Article

Evaluation of Rural Landscape Resources Based on Cloud Model and Probabilistic Linguistic Term Set

Weiwen Li ¹, Yijiang Zhou ² and Ge Xun ^{3,*}

¹ College of Landscape Architecture, Central South University of Forestry and Technology, Changsha 410004, China; 20181200161@csuft.edu.cn

² School of Business Administration, Hunan University, Changsha 410082, China; zhouyijiang1999@hnu.edu.cn

³ School of Economics, Central South University of Forestry and Technology, Changsha 410004, China

* Correspondence: xunge6486999@163.com

Abstract: Rural landscape resources are important ingredients of rural revitalization and modernization in developing countries and regions. Evaluation methods play a crucial role in the development planning, design, transformation, and protection of these resources. However, there has been a lack of research on the evaluation of rural landscape resources, especially from the perspective of rural revitalization. Based on previous evaluation methods and expert consultations on landscape planning and design, we proposed a new approach for evaluating rural landscape resources by establishing a new index system and using the Analytic Hierarchy Process (AHP) and probabilistic linguistic Cloud Model. To demonstrate its applicability and effectiveness, we applied our model to the case of a village (Xiapu) in Guangdong, China, determined the parameter set of its rural landscape resources, and obtained related results showing that the method is practical and can reflect the value of resources objectively and efficiently. Based on this model, further suggestions are provided to improve the design and other utilizations of rural landscape resources.

Keywords: rural revitalization; rural landscape resources; evaluation methods; probabilistic linguistics; Analytic Hierarchy Process (AHP); Cloud Model

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1. Introduction

According to the Council of Europe Landscape Convention (CELC), a landscape is a perceived area characterized as the result of the action and interactions of natural and/or human factors. The landscape is an essential part of people's surroundings, an expression of the diversity of their shared cultural and natural heritage, a key element of the individual and social well-being, and the foundation of their identity [1]. It is also an important paradigm in sustainable development, with the aim of harmonious integration of social, economic, and environmental factors in space and time. Landscapes are being promoted at the global level by important institutions, such as UNESCO (United Nations Educational, Scientific and Cultural Organization) and the IUCN (International Union for Conservation of Nature), and through key regional directives and policies, such as the ELC (European Landscape Convention) and the CAP (Common Agricultural Policies) of Europe [2].

The rural landscape is usually defined as the landscape outside a town, consisting of natural landscape and agricultural production [3]. It includes a variety of geological and geographic features such as cropland, forests, deserts, swamps, grasslands, pastures, rivers, and lakes [4]. The rural landscape is not only the earliest landscape that appeared but also the most distributed one in the world [3]. After a long period of natural evolution and human management practices, environmental and social factors have interacted with each other and led to all kinds of complex rural landscapes [5].

The rural landscape provides natural resources and greenery to our living environment and maintains ecological equilibrium. It is also an important link between urban and rural areas, a possible cure for metropolitan health issues, and an essential source for tourism

and rural modernization [6]. Therefore, rural landscapes play a key role in integrating human civilizations with natural environments and consolidating urban-rural relationships and prosperities [7–12].

The main content of the rural landscape is the rural agricultural landscape [13]. Since the 1950s, the intensification and expansion of modern agriculture have changed agricultural landscapes across Europe [14]. The CAP has impacted the evolution of European agricultural landscapes by driving changes in land use and farming practices [15]. According to the CAP, agri-environmental schemes focus on the maintenance and improvement of the agricultural landscape [16]. In some developing countries, rural revitalization is a strategy that promotes sustainable rural development and represents an inevitable trend toward global urbanization. The implementation of rural revitalization strategies is foundational to a modern economic system in developing countries. Rural revitalization requires that rural living environments should be improved, rural culture preserved, and rural industry promoted. It is crucial that the planning, design, development, transformation, and protection of the rural landscape follow the guidance of the rural revitalization strategy and policy and, more importantly, should be based on a comprehensive and accurate evaluation of landscape resources. Therefore, quantitative methods and results are indispensable in the study of the evaluation of rural landscape resources. Rural landscape resources are composed of the natural environment, agricultural activities, and natural, historical, and cultural factors of rural settlement in landscape form. (Rural landscape resources are composed of the natural environment, agricultural activities, historical and cultural factors of a rural settlement in landscape form). Their evaluation categories include the type, quality, structure, distribution, development, and utilization of landscape resources. Different scholars have evaluated the rural landscape resources from different perspectives, including experience evaluation [17], landscape features evaluation [18], aesthetic quality evaluation [19], visual aesthetic evaluation [20], visual quality evaluation [21], rural amenity resources [22], and so on. Various evaluation methods for rural landscape resources have been developed in the last few decades. These include single factor evaluation methods [23], fuzzy comprehension evaluation methods [24], AHP (Analytic Hierarchy Process) methods [25], and so on. Most evaluation methods focus on a single factor. For example, Wang and Deng (2016) constructed a comprehensive evaluation index of the rural landscape from the perspective of AVC (attraction, validity, and capacity) and evaluated a village in China [25]. Junge (2015) researched the influence of single agricultural landscape elements in different seasonal stages on landscape aesthetics, and the aesthetic preferences of Swiss residents for typical agricultural landscape elements in the Swiss lowlands were investigated by a photo survey [19]. Saronson (2007) identified landscape features in Indonesia and evaluated the environmental quality. It has been believed that the evaluation of landscape resources is usually affected by personal opinion, and there is a lack of quantitative processing of indicators when indicators are determined [18]. Panek (1997) analyzed agricultural landscape resources in the western region of Poland through climatic factor analysis and constructed appropriate landscape resources evaluation indicators [26].

