHP by introducing fuzzy judgment matrices, it still faces challenges in ensuring the consistency of these matrices, and its final computational results often do not fully meet expectations. In light of this, we further introduce the concept of fuzzy consistent matrices, aiming to screen out more reasonable and scientific solutions through this innovative approach, thereby constructing a more ideal and effective decision-making method.

To construct the priority relationship matrix: Perform simple processing from different scales to establish an individual factor's fuzzy matrix, its values being:

$$b_{ij}^{k}=\begin{cases} 0 \\ 0.5 \\ 1 \end{cases} \quad (13)$$

To establish a priority relationship matrix using a theorem-based method, each factor within a category is referred to as a first-level fuzzy comprehensive evaluation. The discriminant for the first-level single-factor evaluation matrix is:

$$R^k=\left(r_{ij}^{k}\right)_{n\times n} \quad (14)$$

$$r_{ij}^{k}=\frac{r_i^k-r_j^k}{2n}+0.5 \quad (15)$$

$$r_i = \sum_{i=1}^{n} b_{ij} \tag{16}$$

$$r_j = \sum_{j=1}^{n} b_{ij} \tag{17}$$

i, *j* = 1, 2, ..., n is quantized to obtain a fuzzy consistent matrix:

$$R^k = (k, 1,2, \ldots, n) \tag{18}$$

Hierarchical single ranking: Based on the judgment matrix, the relative importance weight of each factor at this level relative to the specific factor at the previous level is determined by calculation. This process is called hierarchical single ranking. In this process, the square root method and other methods can be used to calculate the weight superiority of each index. Square root calculation [25].

$$s_i^k = \frac{s_i}{\sum_{i=1}^{n} s_l} \tag{19}$$

$$s_i = \left(\prod_{i=1}^{n} r_{il}^k \right)^{\frac{1}{n}} \tag{20}$$

Hierarchical total ordering: This process aims to determine the importance ranking weights of all factors at the same level relative to the highest level (the overall goal). By integrating the single-ranking results of each level, the total weights of the factors at this level relative to the previous level are calculated layer by layer. Specifically, for the second level directly under the highest level, its single-ranking result serves directly as the total ordering. In the optimization and selection of schemes, based on the principle of system divisibility, we categorize influencing factors into multiple subsystems according to their attributes and apply a single-level multi-factor model to calculate the degree of preference for each scheme within the subsystems. The specific calculation formula is as follows:

$$s_i = \sum_{k=1}^{m} w_k \cdot s_i^k \, , i = 1,2, \ldots, n \tag{21}$$

The sorting process yields the preference ranking of *n* alternatives based on *m* factors. The implementation of the FAHP includes four main stages: hierarchical modeling, expert consultation, ranking calculation, and alternative selection. The key points of each stage are as follows:

- First stage: Hierarchical structure modeling

This stage is the cornerstone of the FAHP method, and its quality directly impacts the analysis results. It follows a logical progression from abstract to concrete and from qualitative to quantitative, encompassing key steps such as defining decision-making objectives, delineating object attributes, and constructing an evaluation index system.

- Second stage: Expert consultation

This stage is crucial, as expert opinions directly affect the accuracy and practicality of the analysis results. It involves developing consultation questionnaires, selecting an expert team, and summarizing and analyzing feedback to ensure comprehensive and authoritative information.

- Third stage: Sorting calculations

Based on the calculation rules and formulas of the FAHP, this stage performs single-level sorting, calculates the preference values of each alternative, and obtains the average preference value. Subsequently, by combining these with weight factors, composite evaluation values are calculated, leading to the final hierarchical total ordering.

- Fourth stage: Optimal scheme selection

Based on the results of the sorting calculations, a comprehensive evaluation of each candidate scheme is conducted, and the scheme with the best performance is selected as the final choice.

2.5. Machine learning algorithms

Machine learning is the science of enabling computers to learn and infer from data. Machine learning algorithms are specific methods that achieve this, and they can be classified and compared based on their objectives, data types, and application scenarios. These algorithms can be viewed as mapping functions from input to output, adjusting their parameters based on a given dataset (training set) to minimize the discrepancy between the output and the expected results (labels or target functions).

Key components of machine learning algorithms:

1) Data representation: The raw data must be transformed into a form suitable for mathematical computation, such as numerical values, vectors, or matrices.
2) Model definition: The model is a mathematical expression that defines the relationship between inputs and outputs, as well as the meaning and range of parameters. Models can be linear, nonlinear, probabilistic, or deterministic.
3) Objective function: The objective function (also known as the loss or cost function) measures the discrepancy between the model's output and the expected results. Common objective functions include mean squared error, cross-entropy, and log-likelihood.
4) Optimization algorithm: The optimization algorithm is the method used to solve the machine learning problem by iteratively updating parameters to minimize or maximize the objective function. Common optimization algorithms include gradient descent, Newton's method, and stochastic gradient descent.
5) Hyperparameters: Hyperparameters are parameters that need to be manually set and influence the model's structure, complexity, and generalization ability. Common hyperparameters include learning rate, regularization coefficient, and the number of hidden layers.

Long Short-Term Memory (LSTM) is a type of machine learning algorithm, particularly within the domain of deep learning. It is a variant of Recurrent Neural Networks (RNNs) designed to address the vanishing and exploding gradient problems encountered by RNNs when processing long sequences. LSTMs are especially useful in handling data involving sentiment, opinions, or preferences, where potential biases may exist. Different applications have varying requirements for model performance. For example, in sentiment analysis, texts from different domains may have distinct expressions and sentiment tendencies, necessitating models that can adapt to these domain-specific characteristics. When applying models to new domains or tasks, retraining or fine-tuning may be required to reduce bias.