At present, the evaluation of landscape resources in existing research focuses on the evaluation of tourism resources and visual aesthetics. There is a lack of research on the evaluation of the value of rural landscape resources from the perspective of rural revitalization.

Some of the previous methods can certainly be used to evaluate rural landscape resources; nevertheless, they usually neglect the uncertainties in the evaluation process and hence, cannot be transformed into effective and simple models. One of the solutions to this problem is to use the fuzzy sets theory, in which the uncertainty of the index system can be divided into fuzziness and randomness. As the main tool to tackle fuzzy problems, fuzzy sets theory portrays the uncertainty of fuzzy things by the degree of membership [27]. However, the concept of fuzzy is no longer fuzzy when it is introduced into the field of mathematics. About this problem, Li et al. propose a transition model of uncertainty between quality and quantity based on traditional fuzzy set theory and probability statistics: the Cloud Model [28]. They demonstrated that the knowledge

representation and reasoning method of the Cloud Model could fully express the vagueness and randomness of uncertain knowledge and exhibits greater objectivity, which makes it possible to solve the problem of information loss in the process of information aggregation to a certain extent. The outstanding advantage of the Cloud Model lies in the randomness of membership and the inherent relationship between fuzziness and randomness, and it is an effective tool for dealing with the two [29]. Through the three mathematical characteristics of expectation, entropy, and hyper-entropy described by the Cloud Model, the conversion between qualitative and quantitative linguistics can be realized. After decades of research and development, the application of the Cloud Model has become increasingly extensive. The Cloud Model has many applications in various fields and has become a useful tool to deal with fuzziness and randomness. With the gradual maturity of cloud theory, more and more applications on Cloud Models emerge, such as online review analysis, energy assessment, supplier selection, plant siting, etc. The affiliation cloud enables the conversion between exact and value values by combining fuzziness and randomness. The value evaluation results can be expressed by the affiliation cloud to achieve a comprehensive evaluation of the effectiveness of rural landscape resources through uncertainty inference of the Cloud Model.

In this paper, we proposed a model based on the Cloud Model and the Probabilistic Linguistic Term Set (PLTS), which can solve the problem of the previous models in neglecting the evaluation of uncertainty. We then applied our model to a specific case—By analyzing the data sets provided by rural landscape resources of Xiapu Village in Guangdong, China, we evaluated the current rural landscape resources of Xiapu Village in specific areas, analyzed the evaluation results, and obtained an overall level for its rural landscape resources. Although this is an application of our model to a small village, it is not hard to generalize this model by incorporating more indicators and parameters to handle evaluation tasks with large scales and tackle more challenging evaluation questions. The quantitative results from the model can be considered important references that provide valuable suggestions for the further development, planning and design, transformation, and protection of the rural landscape at the practical level.

The rest of this paper is organized as follows: Section 2 illustrates the methodology of our model-building. Section 3 contains the results of applying our model to the case of Xiapu Village in Guangdong, China. Discussions are given in Section 4, and conclusions are drawn in Section 5.

2. Methods

2.1. Cloud Model

Cloud is an uncertainty transition model between some qualitative concepts and their quantitative expression in terms of the natural language value. In other words, the Cloud Model is an uncertainty model used to realize the transition between quality and quantity [30]. A Cloud is used to compare to an uncertainty mapping between quantity and quality. A Cloud can be formed by combining many Cloud drops, which individually may look insignificant, but the whole shape of the Cloud reflects the important characters of the quantity [31].

Assume that there is a set of evaluation attributes that are exactly represented on the quantitative universe U and that there is a corresponding qualitative fuzzy concept. There is an arbitrary ($m = 1, 2, \dots, n$) corresponding membership degree in the universe U , which is a stable random value and can reflect the certainty of attribute x . Then, the distribution of x on U is a Cloud. The Cloud can be expressed as: $C = (Ex, En, He)$ where each component of C has the following meaning, respectively.

Expected value Ex is the expectation and represents the center value of the corresponding qualitative concept linguistic domain.

Entropy En is a measurement of the fuzziness of qualitative concepts, reflects the numerical range that can be accepted by this concept in the theory field, and embodies the uncertain margin of the qualitative concept.

Hyper Entropy He reflects the dispersion degree of cloud droplets and measures randomness. The bigger the Hyper Entropy is, the bigger of its dispersion and the randomness of the degree of membership, and so is the Cloud's thickness.

Therefore, the fuzziness (the uncertainty of qualitative concept) and randomness (randomness of the degree of membership) are completely combined together by three characteristic numbers of the Cloud Models, which make up the mapping between quality and quantity as the foundation of knowledge expression.

2.2. Linguistic Scaling Function

In the linguistic assessment scale, the semantic absolute deviation between any two adjacent linguistic terms may increase or decrease with an increase in linguistic subscripts. To reflect this situation, Bao et al. [32] introduced the linguistic scaling function (LSF).

Suppose there is a linguistic term $s_i \in S$ in which $S = \{s_i | i = 1, 2, \dots, 2t + 1\}$. When $\theta_i \in [0, 1]$ represents a value, LSF is defined from s_i mapping to θ_i as follows:

$$H : s_i \rightarrow \theta_i (i = 1, 2, \dots, 2t + 1) \quad (1)$$

LSF is a strictly monotonic function that is currently used in two linguistic-scaling functions as follows:

$$LSF_1 = H_1(s_i) = \theta_i = \begin{cases} \frac{a^t - a^{t-i+1}}{2a^t - 2} (i = 1, 2, \dots, t + 1) \\ \frac{a^t + a^{t-i-1} - 2}{2a^t - 2} (i = t + 2, t + 3, \dots, 2t + 1) \end{cases} \quad (2)$$

$$LSF_2 = H_2(s_i) = \theta_i = \begin{cases} \frac{t^\alpha - (t-i+1)^\alpha}{2t^\beta} (i = 1, 2, \dots, t + 1) \\ \frac{t^\beta + (i-t-1)^\beta}{2t^\beta} (i = t + 2, t + 3, \dots, 2t + 1) \end{cases} \quad (3)$$

The LSF1 is defined according to the exponential scale, taking different parameters α , different types of exponential scales can be obtained. Through a large amount of experimental investigation data, α can be subjectively valued at 1.37 [32]. When the LSF2 is proposed based on prospect theory [33], the α and β values can be 0.88 [34].

2.3. Probabilistic Linguistic Term Sets

Owing to the complexity of society, experts may feel comfortable using Linguistic Term Sets (LTSs), such as "good" and "poor", to express their opinions rather than crisp numbers. In many cases, experts are hesitant in the use of their words and may wish to use many linguistic terms to express their opinions. Especially for group decision-making processes, different experts may express many different opinions using many different terms for even one evaluation. For example, if there are three experts to evaluate a car, their opinions may range from "good" to "poor". Pang et al. proposed the definition of Probability Linguistic Term Sets (PLTS) [35].

Let $S = \{s_1, s_2, \dots, s_{2t+1}\}$ be a finite and completely ordered discrete linguistic term set with odd elements, then a probabilistic linguistic term set $T(p)$ is defined as follows:

$$T(p) = \{t_i(p_i) | t_i \in S, 0 \leq p_i \leq 1, i = 1, 2, \dots, \#t, \sum_{i=1}^{\#t} p_i \leq 1\} \quad (4)$$

where $t_i(p_i)$ is a linguistic item associated with probability value p_i , and $\#t_i$ represents the number of elements in $T(p)$.

Based on the idea of prospect theory [36], a new preference value function is proposed for PLTS by considering the limited rationality of experts. For an evaluation value, different experts may make different subjective judgments due to their risk-preference attitudes. The preference value function is an effective way to convert the evaluation value into a preference value.

2.4. Evaluation Index Selection of Rural Landscape Resources

In this study, the literature research and the Delphi methods were adopted based on the relevant literature and expert consultation. Finally, an evaluation system of rural landscape resources was established (see Table 1).

Table 1. Evaluation index system of rural landscape resources.

Evaluation Target	Evaluation Dimension	Evaluation Index	Indicator Source
Evaluation index of rural landscape resources A	Environmental value B1	Landscape ecological value C1	Yang, D. et al. (2014) [37]
		Landscape environmental protection degree C2	Wang, J.L. et al. (2013) [38] Cai, Z.R. et al. (2021) [39]
		Environmental cleanliness degree C3	Liu, R. et al. (2021) [40]
		Environmental fusion degree C4	(Obtained from CELC and expert consultations)
		Geographical location value C5	Kristensen, S.B.P. et al. (2016) [41]
	Social value B2	Rural livability C6	Dissanayake, D. et al. (2018) [42]
		Attribution value C7	Ian, C.M. et al. (2013) [43]
		Historical heritage value C8	Tengberg A. et al. (2012) [44] Dupont, L. et al. (2013) [45]
		Educational memorial value C9	Irina-Maria, N. et al. (2015) [46] Enslin, P., (2020) [47]
		Social popularity C10	Prakash, K., (2016) [48]
	Economic value B3	Cultural value C11	Janet, S., (2007) [49] Koen, F. et al. (2017) [50]
		Agricultural production value C12	Mara, T. et al. (2013) [51]
		Rural tourism value C13	Kaswanto (2015) [52]
	Landscape value B4	Sustainable development value C14	Cerreta, M. et al. (2014) [53]
		Landscape type richness C15	Oehri, J. et al. (2020) [54]
		Landscape quantity richness C16	(Obtained from CELC and expert consultations)
		Landscape uniqueness C17	Zelinsky, W., (2001) [55], Asrina, M. et al. (2017) [56]
		Landscape integrity C18	Walston, L.J. et al. (2018) [57] Rasouli, S. et al. (2012) [58]
		Landscape artistic value C19	Chen, Y. et al. (2016) [59]
		Landscape aesthetic value C20	Yang, D. et al. (2014) [37] Tribot, A.S. et al. (2018) [60]

We set up a 3-layer index. The first layer is the evaluation target, the second layer is the evaluation dimension, and the third layer is the evaluation factor.

The second layer includes the following indicators: environmental value B1, social value B2, economic value B3, and landscape value B4. The third layer includes 20 indicators C1, C2 ... C20, such as landscape ecological value, attribution value, rural production value, and landscape type richness.

These evaluation indicators are all 5 levels. The score of each question ranges from 1 to 5. The meanings of different scores are as follows: 1 is “very poor”, 2 is “poor”, 3 is “fair”, 4 is “good”, and 5 is “very good”.

2.5. Construction of the Rural Landscape Resources Value Evaluation Model

The Analytic Hierarchy Process (AHP) is a simple method for analyzing non-quantitative events using quantitative analysis, which is very effective in systems analysis and scientific decision-making. Landscape resources are complex and have multiple value attributes, and

different factors have varying levels of importance. Concurrently, in the existing evaluation system research, AHP is the most commonly used method, which is consistent with the purpose of this study; therefore, this study intends to use AHP to determine the weight of rural landscape resources value evaluation index.