3. Ecological analysis of vegetation landscape in nature reserves

Nature reserves are designated areas according to law, aimed at protecting representative natural ecosystems, habitats for rare and endangered wildlife, as well as natural relics of special significance. These areas are widely distributed across terrestrial, inland water, and marine environments, with specific management and conservation measures implemented. They play an indispensable role in maintaining global biodiversity, safeguarding environmental stability, and promoting scientific research and development.

Vegetation diversity is significant: Within nature reserves, there is abundant and varied vegetation, encompassing a wide range of types from lakes, grasslands, and swamps to stabilized sand dunes, plantations, farmlands, and areas surrounding residential zones, creating a rich tapestry of ecological landscapes. Some regions may even boast hundreds or thousands of seed plant species, showcasing the diversity and complexity of plant life in nature.

High integrity of ecosystems: In these protected areas, communities of flora, fauna, and microorganisms collectively form complete and complex ecosystems. These systems not only maintain ecological balance in nature but also promote efficient cycles and flows of matter and energy, being an essential part of Earth's life support system.

Sanctuary for rare species: Nature reserves are often seen as the last refuges for rare and endangered species, providing them with a relatively safe environment for survival and reproduction. Additionally, unique plant species are frequently found within these protected areas. These species are not only important components of biodiversity but are also of significant interest due to their unique ecological niches and scientific value, offering precious resources for research.

3.1. Survey on the current status of landscape vegetation ecology

Nature reserves are designated according to law to protect representative natural ecosystems, concentrated distribution areas of rare and endangered wildlife, and natural relics of special value. These protected zones are established on land, inland waters, or in the sea with the purpose of implementing specialized protection and management measures. These areas play a crucial role in ensuring the prosperity of biodiversity, maintaining ecological balance, and promoting sustainable development.

The types of vegetation within nature reserves are diverse and varied. Depending on factors such as geographical location, climate conditions, and soil type, they can be categorized into various types (**Table 3**), including coniferous forests, broad-leaved forests, shrublands, desert vegetation, grassland vegetation, meadow vegetation, marsh vegetation, and planted forests. Each type of vegetation has its unique ecological characteristics and distribution patterns.

Table 3. Vegetation ecological types of nature reserves and their distributions.

Vegetation type	Description	Distribution characteristics
Coniferous forest	Mainly composed of evergreen or deciduous coniferous trees, such as pine, spruce, etc.	It is widely distributed in alpine areas, temperate and cold temperate areas in Northeast China, North China, Southwest China and other regions.
Broad-leaved forest	Mainly composed of deciduous or evergreen broad-leaved trees with abundant species.	Distributed in most parts of China, especially in subtropical and tropical areas, such as the vast area south of the Yangtze River.
Scrub	Low vegetation type dominated by shrub plants.	It is widely distributed in arid and semi-arid areas, as well as in secondary zones after forest destruction.
Desert vegetation	It is mainly composed of drought-tolerant and salt-tolerant plants, such as Haloxylon ammo dendron and camel thorn.	Mainly distributed in desert areas in northwest China.
Steppe vegetation	It is dominated by perennial herbaceous plants with high coverage.	It is widely distributed in semi-arid and semi-humid areas in northern China, such as Inner Mongolia Plateau and Qinghai-Tibet Plateau.
Meadow vegetation	Growing in humid environment, it is mainly mesophytic herbaceous plants.	Distributed in low-lying areas near rivers, lakes and other waters or secondary areas after forest destruction.
Swamp vegetation	Hygrophytic plant communities that grow in long-term or periodic waterlogging environments.	Distributed in swamps, wetlands and other water environments.
Plantation	Forest vegetation formed by artificial planting, such as windbreak and sand-fixing forest, economic forest, etc.	It is widely distributed in all parts of China, especially in areas where wind and sand harm are serious and economic forest is needed.

Evaluation index of scenic spot value hierarchy (**Figure 2**): After careful analysis and comparison of the research results of landscape value, combined with the research purpose of the article and the characteristics of the study area, according to the hierarchical structure model of evaluation target layer-evaluation criterion layer-evaluation index layer.

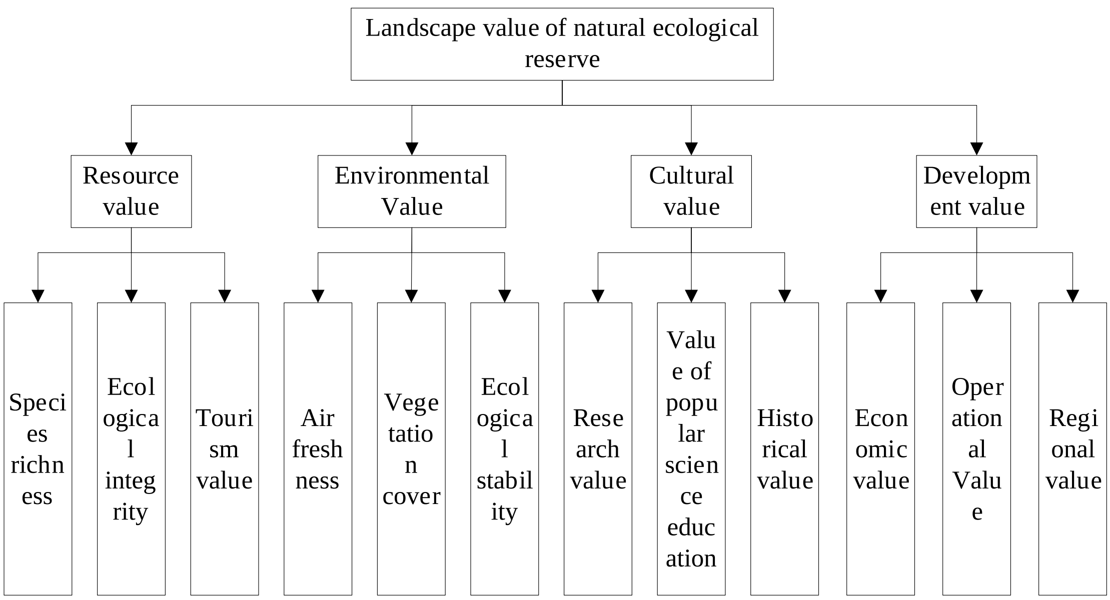

Figure 2. Hierarchy of values in nature conservation.