The former evaluation models include factor analysis, fuzzy comprehensive evaluation, and the entropy weight method. Because the evaluation index established in this study is difficult to quantify, the evaluation object itself is fuzzy, the content is complex, and it has the characteristics of a multi-layer structure. Moreover, the subjectivity of expert knowledge must be considered as well as the potential inadequate mastery of known information; therefore, this paper introduces the Probabilistic Linguistic Term Set (PLTS), which can not only comprehensively depict the evaluation preference of decision-makers but also quantify the preference degree so that the decision results are more reliable and practical. In addition, the existing research on PLTSs inevitably involves the loss and distortion of probabilistic linguistic information [61]; thus, existing methods cannot effectively deal with the decision information of PLTSs. Therefore, this study introduces a probabilistic linguistic cloud to address decision-making problems.

Based on the theory of AHP and the probabilistic linguistic Cloud Model, we now build a comprehensive evaluation system of the AHP-probabilistic linguistic Cloud Model. The specific steps for constructing this model are detailed as follows.

Step 1: Expert comment conversion into probabilistic linguistic information

Assuming that there are n evaluation indexes to form a set $C = \{c_1, c_2, \dots, c_n\}$, the expert scoring set under the index is determined as $S = \{s_1, s_2, \dots, s_m\}$. Assuming that there are K experts $V = \{v_1, v_2, \dots, v_k\}$, the probability linguistic evaluation matrix of expert evaluations can be obtained using the comment set S to evaluate n evaluation indexes $H = (h_i)_{m \times n} = (t_i(p_i))_{m \times n} = (He_i, \underline{En}_i, Ex_i, \overline{En}_i, \overline{He}_i)$. According to the evaluation system, the Cloud Model interval is divided into $[0, 10]$, and the corresponding domain is $[X_{\min}, X_{\max}]$.

- (1) Calculate the value of linguistic terms θ according to the linguistic scale function. According to the experimental results of Chen et al. [34], different LSFs do not affect the final experimental results; to facilitate the calculation, LSF1 is selected as the linguistic scale function.
- (2) Calculate Ex_i , $Ex_i = X_{\min} + \theta_i(X_{\max} - X_{\min})$;
- (3) Calculate $\underline{En}_i$ and $\overline{En}_i$,
 $\underline{En}_1 = 0, \underline{En}_i = (Ex_i - Ex_{i-1})/3, \overline{En}_{2t+1} = 0, \overline{En}_i = (Ex_{i+1} - Ex_i)/3$;
- (4) Calculate $\underline{He}_i$ and $\overline{He}_i$, $\underline{He}_i = \frac{\max\{\max_i\{\underline{En}_i\} - \underline{En}_i, \underline{En}_i - \min_i\{\underline{En}_i\}\}}{3}$,
 $\overline{He}_i = \frac{\max\{\max_i\{\overline{En}_i\} - \overline{En}_i, \overline{En}_i - \min_i\{\overline{En}_i\}\}}{3}$;

Step 2: Probabilistic linguistic cloud Z design

$$Z = (\underline{he}, \underline{en}, ex, \overline{en}, \overline{he}) = (\sqrt{\sum_{i=1}^{\#t} \underline{He}_i^2 p_i^2}, \sqrt{\sum_{i=1}^{\#t} \underline{En}_i^2 p_i^2}, \sum_{i=1}^{\#t} Ex_i^2 p_i^2, \sqrt{\sum_{i=1}^{\#t} \overline{En}_i^2 p_i^2}, \sqrt{\sum_{i=1}^{\#t} \overline{He}_i^2 p_i^2})$$

Step 3: Determining index weight

Obtain the expert's accurate scoring value for each level of the rural landscape resources evaluation index system. According to the AHP, calculating the corresponding index weight vector $W = (w_1, w_2, \dots, w_i)$ and $w_i \in [0, 1]$, $w_1 + w_2 + \dots + w_i = 1$.

Step 4: Comprehensive evaluation information calculation

- (1) According to the index weight obtained in Step 3, the probabilistic linguistic cloud for each factor C can be calculated. The relevant operation rules of the probabilistic linguistic cloud are as follows:

$$\begin{aligned} Z_i + Z_j &= (\sqrt{he_i + he_j}, \sqrt{en_i + en_j}, ex_i + ex_j, \sqrt{en_i + en_j}, \sqrt{he_i + he_j}) \\ \lambda Z_i &= (\sqrt{\lambda}he_i, \sqrt{\lambda}en_i, \lambda ex_i, \sqrt{\lambda}en_i, \sqrt{\lambda}he_i) \end{aligned} \quad (5)$$

- (2) According to the Probabilistic Linguistic Integrated Cloud Weighted Heronian Mean (PLICWHM) operator, the comprehensive evaluation information under each factor is obtained. The calculation formula for PLICWHM is as follows:

$$\begin{aligned} PLICWHM(z_1, z_2, \dots, z_q) &= \sum w_i z_i \\ &= (\sqrt{\sum_{i=1}^q (w_i he_i)^2}, \sqrt{\sum_{i=1}^q (w_i en_i)^2}, \sum_{i=1}^q w_i ex_i, \sqrt{\sum_{i=1}^q (w_i en_i)^2}, \sqrt{\sum_{i=1}^q (w_i he_i)^2}) \end{aligned} \quad (6)$$

Here, q is the number of indicators at this level, and w_i is the weight of these indicators.