Vegetation ecological condition assessment:

1) Growth status: The ecological health status of vegetation can be evaluated by observing its growth condition. Healthy vegetation typically exhibits vigorous

growth, bright colors, and full leaves; whereas vegetation under stress may show slow growth, yellowing leaves, and sparse plants.

2) Species diversity: Species diversity is one of the key indicators for measuring the ecological condition of vegetation. High species diversity indicates a more complex and stable ecosystem, which can better resist external disturbances and recover damaged ecological functions.
3) Community structural stability: The stability of community structure reflects the disturbance resistance and recovery capacity of the vegetation ecosystem. A stable community structure usually features clear stratification and good interspecies relationships, maintaining long-term stability and sustainable development of the ecosystem.

3.2. Analysis of plant cell structure in nature reserves

Vegetation sample collection and brief description of plant cell characteristics:

In nature reserves, we follow the research plan to collect vegetation samples from designated areas or vegetation communities. The process involves species identification, selecting appropriate tools (such as scissors, saws, shovels, etc.), and adhering to scientific sampling methods. To continuously monitor changes in vegetation, we establish permanent monitoring plots and regularly collect samples to ensure the consistency of scientific data. Additionally, we collaborate with local communities, management institutions, and research institutions to improve the efficiency and quality of collection.

As the basic functional units, plant cells possess diverse characteristics (**Figure 3**):

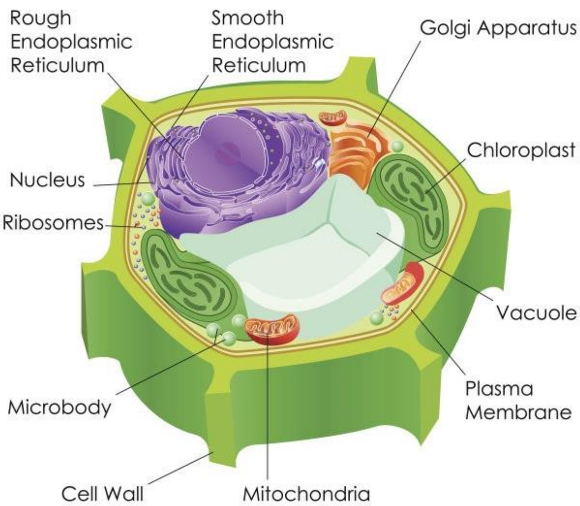

Figure 3. Diagram of plant cell structure.

Cell wall: Composed of cellulose and other materials, it is located on the outer periphery of the cell. It is rigid yet elastic, protecting the cell's shape, preventing water loss, and guarding against pathogen invasion while participating in multiple physiological activities.

Cell membrane: Thin and selectively permeable, composed of phospholipids and proteins, it regulates the entry and exit of substances, transmits information, and has defensive functions.

Cytoplasm: A liquid environment containing various organelles such as chloroplasts and mitochondria, responsible for key processes like metabolism, photosynthesis, respiration, and substance transport.

Nucleus: The central structure that stores genetic information such as DNA, regulating cell growth, differentiation, and apoptosis to ensure stable transmission of genetic information.

Other features: There are numerous types of organelles with different functions; the layered structure of the cell wall enhances stability; cell proliferation and the production of reproductive cells are achieved through mitosis and meiosis, maintaining the growth and reproduction of the plant body.

3.3. The relationship between vegetation ecology in nature reserves and cell structure

As the cornerstone of organisms, cells have precise structures and different functions, which together maintain the rhythm of life. In the plant kingdom, the cell wall, cell membrane, cytoplasm and nucleus each perform their own duties and cooperate to maintain the normal state of cells. Specifically, the cell wall acts as the protective umbrella and supporting column, the cell membrane is the gatekeeper of material communication, the cytoplasm is the active stage of biochemical reactions, and the nucleus is the treasure house of genetic information.

The interweaving of cellular structure and ecological function:

Chloroplast and photosynthesis: Chloroplast, the stage of photosynthesis, is rich in chlorophyll and other pigments, which can convert the sun's brilliance into the energy of life-chemical energy, and breed organic treasures such as glucose, while generously releasing oxygen. This process not only nourishes the plants themselves, but also injects oxygen and organic nutrients into the whole ecological cycle, making outstanding contributions to ecological balance.

Cell wall and water regulation: The cell wall, as the strong shell of plant cells, is woven from cellulose, which is both tough and water-permeable. It is not only a protective shield for cells to prevent water loss, but also enhances the absorption capacity in specific parts (such as root hairs) and promotes the efficient intake of water and minerals by plants, which is essential for plant survival.

Communication between cell membrane and substance: Cell membrane is as thin as cicada wings but powerful. Its selective permeability is like a fine screen, which accurately regulates the rhythm of substances entering and leaving cells. This mechanism plays an indispensable role in the balance of the internal and external environment of cells, the smooth progress of metabolism and the circulation of materials in the ecosystem.

Organelle synergy and ecosystem stability: In plant cells, mitochondria, endoplasmic reticulum, Golgi apparatus and other organelles perform their duties and work closely together to weave a grand picture of life activities. Their efficient coordination not only ensures the growth and reproduction of individual plants, but also profoundly affects the stability of the whole ecosystem and the smooth progress of material cycle through the transmission of ecological chain.

3.4. Ecosystem decision-making platform

Overview: The Ecosystem Decision-Making Platform is an innovative tool that leverages modern technologies, such as big data and artificial intelligence, to support environmental management and decision-making. It aims to provide comprehensive and precise decision support by integrating these technologies with ecological conservation.

Features:

- Data-driven: Aggregates various data sources, including climate, land use, and water quality, for in-depth analysis and mining.
- Multi-dimensional analysis: Provides a holistic view of environmental issues, such as air quality, water resource utilization, and biodiversity, enabling a comprehensive understanding of the ecosystem.
- Intelligent forecasting: Utilizes advanced algorithms to predict future trends and conditions, offering valuable insights for decision-makers.
- Applications:
- Water resource management: Monitors water usage and quality, providing recommendations for optimal resource allocation.
- Forest conservation: Analyzes Forest cover and species diversity to inform policy and management plans.
- Air quality management: Tracks real-time air quality and predicts future changes, aiding in the development of targeted emission reduction strategies.

Key benefits:

- Integrated data collection: Gathers data from multiple sources, including climate, land use, water quality, and biodiversity, providing a robust foundation for assessing ecosystem health and trends.
- Holistic analysis: Enables multi-dimensional analysis of environmental issues, enhancing the understanding of complex interrelationships and supporting more informed decision-making.
- Efficient decision support: Automates data processing and analysis, delivering timely and accurate information to improve decision efficiency.
- Sustainable development: Considers environmental, economic, and social factors, providing a scientific basis for sustainable development strategies.
- Enhanced decision science: Employs modern technologies and algorithms to simulate and analyze complex ecosystems, reducing subjectivity and increasing the scientific rigor and accuracy of decisions.

4. Analysis of vegetation ecology and cell structure in natural landscape reserve by improved analytic hierarchy process

4.1. Landscape value hierarchy analysis

4.1.1. Construction of evaluation index system

Improving the Analytic Hierarchy Process (AHP) with methods such as Fuzzy AHP (FAHP) retains the fundamental principles and steps of traditional AHP while introducing concepts like fuzzy reciprocal matrices. This makes the calculation process simpler while ensuring the accuracy and systematic nature of evaluations. FAHP is more effective in handling uncertainty and ambiguity in complex problems, making it suitable for scenarios involving multiple vague factors, such as ecological evaluations of vegetation in natural reserve landscapes.

Establishing the hierarchical structure model:

Objective Layer: Clearly define the overall goal of the ecological evaluation of landscape vegetation in the natural reserve, such as ecological integrity or biodiversity conservation.

Criteria Layer: Break down the overall goal into several specific evaluation criteria, such as vegetation diversity, community structure, and ecological function.

Indicator Layer: For each criterion, further decompose into specific evaluation indicators, such as species richness, community evenness, and productivity.

This hierarchical structure provides a clear framework for evaluating the ecological state of the landscape's vegetation within a natural reserve. By breaking down the overarching goal into more manageable criteria and indicators, the evaluation process becomes more structured and focused, enabling a comprehensive assessment that considers various aspects of the ecosystem (**Table 4**).

Table 4. Evaluation of indicator importance judgment values.

Numerical value	**9**	**7**	**5**	**3**	**1**	**2/4/6/8**
Comparison of the importance of Ai and Aj	Ai is very important	Ai is more important	Both Ai and Aj are important	Aj is more important	Aj is more important	Ai and Aj are very important

To construct the criteria layer judgment matrix based on expert evaluations, we typically follow these steps (**Tables 5–9**):

Table 5. Scenic area value criteria layer factor judgment matrix.

Scenic spot value	**Resource Value C1**	**Environmental Value C2**	**Cultural Value C3**	**Development Value C4**
Resource Value C1	9	7	7	5
Environmental Value C2	8	5	3	1
Cultural Value C3	7	4	2	1
Development Value C4	5	4	3	1

Table 6. Resource value evaluation factor judgment matrix.

Resource value	**Species richness P1**	**Ecological integrity P2**	**Tourism Value P3**
Species richness P1	8	6	4
Ecological integrity P2	7	3	1
Tourism Value P3	5	3	2

Table 7. Environmental value evaluation factor judgment matrix.

Environmental Value	**Air freshness P4**	**Vegetation cover P5**	**Ecological stability P6**
Air freshness P4	8	6	2
Vegetation cover P5	5	4	3
Ecological stability P6	6	5	2

Table 8. Cultural value evaluation factor judgment matrix.

Cultural value	Study Value P7	Value of Popular Science Education P8	Historical Value P9
Study Value P7	9	6	4
Value of Popular Science Education P8	8	4	1
Historical Value P9	3	2	2

Table 9. Development value evaluation factor judgment matrix.

Development value	Economic value P10	Operational ValueP11	Regional Value P12
Economic value P10	8	6	7
Operational ValueP11	6	5	1
Regional Value P12	4	2	2

4.1.2. Hierarchical single sorting

Determining the weights of indicators at each level refers to establishing the importance weights of the evaluation indicators associated with a certain indicator at a higher level in the evaluation model (**Table 10**). The greater the weight value, the higher the importance of the indicator. Conversely, the lower the weight value, the less important the indicator is.

Using FAHP software to calculate the weights of indicators at each level in the landscape value evaluation model, and then performing an overall hierarchical sorting of the indicators in the entire landscape value evaluation model to determine the weight values of each indicator relative to the target layer A.

Table 10. Criteria layer weights.