Step 5: Similarity comparison

The comprehensive Cloud Model and the model of each attribute in the standard cloud are compared to obtain a standard evaluation cloud that is the most similar. The qualitative evaluation corresponding to the evaluation cloud is the result of computing this index factor. The distance measure formula is as follows:

$$\begin{aligned} d(Z_i, Z_j) &= \frac{1}{2} \left(\left| \left(1 - \frac{en_i^2 + he_i^2}{en_i^2 + he_i^2 + en_j^2 + he_j^2} \right) ex_i - \left(1 - \frac{en_j^2 + he_j^2}{en_i^2 + he_i^2 + en_j^2 + he_j^2} \right) ex_j \right| \right. \\ &\quad \left. + \left| \left(1 - \frac{en_i^2 + he_i^2}{en_i^2 + he_i^2 + en_j^2 + he_j^2} \right) ex_i - \left(1 - \frac{en_j^2 + he_j^2}{en_i^2 + he_i^2 + en_j^2 + he_j^2} \right) ex_j \right| \right) \end{aligned} \quad (7)$$

If $(a_t = b_t = 0)(a_t = en_t, \overline{en}_t; b_t = he_t, \overline{he}_t; t = i, j)$, then $\frac{a_i^2 + b_i^2}{a_i^2 + b_i^2 + a_j^2 + b_j^2} = 0$ and $\frac{a_j^2 + b_j^2}{a_i^2 + b_i^2 + a_j^2 + b_j^2} = 0$.

To demonstrate our method and verify the model, we will take an example, which is the evaluation of rural landscape resources in a village in Guangdong (Xiapu Village), China, in the next section (Section 3). A detailed analysis will be given there, and the values of evaluation parameters will be determined. The original data sets are available on the authors' website.

Duozhu Town is a tourist-oriented town featuring the development of rural tourism and ecological agriculture in Guangdong Province, China. It is also the gateway to the northern mountainous region of Huidong County and a distribution base for agricultural and trade products. The object of our study is Xiapu Village, which is located in Duozhu Town (Figure 1). The overall topography of the study area is characterized by gentle slopes with a maximum height difference of approximately 240 m. The plain is predominant and interspersed with small hills and hollows. The village is one of the areas where Hakka dwellings are concentrated [62–64].

Figure 1. The location of the study area.

In this study, the authors made a field investigation of Xiapu Village, took a lot of pictures, and conducted interviews. On this basis, a questionnaire has been designed (see

Appendix A). The authors also invited professors and doctoral students from Central South University of Forestry and Technology (three people), Sichuan Agricultural University (two people) and Hunan University (two people), experts from landscape planning and design companies (two people), and a manager from Changsha Garden Bureau (one person, 10 people in total) for answering the questionnaire and other consultations related to the model-building.

The steps for evaluating the value of rural landscape resources are as follows.

- (1) According to the evaluation index system of rural landscape resources, the index set is determined as $C = \{c_1, c_2, \dots, c_n\}$, and the comment set $S = \{s_1, s_2, s_3, s_4, s_5\}$ represents very poor, poor, general, good, and very good, respectively. The universe of discourse in the Cloud Model was $[0, 10]$. The scale of the cloud evaluation was calculated accordingly (Table 2).

Table 2. Linguistic term cloud digital features.

Linguistic Terms	En	He	Ex	$\bar{En}$	$\bar{He}$
S_1 Very poor	0	0	0	0.96	−0.32
S_2 Poor	0.09	0.96	2.89	0.70	0
S_3 General	0	0.70	5	0.70	−0.09
S_4 Good	0	0.70	7.11	0.96	−0.09
S_5 Very good	0.09	0.96	10	0	0

- (2) Determining index weight The comprehensive data obtained from the investigation in the region were sent to the experts together with the questionnaire, and the weight was scored according to the index system of rural landscape resources. AHP is a 2-to-2 comparison method to determine the relative importance of each factor in the hierarchy and then integrates the expert's judgment to determine the overall ranking. Therefore, in this paper, AHP takes a 1–9 scale, that is, 1, 3, 5, 7, and 9 representing a factor compared with another factor that is equally important, slightly important, more important, very important, absolutely important; 2, 4, 6, and 8 representing the median of the above two adjacent judgments, and the inverse comparison of the two factors is expressed by the reciprocal. In this study, the final expert scoring data weighted average was determined, a pairwise comparison judgment matrix was constructed, and the weight value of each index was subsequently calculated. The results are shown in Table 3.

In Table 3, weights are given for each evaluation indicator.

- (3) Cloud construction According to the index and comment sets, 10 experts were selected to evaluate the case village according to the evaluation index system of rural landscape resources to obtain the initial evaluation data. Taking the evaluation information given by the experts under the secondary indicators of social value B2 (C7, C8, C9, C10, C11) as an example, the calculation process is described below. The evaluation information is listed in Table 4.

In Table 4, the probability that the C7 indicator belongs to the S3 level is 9%, and the probability of the C7 indicator belonging to the S2 level is 10%. (Of the ten respondents, nine are considered to belong to S3 and 1 to S2.)

Table 3. Evaluation index weight table.

Evaluation Dimension	Weights	Evaluation Factor	Weights
Environmental value	0.14	Landscape ecological value	0.1286
		Landscape environmental protection degree	0.1
		Environmental cleanliness degree	0.1571
		Environmental fusion degree	0.1929
		Geographical location value	0.1214
		Rural Livability	0.3
Social value	0.19	Attribution value	0.2789
		Historical heritage value	0.1526
		Educational memorial value	0.0895
		Social popularity	0.2105
		Cultural Value	0.2684
Economic Value	0.24	Agricultural production value	0.2917
		Rural tourism value	0.4708
		Sustainable development value	0.2417
Landscape value	0.43	Landscape type richness	0.2395
		Landscape quantity richness	0.1791
		Landscape uniqueness	0.0907
		Landscape integrity	0.1395
		Landscape artistic value	0.0791
		Landscape aesthetic value	0.2698

Table 4. Probabilistic linguistic information from the expert evaluation under social value indicator B2.