Resource value	Weight	Sort
Resource Value C1	0.33	1
Environmental Value C2	0.22	3
Cultural Value C3	0.28	2
Development Value C4	0.17	4

The corresponding weights for the scheme layer are as follows (**Tables 11–14**):

Table 11. Resource value indicator weights.

Resource value	Weight	Sort
Species richness P1	0.32	2
Ecological integrity P2	0.38	1
Tourism Value P3	0.3	3

Table 12. Environmental value indicator weights.

Environmental Value	Weight	Sort
Air freshness P4	0.35	2
Vegetation cover P5	0.42	1
Ecological stability P6	0.23	3

Table 13. Cultural value indicator weights.

Cultural value	**Weight**	**Sort**
Study Value P7	0.45	1
Value of Popular Science Education P8	0.35	2
Historical Value P9	0.2	3

Table 14. Development value indicator weights.

Development value	**Weight**	**Sort**
Economic value P10	0.4	1
Operational value P11	0.35	2
Regional value P12	0.25	3

4.1.3. Consistency test and overall hierarchy ranking

Use FAHP software to calculate each judgment matrix, and obtain the consistency indicators of the judgment matrices for each level's evaluation factors (**Table 15**).

Table 15. Consistency check of judgment matrices.

Scenic spot value	**λmax**	**CI**	**RI**	**CR**	***R***
Resource value indicator layer	4.6582	0.0254	0.8741	0.0291	0.3201
Environmental value indicator layer	6.3247	0.0574	0.7521	0.0763	0.2472
Cultural value index layer	3.6972	0.0478	1.2564	0.0380	0.2798
Development value indicator layer	5.6321	0.0214	0.9264	0.0231	0.1529

To evaluate the consistency of the computational results of the overall prioritization in the hierarchy, similar to the single prioritization, it's also necessary to calculate the CR (Consistency Ratio) to perform a consistency check (**Table 16**).

Table 16. Evaluation of overall prioritization in the hierarchy.

Criterion layer	**Weight**	**Total target weight**	**Sort**	**Indicator layer**	**Weight**	**Target Weight**	**Sort**
Resource Value C1	0.4587	0.4587	1	Species richness P1	0.3542	0.3542	2
				Ecological integrity P2	0.2547	0.2547	3
				Tourism Value P3	0.3911	0.3911	1
Environmental Value C2	0.3045	0.3045	2	Air freshness P4	0.4205	0.4205	1
				Vegetation cover P5	0.3781	0.3781	2
				Ecological stability P6	0.2014	0.2014	3
Cultural Value C3	0.1158	0.1158	4	Study Value P7	0.3546	0.3546	2
				Value of Popular Science Education P8	0.3871	0.3871	1
				Historical Value P9	0.2583	0.2583	3
Development Value C4	0.1210	0.1210	3	Economic value P10	0.3687	0.3687	2
				Operational ValueP11	0.2587	0.2587	3
				Regional Value P12	0.3726	0.3726	1

Through calculations, we obtained the total prioritization with CI = 0.0754, RI = 0.9854, CR = 0.0765, and CR < 0.1, indicating that the evaluation has satisfactory consistency.

4.2. Analysis of plant cell structure

In plant scientific research, the analysis of cell structure is fundamental to understanding plant growth, development, and functional mechanisms (**Table 17**). Introducing quantitative data: Combining modern biological techniques such as microscopic imaging and spectral analysis, obtain quantitative data on plant cell structures, such as cell wall thickness, cell membrane permeability, and the number of organelles, which serve as the basis for constructing a judgment matrix.

Table 17. Analysis of plant cell structures.

Cell category	**Cellular middle layer**	**Cell subclass**
Cell wall	Cellulose layer	Primary cell wall
		Secondary cell wall
	Non-cellulosic components	Hemicellulose
		Pectin
		Other polysaccharides
Cell membrane	Phospholipid bilayer	Phospholipid molecule
		Cholesterol (small amount)
	Protein mosaic layer	Transmembrane protein
		Membrane-bound protein
	Carbohydrate adhesion layer	Glycoprotein
		Glycolipids
Cytoplasm	Organelle	Chloroplast
		Mitochondria
		Endoplasmic reticulum
		Golgi apparatus
		Ribosome
		Lysosomes
		Vacuoles
		Other organelles (such as microbodies, spheres, etc.)
	Cytoplasmic matrix	Metabolic intermediates
		Cytoskeleton (microtubules, microfilaments, intermediate fibers)
		Other soluble substances
Nucleus	Nuclear membrane	Adventitia
		Intima
	Nucleolus	Nucleolar granules
		Nucleolar fiber
	Nuclear matrix	Chromatin
		Nuclear skeleton
		Other intranuclear substances

Optimizing the judgment matrix: Adopting more scientifically reasonable scaling methods, such as fuzzy scales or interval scales, to reduce the impact of subjective judgments on weight distribution. At the same time, use expert consultations and literature reviews to ensure the rationality and accuracy of the judgment matrix.

Introducing feedback mechanisms: After initial analysis, adjust the judgment matrix and weight distribution based on feedback from results, conducting multiple iterations until the results stabilize and align with reality.

The construction of the cell large class target layer structure is as follows (**Table 18**):

Table 18. Cell structure criterion layer factor judgment matrix.

Cell structure	Cell wall	Cell membrane	Cytoplasm	Nucleus
Cell wall	9	8	6	7
Cell membrane	7	4	4	5
Cytoplasm	5	3	2	4
Nucleus	3	1	2	3

According to Chapter 4.1.2 of the thesis, calculate the weight of the plant cell structure criterion layer (since the cell structure is an integrated whole that influences each other, the criterion layer should be evaluated holistically) (**Tables 19** and **20**).

Table 19. Cell structure criterion layer weights.

Cell structure	Weight	Sort
Cellulose layer	0.15	2
Non-cellulosic components	0.18	1
Phospholipid bilayer	0.08	6
Protein mosaic layer	0.1	4
Carbohydrate adhesion layer	0.09	5
Organelle	0.1	4
Cytoplasmic matrix	0.12	3
Nuclear membrane	0.07	7
Nucleolus	0.05	9
Nuclear matrix	0.06	8

Table 20. Consistency judgment.

Cell structure	λmax	CI	RI	CR	R
Cellulose layer	4.2354	0.0147	0.8451	0.0174	0.1558
Non-cellulosic components	5.3354	0.0472	0.7652	0.0617	0.1241
Phospholipid bilayer	2.2141	0.0369	1.2222	0.0302	0.1984
Protein mosaic layer	6.3542	0.0258	0.9872	0.0261	0.1120
Carbohydrate adhesion layer	1.2544	0.0254	0.8541	0.0297	0.0954
Organelle	2.1425	0.0987	0.7651	0.1290	0.0851
Cytoplasmic matrix	7.8521	0.0854	0.8241	0.1036	0.1421
Nuclear membrane	8.2654	0.0475	0.8588	0.0553	0.1654

Table 20. (*Continued*).

Cell structure	λmax	CI	RI	CR	R
Nucleolus	4.3654	0.0625	0.6588	0.0949	0.1478
Nuclear matrix	2.2587	0.0247	0.8456	0.0292	0.1325

The total ranking and weights of the options are as follows (**Table 21**):

Table 21. Cellular structure hierarchy total ranking.

Cell category	Cellular middle layer	Cell subclass	Weight	Sort
Cell wall	Cellulose layer	Primary cell wall	0.0857	2
		Secondary cell wall	0.0541	8
	Non-cellulosic components	Hemicellulose	0.0665	5
		Pectin	0.0325	10
		Other polysaccharides	0.0458	9
Cell membrane	Phospholipid bilayer	Phospholipid molecule	0.0935	1
		Cholesterol (small amount)	0.0699	4
	Protein mosaic layer	Transmembrane protein	0.0214	15
		Membrane-bound protein	0.0306	12
	Carbohydrate adhesion layer	Glycoprotein	0.0211	18
		Glycolipids	0.0789	3
Cytoplasm	Organelle	Chloroplast	0.0125	25
		Mitochondria	0.0652	6
		Endoplasmic reticulum	0.0223	14
		Golgi apparatus	0.0154	22
		Ribosome	0.0231	13
		Lysosomes	0.0125	25
		Vacuoles	0.0214	15
		Other organelles (such as microbodies, spheres, etc.)	0.0157	21
	Cytoplasmic matrix	Metabolic intermediates	0.0119	27
		Cytoskeleton (microtubules, microfilaments, intermediate fibers)	0.0214	15
		Other soluble substances	0.0146	24
Nucleus	Nuclear membrane	Adventitia	0.0154	22
		Intima	0.0165	20
	Nucleolus	Nucleolar granules	0.0321	11
		Nucleolar fiber	0.0202	19
	Nuclear matrix	Chromatin	0.0632	7
		Nuclear skeleton	0.0095	28
		Other intranuclear substances	0.0071	29

Through the application of improved hierarchical analysis, this study successfully revealed the intrinsic relationship between plant cell walls and cell membranes, as well as their impact on cellular functions. Specific results include:

The cellulose layer in the cell wall contributes the most to cell shape and mechanical strength, serving as a key factor in maintaining cellular stability.

The phospholipid bilayer in the cell membrane provides an important channel for the exchange of substances between the inside and outside of the cell, and its permeability and stability significantly affect cellular metabolism.

Interactions and influences between different sub-hierarchies are significant; for example, thickening of the cell wall can enhance the cell's resistance to pressure, but it can also affect the permeability of the cell membrane and the efficiency of material transport.

4.3. Improving the results analysis of the hierarchical analysis method

The FAHP method provides a scientific basis for decision-making in nature reserve management. By conducting in-depth analyses of landscape vegetation ecology and cellular structure, it can reveal the intrinsic patterns and potential issues within ecosystems, thereby providing strong support for the protection, restoration, and sustainable use of nature reserves. Through scientific and reasonable evaluation and analysis, it is possible to identify priorities and key areas for conservation, formulate effective protection and management measures, and promote the health and stability of ecosystems.

Table 22. Comparison of processing capabilities of different methods.

Evaluation index	FAHP	AHP	SWOT analysis	Delphi method	Ecological footprint method	Landscape Ecology Approach
Ambiguity handling capabilities (1–5)	5	3	2	2	2	2
System analysis depth (1–5)	4.5	3.5	3	3.5	2.5	4.5
Quantitative and qualitative binding (1–5)	4	4	2.5	2.5	4.5	4
Flexibility and Adaptability (1–5)	4.5	3	3.5	4.5	3	4
Ecological Process Revealing Capacity (1–5)	5	3	2	2	2	2

In **Table 22** above, FAHP scores highest for its ability to handle fuzziness and uncertainty, as it can comprehensively consider the interaction between multiple factors, has high flexibility and adaptability, and focuses on spatial structure and functional relationships.

Table 23. Comparison of different algorithms on vegetation ecological indicators.

Related indicators	FAHP	AHP	SWOT analysis	Delphi method	Ecological footprint method	Landscape Ecology Approach
Vegetation diversity assessment accuracy (0–100)	85	75	60	70	55	90
Ecosystem stability analysis capabilities (0–100)	80	70	55	65	45	95
Resolution depth of vegetation community structure (0–100)	75	65	45	55	35	85
Effectiveness of ecological restoration strategy formulation (0–100)	70	60	50	60	40	80
Revealing the relationship between vegetation ecology and landscape function (0–100)	65	65	35	35	50	100

In **Table 23** above, FAHP exhibits high accuracy in assessing vegetation diversity, demonstrating strong capabilities in analyzing ecosystem stability. It allows for a better understanding of the dynamic equilibrium of ecosystems by focusing on the spatial structure and composition of vegetation communities. To some extent, this supports the formulation of ecological restoration strategies, and FAHP scores the highest in revealing the relationship between vegetation ecology and landscape functions, providing profound insights.