	S1	S2	S3	S4	S5
C7		0.1	0.9		
C8	0.3	0.6	0.1		
C9	0.1	0.8	0.1		
C10		0.1	0.8	0.1	
C11		0.2	0.6	0.2	

The expert evaluation information (Table 4) was converted into a probabilistic linguistic Cloud Model according to the conversion formula between probabilistic linguistic and PLIC as well as the linguistic term cloud digital feature of Table 2, and the results are shown in Table 5. Similarly, the probability linguistic Cloud Model corresponding to each indicator can be obtained, and the calculation results are listed in Table 6.

Table 5 is a probabilistic language Cloud Model converted from Table 4.

The calculations in Table 6 are similar to those in Table 5.

The probabilistic linguistic cloud parameters of each project evaluation layer B can be calculated according to the PLICWHM operator of the probabilistic linguistic cloud calculation formula (Table 7).

Table 5. Expert evaluation of secondary indicators under social value indicator B2.

Index C	$\underline{En}$	$\underline{He}$	$\underline{Ex}$	$\overline{En}$	$\overline{He}$
C7	0.0114	0.1269	0.3877	0.1226	0.0266
C8	0.0115	0.1300	0.4166	0.0963	0.0032
C9	0.0017	0.0784	0.5444	0.0774	0.0094
C10	0.0003	0.1015	0.8030	0.1114	0.0125
C11	0.0159	0.1782	0.5582	0.1313	0.0027

Table 6. Probabilistic linguistic cloud of each evaluation index.

Index C	$\underline{En}$	$\underline{He}$	Ex	$\overline{En}$	$\overline{He}$
C1	0.0031	0.0594	0.3641	0.0552	0.0082
C2	0.0015	0.0546	0.5203	0.0669	0.0064
C3	0.0021	0.0739	0.5229	0.0745	0.0086
C4	0.0022	0.0240	0.1401	0.1162	0.0383
C5	0.0034	0.0673	0.4176	0.0628	0.0069
C6	0.0020	0.1301	0.9143	0.1293	0.0158
C7	0.0114	0.1269	0.3877	0.1226	0.0266
C8	0.0115	0.1300	0.4166	0.0963	0.0032
C9	0.0017	0.0784	0.5444	0.0774	0.0094
C10	0.0003	0.1015	0.8030	0.1114	0.0125
C11	0.0159	0.1782	0.5582	0.1313	0.0027
C12	0.0078	0.1268	1.2732	0.1229	0.0114
C13	0.0165	0.1859	0.5884	0.1700	0.0337
C14	0.0090	0.1262	0.6444	0.1082	0.0095
C15	0.0242	0.2706	0.8335	0.1986	0.0036
C16	0.0137	0.1739	0.7520	0.1393	0.0104
C17	0.0000	0.1137	1.1299	0.1533	0.0140
C18	0.0027	0.1531	1.5492	0.2055	0.0185
C19	0.0115	0.1305	0.4552	0.0991	0.0032
C20	0.0123	0.1827	1.8688	0.1640	0.0149

Table 7. Probabilistic linguistic cloud parameters of each project evaluation layer.

Index C	$\underline{En}$	$\underline{He}$	Ex	$\overline{En}$	$\overline{He}$
B1	0.0060	0.1844	1.3064	0.2173	0.0441
B2	0.0228	0.2849	1.2556	0.2448	0.0312
B3	0.0204	0.2580	1.5435	0.2360	0.0368
B4	0.0326	0.4361	2.9388	0.4016	0.0298

- (4) Similarity comparison The distance between the Cloud Model and standard linguistic set under each index can be obtained using the distance measure formula. The calculation results are shown in Table 8, where the shortest distances are represented in bold font.

The final cloud parameters of target layer A are (0.0778, 0.4269, 10.434, 0.0461, 0.21).

Table 8. Distance measurement between the cloud and the standard linguistic set under each index.

	S1	S2	S3	S4	S5
C1	0.2032	1.6002	2.6520	3.7038	5.1445
C2	0.5175	0.4997	0.4866	0.4736	0.4558
C3	0.5171	0.4850	0.4616	0.4382	0.4061
C4	0.1379	0.1133	0.0953	0.0774	0.0712
C5	0.2366	1.6746	2.7245	3.7744	5.2123
C6	0.4507	1.8722	2.9100	3.9478	5.3692
C7	0.3783	0.3085	0.2576	0.2066	0.1368
C8	0.4058	0.3308	0.2761	0.2213	0.1463
C9	0.5393	0.5120	0.4920	0.4721	0.4448
C10	0.4685	1.7530	2.7964	3.8398	5.2690
C11	0.3992	1.5629	2.6004	3.6379	5.0590
C12	1.2426	1.1744	1.1246	1.0748	1.0065
C13	0.5522	0.3741	0.2441	0.1141	0.0640
C14	0.6314	0.5676	0.5210	0.4744	0.4106
C15	0.7632	2.1020	3.0794	4.0568	5.3955
C16	0.4999	1.6481	2.6834	3.7187	5.1367
C17	1.1015	1.0150	0.9519	0.8887	0.8023
C18	1.4514	1.2716	1.1404	1.0091	0.8294
C19	0.4466	0.3826	0.3359	0.2891	0.2251
C20	1.1291	2.5237	3.5420	4.5603	5.9550
B1	1.1689	1.2084	1.1527	0.8222	1.1817
B2	0.5928	0.8618	0.4738	0.4069	5.1757
B3	1.1661	0.7313	0.8194	0.7214	5.3860
B4	1.4683	2.0854	1.1915	0.9872	3.9100
A	5.3709	0.7623	0.4559	0.3561	0.9053

3. Results

According to the results in Table 8, for the evaluation of the rural landscape resources in Xiapu Village, index A belongs to S4 (good) because the distances between the A indicator and S1, S2, S3, S4, and S5 are 5.37, 0.76, 0.46, 0.35, and 0.91, respectively, and the distance from S4 is the closest, so it belongs to S4.