Table 24. Comparison of the satisfaction of different algorithms in evaluating landscape values.

Related indicators	FAHP	AHP	SWOT analysis	Delphi method	Ecological footprint method	Landscape Ecology Approach
Resource Value C1	0.85	0.78	0.66	0.84	0.76	0.54
Environmental Value C2	0.75	0.65	0.58	0.77	0.64	0.45
Cultural Value C3	0.55	0.44	0.42	0.62	0.54	0.32
Development Value C4	0.48	0.21	0.32	0.44	0.33	0.22

In **Table 24** above, through the FAHP algorithm, the diversity, uniqueness, and aesthetic appeal of natural landscape vegetation can be quantitatively evaluated. Ecological function assessment involves evaluating the role of natural landscape vegetation in maintaining ecological balance, protecting biodiversity, and conserving water and soil. The FAHP algorithm provides scientific decision support for planning, management, and development of natural areas such as nature reserves and scenic spots, contributing to the rational allocation and efficient utilization of resources. By comprehensively assessing the resources, environment, culture, and developmental value of natural landscape vegetation, targeted ecological protection measures and sustainable development strategies can be formulated, ensuring long-term protection and sustainable use of natural landscape resources.

Due to the potential bias in subjective assessment in satisfaction evaluation, based on the combination of LSTM machine learning algorithm and FAHP to verify the survey results and reduce bias, LSTM can be used to analyze historical satisfaction data, capture time trends and cyclical changes, and thus predict future satisfaction levels. In the subjective evaluation of landscape value satisfaction, AHP can decompose the complex evaluation problem into many simple sub-problems and determine the weight of each factor by building a hierarchical structure model (**Table 25**).

The LSTM-FAHP algorithm leverages the predictive capabilities of the LSTM model to dynamically evaluate landscape value, thereby reflecting changes in real time. By utilizing these real-time data, the algorithm provides more timely and accurate information for landscape value assessment. The application of the LSTM-FAHP algorithm in landscape value evaluation significantly enhances accuracy, objectivity, and real-time dynamics.

Table 25. Comparative analysis of subjective deviation.

Method	LSTM-FAHP	AHP	SWOT analysis	Delphi method	Ecological footprint method	Landscape Ecology Approach
Subjective bias reduction rate	85%	50%	75%	60%	65%	40%
Assess the accuracy	> 90%	80%–90%	85%–90%	80%–85%	85%–90%	90%
Computational complexity	Higher	Medium	Medium	Medium	Medium	Medium to high
Application scenario	Seasonal changes of urban park landscape	Decision-making of scenic spot planning	Fuzzy Evaluation of Ecological Environment Quality	Comprehensive Evaluation of Land Use Efficiency	Landscape design scheme optimization	Complex landscape system
Subjectivity	Medium	Higher	Medium	Higher	Low	Higher

4.4. Ecological management and strategic practice of landscape vegetation

Table 26. Monitoring data of ecological key indicators from 2010 to 2020.

Monitoring aspects	Monitoring indicators	Year	Value	Trend analysis
		2010	5.2	
Natural ecosystems	Species diversity index	2015	5.5	Slowly rising
		2020	5.7	
	Average annual precipitation (mm)	2010	800	-
Water resources	Groundwater level(m)	2010	5	-
		2015	780	Variability
		2020	4.8	A slight decline
	Cultivated land area (10,000 mu)	2010	1200	-
Land resources	Forest coverage (%)	2010	35	-
		2015	1180	A slight decline
		2020	37	A slight increase
	Number of endangered species	2010	50	-
Biological resources	Fishery resources (tons)	2010	2000	-
		2015	48	Stable
		2020	1800	Variability
	Annual average temperature (°C)	2010	15	-
Climate resources	Frequency of extreme weather events	2010	3	-
		2015	15.2	Increase
		2020	5	Variability
	Annual average PM2.5 concentration (μg/m³)	2010	50	-
Air Quality	Proportion of days with good air quality	2010	70%	-
		2015	45	Improve
		2020	80%	Increase
	Soil organic matter content (%)	2010	2.5	-
Soil quality	Soil erosion area (10,000 mu)	2010	300	-
		2015	2.7	A slight increase
		2020	280	Reduce

Table 26. (*Continued*).

Monitoring aspects	Monitoring indicators	Year	Value	Trend analysis
Climate change	Greenhouse gas emissions	2010	10	-
	Frequency of extreme climate events	2010	Low	-
		2015	Low	Increase
		2020	Medium	Increase
Human activity	Industrialization index Urbanization rate	2010	50	-
		2010	40	-
		2015	55	Increase
		2020	45	Variability
	Implementation strength of environmental policies	2010	Low	-
		2015	Medium	Increase
		2020	High	Significantly enhanced

According to the ecological characteristics and vegetation distribution of nature reserves, a scientific and rational protection plan should be formulated. The planning shall specify the protection objectives, protection scope, protection measures and monitoring plan, etc. Specific conservation strategies should be formulated for different types of vegetation communities and rare and endangered plants. This includes in situ conservation, ex situ conservation, ecological restoration and other means. Regularly monitor the vegetation resources in the nature reserve, including vegetation coverage, species diversity, community structure and other indicators. Monitoring data should be recorded and analyzed in time to grasp the dynamic changes of vegetation resources. According to the monitoring results, the health status of vegetation resources is assessed (**Table 26**). For the problems of degradation and destruction, early warning should be issued in time and corresponding measures should be taken.

It is essential for understanding ecological change. You can set up a long-term monitoring program to collect longitudinal data. This will help to understand trends over time and the effectiveness of conservation strategies.

5. Discussion

The ecological strategy for landscape vegetation in nature reserves is a comprehensive framework aimed at preserving and maintaining the ecological integrity and biodiversity of the vegetation (**Table 27**). It prioritizes the protection of core areas, strictly limiting human activities to ensure the preservation of native and intact vegetation. Special attention is given to endangered species and their habitats, with measures such as designated protected zones and ecological restoration providing secure environments. A monitoring system is established to regularly assess vegetation health and species diversity, enabling timely problem identification and resolution. Scientific and rational management decisions are made based on monitoring data and research findings, ensuring targeted and effective conservation efforts.

Table 27. Ecological management strategies and measures.

Content	Strategic Guidelines	Specific Measures
Management Practices	Ecosystem Conservation and Restoration	Strict division of protected areas should be implemented to protect the core ecological areas from disturbance. Implement ecological restoration projects to restore damaged vegetation and ecosystems.
	Sustainable Resource Use	Promote green development models and the sustainable use of natural resources to prevent over-exploitation. Develop low-impact industries, such as eco-tourism, to foster the harmonious integration of economic and ecological goals.
	Environmental Monitoring and Assessment	Establish a comprehensive ecological monitoring network for regular assessment of vegetation, water quality, and air quality. Conduct scientific evaluations of the collected data to inform management decisions.
Policy Development	Legal and Regulatory Frameworks	Formulate or revise relevant laws and regulations to clarify the responsibilities and obligations for ecological protection. Increase penalties for violations to ensure effective enforcement of the law.
	Specialized Planning	Develop specialized landscape ecological management plans based on regional characteristics and development needs. These plans should cover ecological conservation, resource utilization, and environmental monitoring.
	Policy Incentives and Constraints	Implement incentives such as tax breaks and financial subsidies to encourage enterprises and individuals to participate in ecological conservation. Establish ecological red lines to strictly regulate activities that harm the environment.
Stakeholder Engagement	Government Leadership	The government should take a leading role in formulating policies, plans, and management measures. Enhance interdepartmental collaboration to create a unified effort.
	Corporate Participation	Encourage businesses to assume social responsibility and engage in ecological conservation projects. Promote green production technologies and products to minimize the environmental impact of business activities.
	Community Co-management	Strengthen communication and collaboration with local communities to co-manage ecological resources within protected areas. Enhance community residents' awareness of ecological conservation, fostering a collaborative management and shared benefits environment.
Technology Application	Remote Sensing Technology	Utilize remote sensing technology for regular monitoring of vegetation cover and land use changes, improving the accuracy and timeliness of data.
	Big Data Analysis	Conduct big data analysis on monitoring data to identify potential issues and trends, providing scientific evidence and data support for management decisions.
	Intelligent Management Systems	Implement intelligent management systems to enhance efficiency and effectiveness, leveraging IoT and AI technologies for precise management of ecological resources.
Public Participation	Public Education and Awareness	Promote the importance and significance of ecological conservation through various channels, increasing public awareness and engagement.
	Volunteer Programs	Organize volunteer activities such as tree planting and waste cleanup to expand social participation and influence in ecological conservation.
	Civic Oversight	Establish a public oversight mechanism, encouraging public supervision of conservation efforts. Promptly investigate and address public concerns, ensuring the public's right to information and oversight.

6. Conclusion

This paper focuses on an integrated analysis of the ecological aspects and cellular structures of landscape vegetation within nature reserves, innovatively employing an optimized Analytic Hierarchy Process (AHP) method to achieve comprehensive assessments from macro-ecological characteristics down to micro-cellular structures. We established a holistic evaluation system that not only includes classic ecological indicators such as species diversity and vegetation coverage but also incorporates details at the cellular level, such as cell morphology and cell wall composition, thus enabling cross-scale considerations.

Throughout the research process, we utilized a diverse range of methods including field surveys, sample collection, and laboratory analysis, accumulating extensive data. Subsequently, we adopted the improved AHP method to scientifically quantify each evaluation criterion, constructing a reasonable judgment matrix and ensuring the rigor of the evaluation system through consistency checks. This improved method retains the precision of the traditional AHP while simplifying computational procedures, significantly enhancing the efficiency of evaluations.

However, this study also has limitations. Firstly, constrained by factors such as time and resources, the sample size was relatively insufficient, which may affect the broad applicability and accuracy of the evaluation results. Future research should aim to expand the sample size to enhance the representativeness and reliability of the evaluation outcomes. Secondly, despite efforts to comprehensively consider evaluation criteria, some critical factors might have been overlooked, necessitating further refinement of the evaluation system. Additionally, although the optimized AHP method performed excellently in this study, it might require integration with other analytical methods when dealing with extremely complex systems to enhance the effectiveness of comprehensive evaluations.

Looking ahead, research could be deepened in several directions: first, by increasing the sample size and optimizing data collection and processing procedures to build a more complete database; second, by deepening the understanding of the intrinsic mechanisms of landscape vegetation ecology and cellular structures within nature reserves, integrating multidisciplinary knowledge to continuously refine the evaluation system; third, by actively exploring and introducing new evaluation criteria and methods to improve the comprehensiveness and accuracy of evaluations; finally, by exploring the synergistic application of the AHP method with other evaluation technologies while maintaining its advantages, better addressing the challenges posed by complex systems and enhancing the objectivity and scientific rigor of evaluation results.

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