The second-level indicators B1, B2, B3 and B4 all belong to S4 (good), indicating that the overall levels of the rural landscape resources in Xiapu Village are “good”, but there is still much room for improvement as the values of certain indicators suggest. The relevant information (associated with the indicators of our model) is given below for comparison purposes.

According to Table 7, we can draw the cloud models of B1, B2, B3 and B4 (Figure 2).

Figure 2. Cloud image of B1–B4. Note: The X-axis represents En (entropy); On the Y-axis is Ex. In the tertiary indicators (B1), C2, C3, and C4 belong to S4 (good), C1, C6 to S1 (very poor), but because the sum of C1 and C15 is small, the sum of C2, C3, and C4 is large, so the environmental value (B1) is “good”.

4. Discussions

To check whether our model yields reliable results, we have retrieved more information about the landscape resources of Xiapu Village (see [62–64]), which is independent of our field investigation. From [62–64], the original vegetation of Xiapu Village is well protected, the overall environment is clean, and the integration of the architectures and the natural environment is good. Therefore, the degree of landscape environmental protection (C2), environmental cleanliness degree (C3), and environmental fusion degree (C4) is “good”. However, the original mountains and water bodies had not been moderately developed under the premise of protection and did not play the potential value of landscape and economy. The number of vegetation species is also relatively small, and part of the water ecosystem was damaged due to construction. The village is far away from other cities, and the transportation is inconvenient for tourists. The village has some unused land, while the public green spaces and the venues and facilities for public activities are insufficient. Therefore, these are consistent with the result that the landscape ecological value (C1), geographical location value (C5), rural livability (C6) is “very poor”.

In the tertiary indicators (B2), C8, and C9 belong to S5 (very good), C7 to S4 (good), C10 and C11 to S1 (very poor) because the weighted sum of C7, C8, C9 is large and the sum of C10 and C11 is small, so the social value (B2) is “good”. From [62–64], Xiapu Village has kept traditional Chinese architecture, such as ancestral halls, Buddhist temples, Taoist temples, and courtyard folk houses. The protection and inheritance of traditional folk culture are good, and the self-identification of local residents is strong. Therefore, these are consistent with the result that the historical heritage value (C8) and the educational

memorial value (C9) are both “very good”, and the attribution value (C7) is “good”. However, some of the traditional architecture was damaged and lost its original features and styles due to the lack of proper maintenance. The public activities of the village have been restricted to the most basic ones, such as the traditional gathering places, such as the aforementioned ancestral halls, Buddhist temples, and Taoist temples, which are too small for the villagers to carry out social and cultural activities such as ancestor-worshipping and festival-celebrating, not to mention that the historical and cultural characteristics of the village should be used to attract tourists. Thus, these are consistent with the result that the social popularity (C10) and the cultural value (C11) are “poor”.

In the three-level indicators B3, all indicators C12, C13, and C14 belong to S5 (very good), so the economic value (B3) is “good”. From [62–64], Xiapu Village is located mainly in a plain with plenty of water resources and some mountains adjacent to its north side, suitable for the development of rural tourism. The village also has many agricultural economic types that are supported by the local government, especially in the ecological agricultural industry. Therefore, these support the result that the agricultural production value (C12), the rural tourism value (C13), and the sustainable development value (C14) are “very good”.

In the tertiary indicators (B4), C17, C18, C19 belong to S5 (very good), C15, C16, and C20 belong to S1 (very poor) because the sum of C15, C16, and C20 is small, C17, C18, C19 are large, so the landscape value (B4) is “good”. With a memorial monument for soldiers and a few Hakka stores, the village has a distinctive architectural style. Besides the traditional folk activities, the villagers also spontaneously decorated the walls of their houses with paintings, adding certain artistic quality to the landscape. For comparison, the landscape uniqueness (C17), the landscape integrity (C18), and the landscape artistic value (C19) are “very good”. The types of landscapes are quite limited, and most of them are temples and ancestral halls that need renovations. These are comparable with our result that landscape type richness, quantitative abundance, and landscape aesthetic value (C20) are “poor”.

Specifically, we can see from Figure 3, the values of the indices C1, C5, C6, C10, C11, C15, C16, C20 all belong to level S1, very low, shows that these aspects should be improved.

Figure 3. The evaluation levels of the indices.

5. Conclusions and Suggestions

In this article, we proposed a new approach for evaluating rural landscape resources. We have established a new index system by using the Analytic Hierarchy Process (AHP) and a probabilistic linguistic Cloud Model. We explained the details of building such an index system and applied our method to the case study of Xiapu Village. The evaluation results and the item-by-item analysis in the last section show that the method is practical and can reflect the value of resources objectively and efficiently.

We evaluate the landscape resources of Xiapu Village, and the overall evaluation level is “good” because most of the indicators have higher scores. Our method also found the weakness and inadequacy of its landscape resources. Moreover, one can use the indicators and their values as guidance for achieving a higher evaluation score and, hence, better management of the landscape resources. Based on our method and the case study of Xiapu Village, we can make suggestions for improvements on the following aspects:

- (1) Suggestions for improving the environmental value (B1). Rural livability is critical to the B1 value. In some developing countries and regions, the lack of rural environmental protection and planning has resulted in land exposure, soil erosion, and destruction of the original vegetation. Landscape architects can improve the ecological environment and use natural self-purification functions to keep the environment clean, enabling the landscape to maintain its ecological value. The landscape architect can also design ecological revetments and plant aquatic vegetation, which can improve the purification capacity of water. Landscape architects can further enrich the vegetation types of villages and grow plants near the dwellings, which protect the ecosystem and make the countryside more livable. Last but not least, transportations to other places should be made easy and convenient to increase rural livability. Reference [25] believes that convenient transportation conditions and a clean village appearance are conducive to the development of rural tourism advantages. In this respect, our conclusions are consistent with the ref. [25].
- (2) Suggestions to improve the social value (B2). The cultural value (C11) and the attribution value (C7) are very important in B2. Public places such as historical halls, cultural exhibition centers, theaters, and museums can be used to display the local history and culture, the traditional rural customs, such as local folk customs and religions, art and music, legends and anecdotes, and other historical and cultural heritage so that tourists might feel a rich cultural atmosphere with diversity, which certainly increases the cultural value. Landscape designs should be conducted based on the existing infrastructure and the needs of the residents for more social activities. With a more pleasant and convenient living environment and more space and opportunities for social activities, the local residents may choose to stay in their hometown for work, and the attribution value (C7) can be improved as well. In the study of approximate themes, Čurović Ž. et al. suggested preserving the architectural identity with the planned development and renewal of settlements is implemented through landscape [65]. We reached conclusions similar to those of the ref. [65].
- (3) Suggestions for increasing economic value (B3). The rural tourism value (C13) is the major value in B3. When landscape architects consider the rural landscape as a tourist attraction, they should make sure that the normal agricultural production activities are undisturbed through planning and design. For example, the farmland for tourists’ experience should be separated from those for daily production. Alternatively, air trails over the farmland can be built for tourist visits. Other approaches can be taken to increase the richness of landscape types. Landscape architects can improve tourism infrastructure and service facilities, such as information centers, parking lots, comfort stations, and medical stations. Different rural landscape areas, such as an ecological agricultural area, a sightseeing agricultural area, and an education agricultural area, can be set up separately so that tourists can experience the enjoyment of rural agriculture when participating in some agricultural activities. It can certainly establish memorial and educational values while increasing local economic incomes. Rural tourism can also promote the sales of local agricultural products, making rural tourism and agricultural production mutually beneficial and supporting the sustainable economic development of rural areas. Wang and Deng proposed that agricultural production could be organized in accordance with the landscape characteristics with an emphasis on raising the value of local products [25]. We came to much the same conclusions and recommendations as stated above. However, our conclusion that the farmland landscape needs to be protected is different from the conclusion that

Wang and Deng believe that case villages could abandon the farmland landscape when developing rural tourism. The difference might be due to the neglect of the importance of the farmland landscape in [25] and a different focus there.

- (4) Suggestions for increasing the landscape value (B4). B4 includes the landscape type richness (C15), the landscape quantity richness (C16), the landscape uniqueness (C17), the landscape integrity (C18), the landscape artistic value (C19), and the landscape aesthetic value (C20). Among them, the landscape type richness (C15) and the landscape aesthetic value (C20) have the largest weights of evaluation and should be given priority in developing landscape tourism. Places such as ancient architecture, religious temples, and historical monuments are the natural spots for attracting tourists. Other types of the landscape can then be included to increase the variety. For example, public green spaces, small parks, public activity venues, and new landscape buildings could be built to meet the different needs of residents and tourists.

Our model also has certain limitations (for example, the indicators we selected might be more suitable for use in developing countries and regions), and the selection of indicators should follow the needs of rural development in each country or region. Different countries and regions have different development strategies and different needs for the value of rural landscape resources, so the specific contents for evaluation may be adjusted accordingly. However, the evaluation index system we established in this article can be generalized to evaluate the rural landscape projects in other situations. The evaluation results and suggestions can be important references for the local governments at all levels or third-party evaluation institutions to evaluate the performance of rural landscape projects managed by the local governments in the planning, design, transformation, development, and protection of the rural landscape.

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Appendix A

Questionnaire for the evaluation of rural landscape resources

Dear Sir/Madam,

Thank you for supporting our survey.

The purpose of this survey is to study the current situation of rural landscape resources. Your answers will be of great help to our research and also the improvement of the value of rural landscape resources.

Please select

1. You are:

☐ an expert from landscape design firms

☐ a manager of landscape management department (landscape management bureau, planning bureau)

☐ a researcher in universities or institutes

☐ other

2. Your educational background:

☐ B.S./B.A ☐ M.S/M.A ☐ PhD ☐ Others

3. How long have you been engaged in landscape research or practice?

() 3 years () 4–10 years () 11–15 years () 16–20 years () 20 years

4. According to your knowledge of the landscape of the countryside, please comment on the present situation of the following indicators. The score of each question ranges from 1 to 5. The meanings of different scores are as follows: 1 is “very poor”, 2 is “poor”, 3 is “fair”, 4 is “good”, and 5 is “very good”. Use a ‘√’ to select your answer.

Evaluation object (village name): (Xiapu village)

Dimensions of Evaluation	Evaluation Index	Dimensions of Evaluation				
		Very Poor	Poor	Fair	Good	Very Good
Environmental value B1	Landscape ecological value C1					
	Landscape environmental protection degree C2					
	Environmental cleanliness degree C3					
	Environmental fusion degree C4					
	Geographical location value C5					
	Rural livability C6					
Social value B2	Attribution value C7					
	Historical heritage value C8					
	Educational memorial value C9					
	Social popularity C10					
	Cultural value C11					
Economic Value B3	Agricultural production value C12					
	Rural tourism value C13					
	Sustainable development value C14					
Landscape value B4	Landscape type richness C15					
	Landscape quantity richness C16					
	Landscape uniqueness C17					
	Landscape integrity C18					
	Landscape artistic value C19					
	Landscape aesthetic value C20					

We promise that the contents of the questionnaire will be kept strictly confidential and used only for academic research purposes. No specific units or individuals are involved in this survey.

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